Tools for selection for functional traits in Canada

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Abstract

The Total Economic Value index (TEV) for dairy sires has been published in Canada since 1996. The TEV is an index based on total economic merit that allows breeders to select bulls for simultaneous improvement of both production and functional traits. The TEV uses a sub-index approach to combine sire EBV for yield, longevity, and udder health traits. Relative weights for the production, longevity, and udder health sub-indexes are 10, 4, and 1.5, respectively. Within the production sub-index, EBV for protein yield receives a weight of 9, relative to 2 for fat yield. The EBV for protein and fat are actually also sub-indexes, created by combining with approximately equal weights the individual EBV for yields in first, second, and third lactations. No direct emphasis is placed on milk yield. The longevity sub-index for a bull is simply its published EBV for herd life, which is calculated by combining direct information on actual daughter survival and indirect information based on conformation. The sub-index for udder health blends EBV for somatic cell score (SCS), udder depth, and milking speed. Relative weights for these 3 components are -13, 6, and 3, respectively. Similar to the yield traits, the overall EBV for SCS is a combination of separate EBV for SCS in lactations 1 to 3. The TEV is expressed in $(Cdn) as the net present value of cash flow generated by a milking daughter (and its descendants) during the 10 years following insemination, discounted to the time of sire selection. Currently, TEV figures are calculated only for proven sires, because of the relatively low reliability of cow EBV for udder health traits and the lack of cow EBV for longevity. Unfortunately, this absence has seemingly limited the acceptance of TEV and precluded its use in selection of bull dams. The Canadian Dairy Network also publishes the Lifetime Profit Index (LPI). The LPI was developed by breeders and other members of the industry and combines yield and conformation traits with relative emphasis of 6:4. In addition to the traits included the TEV and LPI, sire EBV are also calculated for calving performance (direct and maternal) and approximately 30 conformation traits.

1. **Introduction**

Dairy producers in Canada realise that although they generally derive most of their income from the sale of milk, single trait selection for milk yield will not necessarily yield for them the optimal genetic response in overall economic merit and profit potential. They realise functional traits such as longevity and health must also be considered in selection, because these traits have a direct impact on total economic merit and may be unfavourably genetically correlated with yield. Therefore, they demand genetic evaluations for such traits to aid in their selection decisions.

The dairy research community in Canada and the Canadian Dairy Network has responded to the demands of breeders and now provide estimated breeding values (**EBV**) or estimated transmitting abilities (**ETA**) for a multitude of traits upon which breeders can base their selection decisions. With the recent adoption of the Canadian test-day model (Jamrozik *et al*., 1997), breeders can now select for

- milk, fat, and protein production in lactations 1 to 3 and overall fat and protein percentages, but also for
- somatic cell score and
- lactation persistency in each of the first 3 lactations,
- herd life,
- milking speed (**MS**),
- direct and maternal calving ease, and
- any of approximately 30 conformation traits.

They may also choose sires based on a linear model evaluation for 56-day non-return rate.

Development of programs to collect and evaluate these traits represented only part of the challenge in providing EBV that were useful to producers. With EBV for so many traits available, the possibility of confusing many breeders with too much information is clearly possible. Without guidelines for interpretation and use, breeders may ignore EBV that they don't understand, place more emphasis on certain traits than is economically justified, or combine EBV for multiple traits by using procedures that fail to maximise genetic response. Therefore, additional effort has been made in devising ways to present EBV to breeders so that they can understand and use the EBV in the most efficient manner.

Two approaches have been used to help increase the understanding of the EBV and the efficiency of their use in selection decisions.

The first approach is to compute and publish indexes for sire selection that combine EBV for both production and functional traits according to selection goals that are likely to nearly maximise profit. The primary index that includes functional traits is called the Total Economic Value (**TEV**) (Dekkers, 1995a), which is designed around the expected selection goals of a typical commercial breeder. Also available is the Lifetime Profit Index (**LPI**), for those breeders who sell breeding stock and expect to receive a premium for improved conformation.

The second approach is to express EBV for traits on scales with which the breeders are familiar and would likely choose when evaluating their cattle on a phenotypic basis.

2. TEV: Total Economic Value

2.1. Background and Overview

The TEV is an index for sire selection that combines EBV for production with EBV for two types of functional traits, a) longevity and b) udder health traits. The TEV is actually an index of three sub-indexes or "super-traits" (Wilmink, 1996):

$$TEV = (10\times PROD + 4\times LONG + 1.5\times UDDER)\times 26$$

where PROD is a sub-index for production, based on fat and protein yields; LONG is a sub-index for longevity, based on a genetic goal of improvement for functional herd life; and UDDER is a sub-index for udder health, based on a genetic goal for decreased somatic cell score (**SCS**) and clinical mastitis (**CM**) in lactations 1 and $\geq$2. Each of the sub-indexes are standardised, so the 10, 4, and 1.5 are the respective standardised index weights for the three sub-indexes. These weights were initially established based on the economic values presented in Table 1. More specific details about the individual sub-indexes will be provided later in this article.

The weighted sum of the three sub-indexes is then multiplied by 26 so that TEV is expressed as the expected daughter difference in profitability (in $Cdn) at the farm level. The TEV represents differences between sires in the net present value of cash flow over 10 years from a milking daughter and her descendants (Dekkers, 1995b). In other words, within the same herd, a milking daughter from a sire with a TEV of $500 is expected to return $500 more lifetime profit (discounted to present) than will a daughter of a sire with a TEV of $0.

Table 1. **Economic values for production (PR), functional herd life (FHL), somatic cell score in lactation 1 (S1) and lactations 2 and greater (S2), clinical mastitis in lactation 1 (M1) and lactations 2 and greater (M2), and milking time (MT) used in determining the economic weights among sub-indexes in the TEV**

Trait	Gen. SD[i]	Marginal value ($/cow/yr)	Number of Expressions[ii]	Stand. Econ. Value[iii]
PR	150	1	0.63	100
HL	192	0.3	0.63	38.6
S1	0.42	-35	0.21	-3.3
S2	0.45	-40	0.46	-8.8
M1	0.32	-22	0.21	-1.6
M2	0.32	-44	0.47	-7.0
MT	0.68	-15	0.63	-8.0

[i] Units are $Cdn for production, days for HL, linear score unit for SCS, cases for mastitis, and minutes for milking time.

[ii] Discounted expressions per unit of genetic change over 15 years at a rate of 5%.

[iii] Marginal value times number of expressions divided by genetic standard deviation and expressed relative to 100 for production.

The TEV is expressed in Canadian Dollars to increase its appeal to and use by breeders because it allows them to compare bulls on a scale they easily understand. In addition, the TEV can be used to compare bulls according to semen price and expected profits. Dividing a sire's TEV by the number of units of semen required to produce a milking daughter (approximately 6 in most herds, depending on conception and survival rates) yields the expected future profit from using a unit of semen. Based on this simple calculation, a breeder can afford to spend about $5 more per unit of semen for each additional $30 in TEV. The current top Holstein bull in Canada has a TEV of $846.

2.2. Sub-indexes

The decision to use a set of sub-indexes, rather than a single index with many traits was based on the willingness to sacrifice some potential genetic response by using the theoretically optimal index in exchange for simplicity and, hopefully, a better understanding of the index by breeders. According to Dekkers and Gibson (1998), "an index that is based on sound scientific principles but is not accepted has much less impact on selection for an overall breeding goal than does an index that may not be optimal technically but that receives acceptance by the targeted users". The sub-index procedure simplifies the development, interpretation, and explanation of the overall index because each sub-index can be derived and explained independently from the other sub-indexes (Dekkers and Gibson, 1998). This factor becomes more critical as an index becomes more complex and, at the time of its introduction in 1996, the TEV was much more complex than were the other indexes (such as the LPI) available to dairy breeders in Canada.

In addition to the practical aspects related to simplicity and understanding by breeders, the sub-index approach has several technical advantages over the traditional single index approach that were summarised by Dekkers and Gibson (1998) and include

1) traits within a sub-index are usually biologically related and hence, genetic relationships among them are often known more precisely than are the relationships among less biologically related traits that may be included in a single overall index,
2) weights among traits within a sub-index are relatively robust to estimation errors, due to the usually high genetic relationships among traits in a sub-index,
3) because sub-indexes are often lowly correlated, the weights on sub-indexes follow more closely the perceived relative importance of the selection goals for each sub-index, and
4) sub-indexes facilitate a) the combining of EBV from separate genetic evaluations, b) the adoption of customised selection indexes with varying emphases on sub-indexes, and c) the future introduction of new sub-indexes.

A technical disadvantage to the sub-index approach is that it does not account for genetic correlations among traits in separate sub-indexes, but this factor is not likely to be of great importance in most common situations (Kulak *et al*., 1996).

2.2.1. Production sub-index

The current sub-index for production is

$$\text{PROD} = (9 \times \text{ProteinEBV} + 2 \times \text{FatEBV}) \div 11$$

which places standardised weights of 9 on EBV for protein yield and 2 on EBV for fat yield. (For standardising the sub-indexes in the TEV, the result is divided by 11.) The weights were based on Gibson *et al.* (1995) who considered future demand for dairy products and changes in management. Since the adoption of the current test-day genetic evaluation of dairy cattle (Jamrozik *et al.*, 1997) in February 1999, the EBV for protein and fat have actually become sub-indexes themselves. These sub-indexes use EBV for yield in lactations 1, 2, and 3 to maximise genetic progress for an aggregate genotype that is based on production in lactations 1 to 8. As documented in an unpublished technical report, Collard *et al*. (1999) estimated the relative economic value for yield in each lactation based on the expected number of discounted expressions of lactation production and genetic correlations among lactations. They confirmed that the optimal selection index was one that applied approximately equal weighting upon standardised EBV for yield in each of the first three lactations.

2.2.1. Longevity sub-index

The sub-index for longevity is simply the published sire ETA for functional herd life (then standardised). More detail about the Canadian evaluation for herd life can be found in articles published by Jairath *et al.* (1998) and by Boettcher *et al.* (1999). The published ETA for herd life combine separate ETA for "direct" herd life (**DHL**), which is based on actual records of daughter survival, and "indirect" herd life (**IHL**), which is based on sire ETA for conformation traits.

The ETA for DHL is calculated with a three-trait animal model, for which the three traits are cow survival in lactations 1, 2, and 3. The most recent evaluation was based on records from approximately 1.7 million cows. Although survival is recorded as a binary (0/1) trait, a linear model is used for the evaluation. Fat and protein production (deviation from herd average in first lactation) are included as covariates in the analysis, so the resulting ETA are for functional herd life. The overall ETA for DHL is the average of ETA for survival in lactations 1, 2, and 3.

The ETA for IHL are calculated based on an index of sire ETA for mammary system, feet and legs, frame and capacity, and rump. Respective weights for these 4 components are 8, 4, 1, and 1.

The ETA for DHL and IHL are then combined with procedures similar to the method used to calculate international sire ETA (Schaeffer, 1994). The resulting ETA for combined herd life has a correlation of approximately 0.80 with the ETA for both DHL and IHL. The combined ETA for herd life are calculated and published for approximately 6000 sires with progeny test information for both DHL and conformation. The ETA are expressed in terms of the average life expectancy (measured in lactations) of daughters of a given sire, set to a base of 3 lactations. Cows do not currently receive ETA for herd life, due to the low heritability and late expression of the trait.

2.2.3. Udder health sub-index

The sub-index for udder health is

$$\text{UDDER} = (-13\times\text{SCS} + 3\times\text{MSpeed} + 6\times\text{UDepth})\div 17$$

where SCS, MSpeed, and UDepth are standardised EBV or ETA for somatic cell score, milking speed and udder depth. The values -13, 3, and 6 are respective weights. (The index is divided by 17 for standardisation in the TEV.) Details about the development of the udder health index have been published by Boettcher *et al.* (1997 and 1998). The selection goal for the udder health index is decreased SCS and incidence of CM and decreased milking time. No genetic evaluation for CM is available in Canada, so the other traits are used as indicators for mastitis resistance. Udder depth has no direct economic value but is included in the index for its relatively high genetic relationship with SCS and milking time. Sire ratings for the udder health index are not published, only its individual components.

2.2.3.1. Somatic cell score

The ETA for somatic cell score are now calculated as part of the Canadian test-day genetic evaluation (Jamrozik *et al.,* 1997). The evaluation is a multiple trait procedure with SCS and milk, fat and protein yield for first, second, and third lactations. The published ETA for SCS is a sub-index of SCS in each lactation, standardised to an average of 3.00. Weights for SCS across lactations are 0.25, 0.65, and 0.10 for lactations 1, 2, and 3, respectively, based on work recorded by Dekkers (1995a). In contrast to the weights for the components of the production sub-index, the weights for SCS vary across lactations because SCS and resistance to mastitis have greater standardised economic values in later lactations. This difference occurs because mastitis occurs more frequently in later lactations and causes more losses in terms of discarded milk and other factors (Kolstad and Dekkers, 1994, unpublished). The weight on second lactation is much greater than on third lactation because these weights were derived by assuming that SCS and resistance to CM were the same traits genetically in all lactations >1. Only the combined ETA is generally published for bulls in Canada, but sire ETA for the individual lactations are available over the internet (http://www.cdn.ca). Like ETA for herd life, ETA for SCS are not officially published for cows.

2.2.3.2. Milking speed

Banos and Burnside (1992) give details about the development of the national genetic evaluation for MS in Canada. Farmers provide to their milk-recording agency a subjective appraisal of MS for each first lactation cow during the first few months in milk. Each cow is evaluated on a 1 to 5 scale as very slow, slow, average, fast or very fast in relative total milking time independent of milk yield. The data are then normalised using the Snell (1964) transformation and evaluated with an animal model. Since February 1997, the sire ETA for MS have been expressed as the percentage of future first lactation daughters that are expected to be average or fast milkers. These bull ratings range from about 55% to 80% with the average 69% Average or Fast. No ETA for MS are published for cows.

2.2.3.3. Udder Depth

Sires in Canada receive EBVs for 12 udder conformation traits. Nine of these traits are specific descriptive traits such as fore udder attachment, front teat placement, and udder texture, and three are the composite traits mammary system, fore udder, and rear udder, which are based on combinations of the various descriptive traits. Cows are assigned a linear score on a 1 to 9 scale for the descriptive traits and on a 1 to 18 scale for the composite traits. Genetic evaluation of all conformation traits is with a single trait animal model. The resulting EBVs are expressed on a standardised scale with an average of 0 and standard deviation of 5.0. The EBVs for 29 conformation traits (for the Holstein breed) are officially published for both bulls and cows.

Udder depth is the only conformation trait included in the sub-index for udder health because it had the greatest relationship with SCS and MS (Boettcher *et al.* 1997; 1998). Addition of other udder traits to the sub-index improved the accuracy of the index by only a relatively small amount (Boettcher *et al.* 1997; 1998) and resulted in essentially no difference in sire ranking for the udder health index and TEV.

3. LPI: Lifetime Profit Index

3.1. Background and Overview

The LPI (Dekkers, 1992) was the first official selection index value introduced in Canada in 1990. From the very beginning it was designed to evaluate proven bulls and cows as well as young sires, embryos, and even pregnancies based on a combination of production and conformation traits. Following the basic Canadian philosophy of "balanced breeding", the LPI places a relative emphasis on its two sub-indexes, namely production (60%) and type (40%):

$$LPI = (6 \times PROD + 4 \times TYPE) \times 8$$

where PROD is exactly the same sub-index as described for the TEV index and TYPE is a sub-index that includes conformation traits that contribute to overall longevity. As with all other sub-indexes used in Canada, each of these are standardised so the weights of 6 and 4 represent the standardised index weights for each sub-index. The multiplicative factor of 8 simply expands the range of the scale such that the top Holstein bulls have LPI slightly over 2000 points.

The desire to have a selection tool which

1. can be easily understood,
2. can be applied to all groups of animals since EBV for traits involved are available for all animals or their parents, and
3. reflects the Canadian breeding philosophy

has resulted in relatively heavy use of the LPI in Canada. Although the TEV reflects true economic weights, the fact that it includes functional traits, such as herd life, SCS and milking speed, for which official EBV for cows are not currently available, has resulted in a more limited use in Canada. Continued development and extension of the TEV is ongoing, which will undoubtedly lead to greater usage of TEV compared to LPI (Van Doormaal, 1999c). The maintenance of these two indexes, however, helps serve the interests and breeding objectives of the diverse pool of producers and breeders in Canada so both will likely remain for many years to come. Sivanadian *et al.* (1998) demonstrated that a commercial producer could expect to increase the genetic potential of his herd for profitability by selecting from among the top bulls for either the TEV or LPI.

3.2. Type sub-index

Because the production sub-index of the LPI formula has previously been described, the focus here is on the sub-index for conformation traits, as a measure of longevity:

$$TYPE = (5xMAMM+4xFL+CAP+CONF) xCAF.$$

This sub-index includes EBV for mammary system (MAMM), feet and legs (FL), capacity (CAP) and overall conformation (CONF) with relative weights of 5, 4, 1 and 1, respectively. The production sub-index includes EBV for two highly correlated traits (protein and fat), whereas the type sub-index includes EBVs for a combination of four traits that are less genetically correlated. Therefore, the type sub-index also includes a correlation adjustment factor (CAF) which is approximately 1.2 for the Holstein breed. In this way, the desire of the industry to have, on average, 60% of the LPI points for bulls coming from the production sub-index and 40% from the type sub-index is achieved (Van Doormaal, 1999a).

The EBV for each of the conformation traits included in the type sub-index are calculated from a single trait animal model genetic evaluation system, based on only first lactation first classifications, as briefly described earlier related to udder depth. Although the four conformation traits in the LPI are often considered general traits rather than descriptive traits, the EBV are computed based on actual classification scores for each trait not as composites of EBV for descriptive linear traits.

4. Other Functional Traits in Canada

Canadian Dairy Network (CDN) is responsible for the calculation and publication of all dairy cattle genetic evaluations in Canada. In addition to the traits already discussed, namely production, conformation, herd life, somatic cell score and milking speed, bulls in Canada also receive an evaluation for calving ease, lactation persistency and non-return rate with ETA for milking temperament and health traits expected in the future. Research is ongoing to determine how these traits can be included in the existing TEV and LPI formulae with the appropriate emphasis in conjunction with the Canadian breeding goal; maximising on-farm profits.

4.1. Calving ease

Bull evaluations for calving ease, both direct and maternal, have been available in Canada for several years. The published bull ETA are calculated using a multiple trait (direct calving ease and maternal calving ease) animal model based on a subjective appraisal of all calvings on the farm provided by the herdsman. Each calving is scored on a 4-point scale as unobserved or unassisted, easy pull, hard pull, and surgery required. Stillbirths and multiple birth calving are excluded. The actual scores are transformed to Snell (1964) scores prior to analysis with a linear model. Knowledge of the service sire and the sire of the female giving birth as well as all pedigree data allows for the determination of bull evaluations for direct calving ease and maternal calving ease, respectively.

Since 1997, calving ease ETA, which are only available for bulls in the Holstein breed, have been expressed on a positive descriptive scale which is closely related to the scale used to report the calving ease appraisal on the farm. This approach helps in the proper interpretation of published calving ease evaluations (Van Doormaal, 1997). For example, direct calving ease ETA range from 75% to 90%, with an average of 85%, and represent the percentage of calving from virgin heifers that are expected to be scored either Easy, Unassisted, or Unobserved. Calving ease ETA are mainly used by producers to avoid mating that can result in problems (i.e. to avoid mating bulls with poor calving ease ETA to virgin heifers or small cows) rather than explicitly selecting for improved direct calving ease on a population level. The combined information on direct and maternal calving ease is useful for identifying bulls that do not have the typical negative genetic relationship between these two components of calving ease.

4.2. Lactation persistency

Lactation persistency describes the average lactation curve of a bull's daughters, at a genetic level, over the first three lactations. Sölkner and Fuchs (1987) stated that cows with flatter lactation curves are easier to feed, subject to less physiological strain, and can be fed diets with a greater proportion of roughage. Dekkers *et al*. (1998) reported that the economic benefits of increased persistency were particularly important within herds with longer than average lactations. Bull ETA for each lactation are a by-product of the multiple trait, random regression test-day animal model used in Canada since February 1999. The ETA for lactation persistency are based on milk yield (rather than fat or protein) and each bull's ETA for 24-hour milk production on day 280 of lactation is expressed as a percentage of their ETA for the same trait on day 60 of lactation. This ratio is calculated for each of the three lactations and the resulting ratios are combined into one overall lactation persistency rating, or sub-index, using relative weights of 50%, 25% and 25% on lactations 1, 2, and 3, respectively. Published ETA for combined lactation persistency have varying averages and ranges across breeds (Van Doormaal, 1999b) but for Holsteins the average ETA is 63% with a range of ±10% points.

4.3. Non-return rate (NRR)

Bulls available through artificial insemination (**AI**) receive a linear model fertility evaluation measured in terms of 56-day NRR. First inseminations performed by AI technicians during the most recent rolling 12-month period are analysed using a mixed linear model which includes the effects of month of first insemination, age of cow at insemination, semen price, breed of service sire, AI technician, herd, service sire and residual error. Van Doormaal (1993) describes details on the data, model and results.

Bull evaluations for 56-day NRR are provided to AI centres and breed associations in Canada for all bulls but basically only those for actively marketed sires are available to producers. Average bull ratings vary across breeds and is 71% for Holsteins. Low fertility bulls seldom get totally excluded from use but bulls with above average ratings do get used more frequently, especially on poorer reproductive cows.

4.4. Future functional traits

For several years now, Canadian milk recording agencies have been collecting a subjective measure of milking temperament within the first 120 days of the first lactation. Researchers are currently in the process of collating this data into one database for purposes of genetic evaluation. Canadian producers have expressed a desire for genetic information on this trait because it affects their culling decisions, and therefore, profitability.

An area of growing interest in Canada is health traits. Work has been initiated for identifying important measures related to health and disease as well as establishing standards for data collection. Similarly, body condition score and mobility have received recent attention (Van Dorp *et al.*, 1998) which will likely lead to genetic evaluations in the future.

5. Conclusion

The Total Economic Value (TEV) is a sire selection tool designed for commercial dairymen interested in selecting for increased profits via production and functional traits including herd life, somatic cell score, milking speed and udder depth. The development of the TEV in Canada has been based on the establishment of sub-indexes for production, longevity and udder health so that a clear understanding of the relative economic importance of each component is easily identified. The TEV was originally designed as an index for sire selection. However, the extensive use of the TEV is currently limited by the fact that it is only available for proven bulls and, therefore cows, young bulls, and heifers do not have any published values either directly or calculated as a parent average.

Lifetime Profit Index (LPI) has seen extensive use in Canada since its introduction in 1990, resulting in a significantly increased selection intensity and genetic gain. Although its development was less scientifically oriented compared to the TEV, it has received widespread acceptance by breeders who sell breeding stock nationally and internationally.

Canadian Dairy Network calculates and publishes genetic evaluations for an array of traits, some of which are included, either directly or indirectly through the use of sub-indexes, in the TEV and LPI selection indexes. Additional functional traits such as lactation persistency and milking temperament will no doubt also eventually be added into the TEV formula, as will future genetic evaluations for important health traits.

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