An Example from the Dairy Industry: The Net Merit Index

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Introduction

Dairy cows produce a lot of milk, but a more important goal of those who milk cows is to make a profit. Selection goals in the dairy industry focus as much on reducing expenses as on increasing income. In the last decade, several important traits have been added to routine genetic evaluations and selection indexes. Dairy cattle breeders now select for longevity, mastitis resistance, fertility, and calving ease in addition to conformation and production.

Because of U.S. exports of dairy semen and embryos and effective progeny-test programs overseas, foreign cattle have become more competitive with U.S. dairy breeds. Today dairy breeders can choose from the best bulls in the world ranked on their combined economic value for the many traits included in the Net Merit index (**NM$**).

Net Merit

Breeders select for traits that can be easily measured, evaluated, and marketed. Until recently, dairy breeders selected mainly for milk and fat production and for various conformation traits that are favored by judges and classifiers. In the late 1970's, dairy breeders also began measuring and selecting for protein production. However, most milk processors did not pay for protein until recently, and grocery stores still label only differences in the fat content and not in the protein content of milk. Jersey breeders successfully lobbied for changes in milk marketing laws to reward higher protein production both within and across breeds.

The first economic index that was introduced by the USDA in 1971 estimated gross income per lactation based on genetic merit for milk and fat yields (Norman and Dickinson, 1971). That index was updated to include genetic merit for protein yield in 1977 (Norman et al., 1979), and an economic index that reflected milk pricing based on cheese yield was introduced in 1984 (Norman, 1986). In 1994, productive life and somatic cell score (**SCS**) were combined with yield traits into NM$ based on economic values that included direct and indirect measures of expense as well as income. In 1999, merit indexes based on cheese and fluid milk pricing were introduced (VanRaden, 2004). The net, cheese, and fluid merit indexes were revised in 2000 to include linear conformation composites (Holstein Association USA, 2005) based on a lifetime (rather than lactation) profit function (VanRaden, 2000). In August 2003, calving ease and daughter pregnancy rate were added to the merit indexes (VanRaden and Seykora, 2003).

Traits

A total of 27 traits are currently measured and evaluated for genetic merit of U.S. dairy animals. Those evaluations represent the genetic merit that an animal is predicted to be able to transmit to its future offspring (predicted transmitting ability) rather than the animal's own genetic merit (breeding value); predicted transmitting ability is equivalent to the expected progeny difference reported for beef cattle. Health, fertility, and longevity evaluations now are widely accepted by dairy breeders in addition to yield and conformation traits.

Lactation yields for milk and fat have been evaluated since 1936 (Kendrick, 1936), and genetic evaluations for protein yield began in 1977 (Norman et al., 1979). Evaluations of component percentages also are released as ratios of fat and protein to milk yield. Testing and sampling from one milking per month is common, and SCS is obtained from almost every sample. Less frequent sampling of components and daily recording of milk by electronic meters are helping to reduce costs on many larger farms. The national cost of collecting production data is about $50 million per year.

Conformation (type) traits are scored visually. Udder traits include udder depth, udder cleft, fore udder attachment, rear udder height, rear udder width, teat placement, and teat length, which are combined into an udder composite. A foot-and-leg composite includes foot angle, mobility, and rear leg angles (side and rear views). A size composite includes stature, strength, body depth, and rump width. No actual body weights are taken or estimated by classifiers, but formulas to predict cow weights from conformation traits were obtained research herd data (VanRaden and Seykora, 2003). Traits final score, rump angle, and dairy form are not used in NM$, but Holstein Association's TPI index includes final score and also selects against dairy form to prevent cows from becoming too thin.

Genetic improvement of dairy cattle for resistance to mastitis, the most costly health problem of dairy cows (Shanks et al., 1982), is possible through selection for fewer somatic cells in milk (Shook and Schutz, 1994). Somatic cell counts, which are recorded through Dairy Herd Improvement testing, are transformed into sample-day log2 SCS, and those scores are used to calculate USDA genetic evaluations for mastitis resistance (Schutz, 1994). Higher evaluations for SCS indicate more mastitis and lower quality payments.

Calving ease (dystocia) of dairy cattle is scored on a scale of 1 (no problem or unobserved) to 5 (extreme difficulty). Because each unit increase in score does not represent the same increase in difficulty, USDA uses a threshold model for genetic evaluations (Van Tassell et al., 2003). Genetic merit for calving ease is reported as the estimated percentage of births that are difficult (calving ease scores of 4 or more) for first-calf heifers. Both service sire and daughter evaluations are released for bulls.

Pregnancy rate measures the percentage of nonpregnant cows that become pregnant for each 21-day opportunity period (each heat cycle). Genetic evaluations for daughter pregnancy rate (cow fertility) are based on days open and indicate the ability of a bull's daughters to cycle, express estrus, conceive, and retain the pregnancy (VanRaden et al., 2004). Genetic rankings for bull fertility (e.g., conception rate) are available from regional data, and much of the research to provide national rankings has been completed (Clay and McDaniel, 2001, Kuhn et al., 2004, Weigel, 2004).

Evaluations of productive life, USDA's measure of longevity for dairy cattle, are based on direct observations of length of productive life and also correlated traits (yield, conformation, SCS, calving ease, and pregnancy rate) measured earlier in life (VanRaden and Wiggans, 1995; VanRaden and Wiggans, 2003). Replacement costs decrease as longevity increases, and cows with high productive life also are healthier (Rogers et al., 1999). The initial emphasis on productive life decreased slightly in 2000 and in 2003 when more of the individual traits that contribute to longevity were added to the merit indexes (VanRaden et al., 2003).

Most artificial-insemination companies also evaluate milking speed and temperament from their own data, but those traits are not available for national selection.

Economic Values

Past selection has focused on gross income instead of profit because prices of income traits are easier to obtain than costs of expense traits. Often, only correlated traits such as cow size are available instead of actual expense traits such as feed consumption. Selection indexes should consider not only the direct values of the measured traits but also correlations of measured traits with any unmeasured expenses or incomes.

Economic values can be obtained as averages of literature estimates if the index includes only a few traits. Economic values of existing traits change as more traits are included, and literature values are less useful because no two studies may include exactly the same set of traits. A profit function is needed then to obtain the value of each trait when many traits are included in the index. NM$ in 1994 used an average of literature estimates for the 5 traits included, but a profit function was used beginning in 2000, when 8 traits were included (VanRaden, 2000).

The percentage of emphasis that is placed on various traits allows for convenient comparisons among selection indexes. A trait's economic value is multiplied by its genetic standard deviation and then is divided by the sum of such products across all traits to give the fraction of total emphasis. Table 1 compares the selection emphasis for traits that are included in NM$ with that for traits in the official indexes of many other countries. Protein and fat yields get about half of the total selection emphasis in most indexes.

Milk component prices differ widely depending on milk use. NM$ includes average expected U.S. prices, but the fluid merit and cheese merit indexes are alternatives for farmers who receive higher incentives for the water or protein content of milk, respectively. Until 1998, the average price from the previous year was used for yield traits in USDA selection indexes for dairy cattle. Since then, future prices are forecast, but this process is not very accurate. Feed costs per pound of protein produced are assumed to be higher than feed costs per pound of fat produced, but this assumption is based only on limited research and on phenotypic rather than genetic correlations. Milk with low somatic cell count now receives price premiums paid by milk processors that often exceed the direct farm expenses from treating mastitis.

Conformation traits may not have direct economic value but are more easily measured and have higher heritability than most direct expense traits. Cows with deep udders require more time and labor to milk. Cows with poor feet and legs do not survive long on concrete flooring. Large cows have more beef income including their own salvage value and heavier calves produced but are less profitable because of the high cost of raising and maintaining the additional cow weight. More research is needed to quantify these expenses.

Cow fertility has a large correlation with productive life and is preferred in selection because data arrive sooner. Longevity and fertility currently receive 11% and 7%, respectively, of total selection emphasis in NM$. Calving ease as a trait of the service sire has been evaluated for Holsteins since 1978 but was not included in NM$ until 2003 when daughter calving ease (the effect of the maternal grandsire) was also added. The two calving ease traits each receive 2% of total selection emphasis in NM$. Several other countries have genetic evaluations for stillbirth and also include this trait in their selection indexes.

Global Selection

The one-way transfer of genetic material from North America to the rest of the world has become a two-way exchange. During the last 15 years, about 400,000 cows with U.S. yield records had foreign sires. Most of those sires were Canadian, but 44,000 cows had sires from The Netherlands and 10,000 had sires from France. Other countries that had sires with more than 1,000 U.S. daughters included New Zealand, Italy, Germany, and Denmark. Currently, 6 of the top 10 sires of progeny-tested sons are foreign, which shows the importance of global selection.

Bull rankings differ by country because international evaluations account for genotype by country interactions and because countries may emphasize different traits. National genetic evaluation methods and selection indexes are documented on national evaluation center web sites and by Interbull (International Bull Evaluation Service, 2004) Centre in Uppsala, Sweden. National selection indexes are updated quite frequently and have become more similar over time. Most countries have decreased their selection on yield traits and increased their selection for health and fertility traits during the last five years.

Table 1. Relative emphasis on traits in national selection indexes for Holstein populations.

	Country (Index)												
Trait	Australia (APR)	Canada (LPI)	Denmark (S-I)	France (ISU)	Germany (RZG)	Italy (PFT)	Japan (NTP)	Netherlands (DPS)	New Zealand (BW)	Spain (ICO)	Sweden (TMI)	United Kingdom (PLI)	United States (NM$)
Protein	36	31	21	35	36	42	55	32	34	32	21	41	33
Fat	12	20	10	10	9	12	20	7	13	12	4	18	22
Milk	−19		−3					−12	−17	12	−4	−18	
Protein (%)		2		2	4	3				3			
Fat (%)		1		2	1	2							
Longevity	9	7	8	13	25	8		8	8	3	6	17	11
Udder health (somatic cell score)	5	3	14	13	5	10		14		3	12	4	9
Fertility	8	5	9	13	1			10	10		10		7
Other diseases			2								3		
Udder conformation		16	9	8	6	13	21			16	12		7
Feet and legs (mobility)		11	5	1	4	6	4	5		10	9	3	4
Size	−4	4	2	2	2			−5	−18				−3
Dairy character					2								
Rump				1	1								
Final score						4				9			
Calving traits			6		4			7			12		4
Growth (meat)			5								6		
Temperament	4		2								3		
Milking speed	3	<1	6										

Completing the Package

All domestic dairy bulls and cows and all foreign dairy bulls evaluated by Interbull receive an evaluation for each trait in NM$. The same index is applied to young stock, males, females, and foreign males. If an animal has no data for a particular trait, its parent average is substituted. If parent evaluations are missing, unknown parent group solutions or breed averages are substituted. If a particular country has no data for a particular trait, its population average is assumed to equal the U.S. average. Indexes require an estimate for each trait, and even estimates with zero reliability are released so that breeders do not have to guess what estimate was used in the selection index.

NM$ is computed for 18 million U.S. cows and 110,000 bulls from 25 countries. Interbull and U.S. evaluations for dairy cattle are computed 4 times per year in February, May, August, and November. Most other countries have adopted the same schedule. Timing has been greatly improved so that only 3 weeks are required between data cutoff and delivery of worldwide results. Interbull provides evaluations for all traits in NM$ except cow fertility, and research on that trait is underway. Computer calculation of indexes is much better than hoping that cow and bull owners will take the time to combine all of the information correctly on their own.

Reliability (accuracy) of evaluations for dairy cattle is defined as the squared correlation of true and estimated breeding values. This statistic is less pessimistic than accuracy as defined in beef breeding: 1 minus the square root of the variation in prediction error divided by the additive genetic variation (Beef Improvement Federation, 2005). Both measures of accuracy are less optimistic than the original and better definition of accuracy: correlation of actual and estimated breeding values, which predicts future progress toward the goal. Reliability is provided for each trait and for NM$, along with the parent average, reliability of parent average, and daughter deviations for each trait so that breeders can see how the information from different relatives is combined in the animal model.

Traits with low heritability were once ignored but now are included in selection because some have coefficients of variation (standard deviation divided by trait average) larger than those for traditional traits. Breeders will select for traits that they are convinced have economic value and are evaluated accurately. Some traits have different values to different breeders, but an index based on average expected prices provides a reasonable goal and a useful ranking for the population. Professional researchers should be able to combine traits and to estimate economic values more accurately than individual breeders can in their spare time.

Computer mating programs that avoid inbreeding, protect against mating recessive defect carriers, match strong with weak traits, and assign the easiest calving bulls to heifers are used by about one third of dairy breeders. These programs also allow customized bull selection to meet each breeder's goals. Bourdon (1998) proposed similar flexible selection strategies for beef breeders. Flexibility is useful in free markets, but an official ranking helps breeders promote and locate superior stock, and a national goal gives breeders direction.

Conclusions

Breeders prefer complete and uniform information on a variety of traits along with an overall index of economic value. Dairy breeders can select on the USDA's NM$, breed association selection indexes, or custom indexes of their own creation. Goals have become more similar across breeds and across countries. Traits with lower heritability now receive much more emphasis but also require larger investment in progeny testing. Dairy cattle breeders depend on calculated genetic rankings because most traits of interest are sex limited and cannot be measured for bulls. Dairy cattle selection is a global industry with annual semen sales of nearly $1 billion from the best few thousand bulls worldwide. Breeders can quickly select the best bulls for overall economic return by using NM$.

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