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Selection indices for dairy cattle including fitness traits

Dedicated to Prof. Dr. Dr. h.c. Gottfried Leuthold on the occasion of his 65th birthday

Summary

In the present Swedish Total Merit Index (TMI) 13 subindices are weighted together by means of their economic weights. This is correct under the assumption that all genetic correlations between the subindices have zero-values. Recent research has revealed negative genetic correlations of the order of -0.10 to -0.45 between the subindices for yield and those for daughter fertility and disease resistance. This is one of the reasons behind the present revision of the Swedish TMI. Other reasons are new aspects of 'supertraits' or subindices as components in a TMI and new knowledge about the selection for longevity. The selection index procedure is described and actual estimates on genetic correlations between key-traits in the two main dairy breeds in Sweden are presented. The proposed new TMI for Sweden is illustrated. The construction of it is a two step procedure. In the first step the subindices are constructed. In the second step the TMI is calculated with consideration of the economic weights of the subindices and the genetic correlations among them using the subindices as both variables and traits. In both steps the selection index principles of HAZEL (1943) are adopted.

Key words: selection indices, dairy cattle breeding, fitness traits

Zusammenfassung

Titel der Arbeit: **Selektionsindices für Milchrinder, unter besonderer Berücksichtigung von Fitnessmerkmalen**

In den gegenwärtigen schwedischen Gesamtleistungsindex (TMI) sind 13 Subindices eingegangen, die nach ihrer ökonomischen Wertigkeit gewichtet wurden. Diese Vorgehensweise ist berechtigt unter der Voraussetzung, daß alle genetischen Korrelationen zwischen den Subindices nahe Null liegen. Die neuere Forschung hat negative genetische Korrelationen in der Größenordnung von -0,10 bis -0,45 zwischen den Subindices für den Milchertrag und jenen der Töchterfruchtbarkeit und Krankheitsresistenz aufgezeigt. Dies ist einer der Gründe für die gegenwärtige Überarbeitung des schwedischen TMI. Andere Gründe sind neue Aspekte über „Supermerkmale" oder Subindices als Komponenten in einem TMI und neue Erkenntnisse über die Selektion auf Langlebigkeit. Die Konstruktion des Selektionsindex wird beschrieben und aktuelle Schätzergebnisse über genetische Korrelationen zwischen Hauptmerkmalen bei den beiden wichtigsten schwedischen Rinderrassen aufgezeigt. Der vorgeschlagene neue TMI für schwedische Bedingungen ist dargestellt. Die Indexkonstruktion erfolgt in zwei Schritten. Im ersten Schritt werden die Subindices konstruiert. In einem zweiten Schritt wird der TMI unter Beachtung der ökonomischen Wichtung der Subindices und der genetischen Korrelationen zwischen ihnen kalkuliert, wobei die Subindices sowohl als Variable als auch als Merkmale genutzt werden. Bei beiden Schritten werden die Prinzipien der Selektionsindexkonstruktion von HAZEL (1943) übernommen.

Schlüsselwörter: Selektionsindices, Milchrindzucht, Fitnessmerkmale

Introduction

Traditionally milk yield has been the most important trait in the breeding goal for dairy cattle. In many countries a parallel selection for improved conformation and type has taken place. In the Scandinavian countries the breeding goal was broadened rather early. In the sixties performance testing of the growth rate from birth to the age of one year of prospective AI- bulls was initiated and some selection was employed before the bulls were accepted for semen production and progeny testing. In 1975 this breeding value for growth rate was included in the Total Merit Index (TMI). Recording of stillbirths started early. The first TMI in Sweden (PHILIPSSON et al., 1975) comprised 13 traits in the breeding goal viz. yield, growth rate (based on the performance testing), female fertility, stillbirths as affected by the bull as sire, stillbirths as effected by the bull as maternal grandsire, ease of milking, udder conformation, udder height, teat length, teat placement, supernumerary teats, legs and temperament. In the eighties calculations of breeding values for resistance to "mastitis" and "other diseases" were introduced based on the compulsory recordings of veterinary diagnoses. In 1986 these two traits were included in the TMI. The last addition of new traits is the present introduction of beef production capacity based on carcass evaluation data from the slaughter houses which are combined with birth data from the milk recording scheme by means of identity records of all slaughtered animals. The beef production trait has two components, growth rate and carcass conformation. This new beef trait replaces the earlier growth rate trait and performance testing of prospective AI-bulls for growth rate will be terminated.

Table 1
The present traits in the Swedish breeding goal for dairy cattle and their economic weights for the two main Swedish breeds Swedish Red and White (SRB) and Swedish Friesian (SLB) (Die Merkmale im schwedischen Zuchtziel für Milchrinder und ihre ökonomische Wichtung für die zwei wichtigsten schwedischen Milchrindrassen Schwedische Rote und Weisse (SRB) und Schwedische Friesian (SLB))

Traits in the breeding goal	SRB	SLB
Production traits		
Protein yield	1.00	1.00
Beef traits	0.35	0.35
Health traits		
Daughter fertility	0.30	0.30
Stillbirths in heifers, sire effect	0.10	0.20
" " , maternal grandsire effect	0.10	0.30
Disease resistance, mastitis	0.30	0.35
" " , other diseases	0.15	0.15
Conformation etc		
Body	0.10	0.10
Legs	0.20	0.20
Udder	0.50	0.50
Temperament, above 100 max 1.5	0.15	0.15
, under 100	0.30	0.30

Over the years the definition of yield has changed. The original definition, 4% milk, was replaced by kg fat + kg protein, which in turn was replaced by the present definition, kg protein, in 1990. The actual TMI in Sweden comprises 11 traits which are presented in Table 1 together with their present economic weights. The BLUP-procedures used for the individual traits are listed by LINDHÉ et al. (1994). All proofs have a standardized genetic standard deviation of 7.

Aspects of a revised index

The present TMI is based on the principles, outlined by HAZEL (1943). The recorded variables are identical with the breeding goal traits and as the recorded variables are breeding values and as it is assumed that all genetic correlations have zero-values, the b-values are identical with the economic weights. The actual TMI is at present subjected to a revision. New aspects have been presented on the general strategy in the construction of indices of the complexity of TMI:s for dairy cattle and new knowledge is now available on the genetic correlations between the main traits in the index as well as on the importance of the lenght of productive life in the selection of dairy cattle. In addition the economic weights needed validation. The indices for young animals, for cows and for bulls will all have the same breeding goal traits and identical economic weights.

The construction of selection indices

The selection index developed by HAZEL (1943) can combine information from several sources, the same trait from different types of relatives, different traits measured on the animal or different traits from different types of relatives, to predict the animal's genetic merit. The economic objective is to improve all traits, Y_i, and these are combined into a selection objective, denoted by H, together with the economic weights, a_i, as follows.

(1) $$H = a_1Y_i + a_2Y_2 + \dots + a_mY_m$$

The selection objective can be expressed in matrix notation as a'Y.

According to the vocabulary in CUNNINGHAM (1969) the traits in the breeding goal are named traits in this report.

The selection criteria may be identical with the traits in the breeding goal. However, the phenotypic measures used as selection criteria are often records on progeny etc. In this report the phenotypic criteria are named variables. The variables, denoted X_i, are combined in an index, I, on which the animals are selected.

(2) $$I = b_1X_1 + b_2X_2 + \dots + b_nX_n$$

The selection criterion, I, can be expressed in matrix notation as b'X .

The selection index method determines the b-values that maximise the response in the selection objective and the correlation between H and I.

The information needed to solve the parameters of the index are

v a vector of relative economic values of the traits
C an m * m matrix of genotypic covariances between the m traits.
P an n * n matrix of phenotypic covariances between n variables.
G an m * n matrix of genotypic covariances between m traits and n variables.

The solution of the b-values are

(3) $b = P^{-1} G v$

Derivation of economic values

The methodology in deriving economic values has been subject to a large number of studies which are summarised in an exhaustive report of an EAAP-working group (GROEN et al., 1997). The economic weight of a trait should reflect the predicted contribution to the improvement of the breeding goal (BRASCAMP, 1978). This contribution is determined by time and frequency of future expressions of genetic superiority (cumulative discounted expression), and benefit at the moment of expression of genetic superiority of the trait. To achieve this cumulative discounted expressions (McCLINTOC and CUNNINGHAM, 1974) have to be calculated and multiplied with the marginal value of one expression to arrive at the economic weight for the actual trait.

Genetic correlations

Until quite recently little was known on genetic correlations among traits in the breeding goal for dairy cattle. However, a number of reports have been published recently and summarised by LINDHÉ and PHILIPSSON (1998). A recent paper by PRYCE et al. (1998) support the conclusion that unfavourable genetic correlations of the order of –0.10 to -0.45 generally are found between yield of protein and daughter fertility and between yield of protein and mastitis resistance. In Table 2 the most recent estimates of genetic correlations are given for the two main breeds in Sweden, Swedish Red and Whites, SRB, and Swedish Friesians, SLB. The estimates have been derived by means of the procedure given by CALO et al. (1973) based on correlations between breeding values (calculated within years) for bulls born 1979 – 1991.

The consistency of estimates in different countries and the magnitude of the values makes it obvious that the genetic correlations have to be included in the calculations of the future TMI:s for Sweden. PHILIPSSON et al. (1994) showed that failure to consider functional nonproduction traits as variables reduces the efficiency of the selection index. LINDHÉ and PHILIPSSON (1998) found that the effects of negative genetic correlations (compared to a situation with genetic correlations with zero-values) on the b-values in the total merit index of bulls were rather small but the effects on the estimated genetic gain were large. The total gain was reduced by 9 – 10% if health and fertility traits were omitted as variables but included as traits with their present economic weights. In conclusion, the total gain is larger if health and fertility traits are included as variables although the gain in yield is reduced.

Table 2
Estimated genetic correlations among yield of protein, daughter fertility and resistance against mastitis and "other diseases" for the two main Swedish Dairy breeds SRB (1537 bulls) and SLB (479 bulls) (Geschätzte genetische Korrelationen zwischen dem Proteingehalt, der Töchterfruchtbarkeit und der Krankheitsresistenz gegen Mastitis und andere Krankheiten bei Bullen der zwei wichtigsten schwedischen Milchrindrassen SRB (1537 Bullen) und SLB (479 Bullen))

Traits	SRB	SLB
Protein yield and daughter fertility	-0.34	-0.38
Protein yield and mastitis resistance	-0.16	-0.26
Protein yield and resistance "other diseases"	-0.26	-0.27
Daughter fertility and mastitis resistance	0.23	0
Mastitis and "other diseases"	0.43	0.34

The estimated genetic trends in the two Swedish dairy breeds, SRB and SLB, (LINDHÉ et al., 1994) with negative figures for daughter fertility illustrate the practical effects of the negative genetic correlations between protein yield and daughter fertility. During the period 1981 – 1989 the trend was slightly negative for SRB and negative for SLB. The negative trend for SLB was due to the large-scale importation of bull sire semen from North America. The effect of the Holstein immigration was a strong positive effect on yield and a significant negative effect on daughter fertility. HOEKSTRA et al. (1994) found similar effects of the Holstein immigration in Holland. These observations illustrate the effects of the North American breeding with strong emphasis on yield and no consideration of female fertility. In the SRB-breed young bulls with Finnish or Norwegian sires did not deviate from young bulls with Swedish sires as regards female fertility. In the Nordic countries female fertility has been included in the TMI-selection for long. The lack of genetic gain in this trait, despite of this, reflects the effect of the negative genetic correlation.

The positive trend for mastitis resistance despite of the negative genetic correlation between protein yield and mastitis resistance may be an effect of the positive genetic correlations between udder conformation and mastitis resistance. During the period studied the udder conformation in the SLB-breed was significantly improved as a consequence of the immigration of Holstein genes. This trait has also been improved to a large extent in the SRB-breed as a consequence of the economic weight of the trait, illustrated in Table 1.

Supertraits in the Total Merit Index

WILMINK (1996) argued for the construction of what he called supertraits. The reason was the large number (more than 20) of direct and indirect traits for which data are available and can be used for breeding value estimation. If the number of traits in a selection index is not limited problems may arise with calculating the index weights or index weights may get unrealistic values. In addition, monitoring of the selection process may be difficult. WILMINK proposed the definition of eight supertraits to be used in dairy cattle breeding and that the weighting might be based on desired genetic progress or on marginal economic weights. He proposed tailor-made TMI:s for individual farms, which is not actual in Sweden, but this does not affect the principle. The eight supertraits were efficiency of milk production, efficiency of beef production, fertility, calving ease, health general, udder health, feet and legs and milkability. The supertrait-concept is already a part of the present index in Sweden described in Table 1. Daughter fertility is a "supertrait" with no less than 8 variables behind it. Mastitis resistance has 3 variables etc.

Selection for longevity

A number of countries have recently introduced breeding values for longevity or herd life.

National evaluations for productive life (PL) were calculated for the first time in the USA in January 1994 (WIGGANS et al., 1994). The trait is based on the months that a cow is in milk (up to a maximum of 10 months per lactation) until the cow dies or reaches 84 months of age. For living cows, predicted months of productive life are used. A cow's age, age at first calving, stage of lactation and accumulated months in milk affect this prediction. Productive life measures a cow's ability to resist culling of all types: yield, reproduction, mastitis etc. The statistical procedures behind the PL-evaluations were documented by VanRADEN and KLAASKATE (1993) and VanRADEN and WIGGANS (1995).

In January 1996 official evaluations on herd life were released in Canada. The evaluations were adjusted for production in first lactation to remove the effect of culling for production. Resulting evaluations thus reflect the ability of the daughters of a sire to survive for reasons other than production. Both direct and indirect information was used to arrive at published evaluations. (JAIRATH et al., 1996). The direct evaluations were obtained by combining evaluations for survival in each of the first three lactations, which were obtained through a multiple trait evaluation of survival (0/1) within lactation 1,2 and 3. Indirect evaluations were based on an index of the composite conformation traits mammary system, feet and legs, rump and capacity. The herd life evaluations were normally distributed and represented a range of about one lactation, which implies that daughters of extreme sires are expected to differ by one lactation in functional herd life.

DUCROCQ and SÖLKNER (1998) reported on the implementation of a routine breeding value evaluation for longevity of dairy cows in France and in Austria in June 1997 using survival analysis techniques. Proportional hazards models have been extended to incorporate time-dependent covariates and applied to the analysis of length of productive life. (DUCROCQ, 1987). Arbitrary baseline hazard function in the proportional hazard model has been replaced by a parametric (Weibull) hazard function (DUCROCQ, 1987). This result coupled with the extension of mixed survival models to include relationships between sires have been used in the national evaluations of dairy bulls in the two countries mentioned.

VOLLEMA (1998) has described the three alternative definitions of the breeding goal viz. uncorrected longevity, functional longevity and residual longevity. Uncorrected longevity can be seen as containing all traits that are relevant to the farmer, including milk production. Because in most breeding programs milk production is recorded routinely, functional longevity or longevity adjusted for yield, could be used to breed for all functional traits simultaneously. In breeding programs where some functional traits are measured directly, residual longevity might be used to avoid double counting of traits.

In addition, the definition of longevity can vary. A distinction can be made between traits that measure the whole lifetime of a cow, such as herd life or length of productive life and stayability traits which measure whether or not a cow survived until a certain moment of time, such as stayability until 36 months of age or survival of the third lactation. VOLLEMA (1998) summarised the heritabilities found in the literature. For functional herd life and functional length of productive life , estimates ranged from 0.02 to 0.10 with a weighted average of 0.065 for functional herd life and 0.069 for functional length of productive life. Heritability of stayability until a certain number of months ranged from 0.01 to 0.06, increasing with increasing age at evaluation of stayability. It is thus obvious that the heritability of traits, reflecting the ability of a cow to produce for a long time, are low and of the same order as other fitness traits like daughter fertility and disease resistance. Accurate breeding values for these traits require daughter groups of the order of 100 – 150.

The economic value of longevity has often been estimated. VanRADEN and WIGGANS (1995) made an overview of the relative economic values of yield and herd life from the literature , and concluded that the ratio between both values was on average 2.5:1. VOLLEMA's (1998) estimated value was of the same order. All estimates were expressed on a genetic standard deviation basis. However, the variation between estimates was large, emphasising that the economic value of longevity depends on the production circumstances and on the calculation procedures used.

Consideration of longevity in dairy cattle breeding has the disadvantage that accurate breeding values are not available as early as breeding values for yield, daughter fertility and disease resistance. The simple reason is that a large proportion of the daughters are still alive at the end of the first lactation. Survival analysis techniques which have been used in France and Austria allow the inclusion of information from living animals in a statistically adequate way as censored observations. The length of productive life which the cow has reached at the censoring point is the lower bound of her true length of life and contains valuable information. In addition in survival analysis effects can be modelled in a time dependent way, yielding a more realistic model. VOLLEMA and GROEN (1998) estimated breeding values of sires in three different ways: as the average realized longevity of the sire's daughters, with a best linear unbiased prediction and with survival analysis. The phenotypic average of the sire's daughters had weak rank correlations with the other two methods of breeding value prediction. However the correlation between the best linear unbiased prediction and the survival analysis prediction was strong (-0.91 and –0.94) on small and large farms respectively) if only uncensored records were used in the survival analysis. The relative superiority of survival analysis is thus greatest during the period in a sire's life immediately following the appearance of the first proofs for yield etc. VUKASINOVIC et al. (1996) investigated the impact of censoring on the accuracy of estimated transmitting ability (ETA) for productive life of sires using a simplified model from uncensored data (reference) and the ETA from several different data files with an increased proportion of censored records. The rank correlations among sire ETA decreased as number of daughters per sire decreased and as the proportion of censored records increased. They concluded that the maximum number of censored records that is acceptable to obtain accurate results is 30 to 40 %. It is thus uncertain if suvival analysis can give accurate proofs for productive life as early as accurate proofs for yield etc. are available.

One last aspect on functional longevity is if this trait should be considered as an intermediate step towards development of selection strategies based on genetic evaluations or indicators for fertility and resistance to diseases (DEKKERS and JAIRATH, 1994) or if residual herd life has enough variation to justify its inclusion in a TMI parallell to yield, daughter fertility and resistance against mastitis and other diseases. EMANUELSON et al. (1998) concluded that there is a considerable genetic variation in adjusted LPL. Fixed effects in the model were parity, stage of lactation, milk yield, risk factor diseases (by time of occurrence) and the interactions between stage of lactation and diseases, where stage of lactation, diseases and their interaction were treated as time-dependent. They concluded that ranking of sires for adjusted LPL provides new information. The present Swedish proof for stayability reflects the proportion of daughters surviving the second lactation and is calculated in a single trait model without relationship matrix. The uncorrected proof for 1537 SRB bulls has a standard deviation (calculated within years) of 5.70. If this proof is adjusted for the yield proof of the bull the standard deviation is reduced to 5.40. If it is adjusted for the proofs for yield, daughter fertility and resistance against mastitis and other diseases the standard deviation is reduced to 4.91. Corresponding values for 479 SLB bulls amount to 5.72, 5.63 and 4.83 respectively. It is thus obvious that adjustment of the Swedish stayability proof for the proofs for yield, daughter fertility and resistance against mastitis and other diseases does not eliminate its variation. The procedure for evaluation of longevity, described by DUCROCQ (1987), will replace the present Swedish procedure as soon as possible.

A proposal for a new TMI for Swedish dairy bulls

The proposal for a new TMI for Swedish dairy bulls is, as before, based on the sub index – or the "supertrait"-concept described above. The genetic correlations among the sub indices will be included in the calculations and the calculated b-values will be used when the supertraits are being weighted together into a TMI. A final general idea is that the variables behind Efficiency of milk production, Udder health and Other diseases shall cover the performance in the three first lactations (for bulls with this information) and not only the first. As before the traits reflect the whole life of the cow. The proposed TMI is presented in Table 3.

Originally conformation traits were intended to be used only as predictors (GROEN et al., 1997). Contrary to the primary intentions, the conformation traits are to be found among the sub indices. The opinion among the farmers that udder conformation has a value per se when we are facing new techniques at milking etc and the deliberate desire of the breeding organization of the SRB-breed to create a cow with a height of 140 cm are the arguments behind this decision. This decision means that the genetic correlations between the conformation traits and other sub indices are considered at the final calculation of the TMI and not at the calculation of the sub indices for the functional traits.

Table 3
The proposed TMI for Swedish dairy bulls (Der vorgeschlagene TMI für schwedische Milchrindbullen)

Sub index	Traits	Variables
Efficiency of milk production	Carrier, protein kg, milk quality	Carrier, protein kg, milk quality parameters. Lactation 1 - 3
Efficiency of beef production	Growth rate, conformation	Growth rate, conformation
Female fertility	No. of ins./pregn. Interval calving-first ins. Heat code	No. of ins./pregn Interval calving - first ins. Heat code Sterility treatments Pregnancy 1 - 3
Calving ability	Direct and maternal Stillbirths and dystocia	Stillbirths, dystocia First calving
Udder health	Diagnoses	Diagnoses, cell count, cows eliminated because of mastitis Lactation 1 – 3
Other diseases	Diagnoses	Diagnoses Lactation 1 – 3
Udder	Udder conformation	Udder parameters
Legs	Conformation of feet and legs	Feet and legs parameters
Height	Height	Height at sacral region
Length of life	Residual length of productive life	Residual length of productive life

The reason why calving ability is limited to the first calving is the lack of reliable genetic parameters for later calvings.

The construction of the new TMI will be a procedure performed in two steps. In the first step every sub index is calculated according to the Hazel principles described and is thus a breeding value of the bull, which will be published. In the second step genetic correlations among the sub indices will be calculated, the economic weights will be estimated considering the number of discounted expressions and finally, the Total Merit Index will be calculated with the sub indices as both variables and traits.

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Buchbesprechung

Schweineproduktion in Deutschland (Ausgabe 1998)
Bearb. von E. M. GATZKA, K. SCHULZ, Dr. J. INGWERSEN

Hrsg.: Zentralverband der Deutschen Schweineproduktion e. V., Bonn, 165 Seiten, 100 Tabellen

In bewährter Weise hat der Zentralverband der Deutschen Schweineproduktion in der vorliegenden 45. Auflage die Zahlen aus der deutschen Schweineproduktion des Jahres 1997 vorgelegt. Bedingt durch die Marktentlastung, welche durch das Seuchengeschehen vor allem in den Niederlanden eintrat, hat sich zunächst die Erlössituation für die deutschen Schweinehalter verbessert. Das galt sowohl für die Ferkel- als auch die Schlachtschweinepreise. Verglichen mit den Zahlen des Jahres 1996 hatten sich die Bestandszahlen 1997 in allen Tierkategorien geringfügig verbessert und die Schweinezucht- und KB-Organisationen berichteten über Zuwächse beim Zuchtschweine- und Spermaabsatz. Unter dem Druck des wachsenden Angebotes war im Jahresverlauf abzusehen, daß die Schweinepreise fallen würden und die vorliegenden Zahlen weisen aus, daß vor allem ab dem 4. Quartal 1997 die Preise sowohl für Schlachtschweine als auch Ferkel erheblich sanken. Ein Trend, der sich bekanntlich im Jahr 1998 fortsetzte. In umfassender Weise informiert diese Schrift über Markt, Produktion, Zucht, Zuchtunternehmungen, Leistungsprüfungen, künstliche Besamung sowie die Entwicklung der Schweineerzeugerringe in Deutschland, teilweise in den Ländern der EU. In übersichtlichen Tabellen wurde wiederum ein sehr umfangreiches Datenmaterial zusammengestellt. Es vermittelt im einzelnen Informationen zu folgenden Komplexen:

- Markt für Schweine und Schweinefleisch in Deutschland
- Markt für Schweine und Schweinefleisch in der EU und in Drittländern
- Produktion von Schweinen und Schweinefleisch in Deutschland
- Produktion von Schweinen und Schweinefleisch in der EU und in Drittländern
- Schweinezucht in Deutschland
- Leistungsprüfung in der Schweinezucht
- Künstliche Besamung beim Schwein
- Schweineerzeugerringe in Deutschland und deren Kontrollergebnisse

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