Cumulative discounted expressions of dairy and beef traits in Ireland.

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Introduction

Cumulative discounted expressions (CDEs) are vital in the derivation of economic weights within breeding objectives. They account for differential rates and timing of expression of traits as well as accounting for the transfer of germplasm across sub-populations. This transfer of germplasm across sub-populations (e.g., dairy populations to beef populations or vice versa) occurs internationally although is rarely accounted for within breeding objectives. In Ireland, a large proportion of dams in beef herds originate within the national dairy herd. Despite this, prior to 2005 the expected beef performance of the descendants of a dairy sire was ignored within the national dairy breeding objective.

The aim of the current study was to derive generic equations, using transition probability matrices, to track the flow of genes across alternative production systems and to apply the equations to a representative Irish production system.

Materials and Methods

This study extends the discounted genetic expressions approach outlined by Amer et al. (2001) to a situation where descendants of specific animals are mated to more than one breed.

Lifetime Survivability and Transition Matrices

A vector $\mathbf{a}^{\alpha}$ was calculated for each breed type (α) to represent the probability of a cow surviving to and calving at age *i*, given it was alive at age *i*=1. A vector ($\mathbf{d}^{\alpha}$) describing the probability of a cow not surviving to *i* years of age, was also calculated for each breed type from the respective $\mathbf{a}^{\alpha}$ vector. A vector $\mathbf{f}^{\alpha}$ was created to describe the number of calves born (including stillbirths) per cow at *i* years of age allowing for the probability of multiple births but also for the possibility of barren cows remaining in the herd without producing a calf.

Let $\mathbf{D^{\alpha}}$ be an h by h transition matrix with columns of survival probabilities of breed α times the probability of producing a calf, lagged by one row for each new birth year. The variable h represents the planning horizon, in years, from the birth of the self-replacing female. In the present study h was set to twenty years. Thus, the $(i,j)^{th}$ element of each $\mathbf{D^{\alpha}}$ matrix was specified as follows:

$$D^{\alpha}_{i,j} = \begin{cases} a^{\alpha}_{i-j} \circ f^{\alpha}_{i-j} & \text{for } j < afc^{\alpha} + i - 1 \text{ and } i - j \le c \\ 0 & \text{otherwise} \end{cases}$$

where $\circ$ represents the Hadamard product of the respective vectors, afc^{α} denotes age at first calving for breed type α and c represents the age culling threshold.

Matrices for cull cow expressions ($\mathbf{G^{\alpha}}$) and replacement heifer expressions ($\mathbf{H^{\alpha}}$) were calculated as:

$$G^{\alpha}_{i,j} = \begin{cases} d^{\alpha}_{i-j} & \text{for } j < afc^{\alpha} + i - 1 \text{ and } i - j \le c + 1 \\ 0 & \text{otherwise} \end{cases}$$

$$H^{\alpha}_{i,j} = \begin{cases} 1 & \text{for } i = j + afc^{\alpha} - 1 \\ 0 & \text{otherwise} \end{cases}$$

First Appearance of a Cow's Genes over Successive Generations

An h by 1 vector ($\mathbf{g^{\alpha}_{k}}$) describing first appearances of genes in generation k=1 to m of a cow of breed α that calves at least once were calculated as:

$$\mathbf{g^{\alpha}_{k}} = \begin{cases} [1,0,\ldots,0]' & \text{for k} = 1 \\ \frac{1}{2} \cdot \varpi^{\alpha R} \cdot \mathbf{D^{\alpha}} \cdot \mathbf{g^{\alpha}_{k-1}} & \text{for k} = 2....\text{m} \end{cases}$$

where m is the number of generations for which the flow of genes were tracked; in the present study m was set to twelve. Aggregate yearly first appearances of genes accumulated over the m generations were calculated as the sum of the $\mathbf{g^{\alpha}}$ vectors:

Multiple Expression of a Cow's Genes

The **D**, **G**, and **H** matrices are used to multiply first appearances of a cow's genes to the actual expressions throughout her life and the lives of her self-replacing female descendants. A discounting vector (**q**) was created which is used throughout the calculations to discount the expressions back to a given time period. The vector **q** accounts for a lag of one year (i.e., row) in the **D**, **G**, and **H** matrices and discounts back to the time of birth of the animal accruing from the original mating.

The ith element of the discounting vector was defined as:

$$q_i = \left(\frac{1}{1+\mathrm{r}}\right)^{\mathrm{i}-1}$$

where *r* is a discounting factor.

Trait Categories

Cumulative discounted expressions in integrated cattle populations need to account for the probabilities of cow and calf trait expressions occurring through alternative pathways. Depending on the prevailing circumstances animal breeders may be interested in the CDE following the initial mating of either a breed A male or a breed B male with a breed A female. Separate vectors and matrices may be derived for each (cross)breed.

In the present study, six main trait categories were defined. These included annual traits (e.g., reproductive efficiency, lactation), replacement heifer traits (e.g., live weight at first calving), cull cow traits (e.g., carcass weight at culling), birth traits (e.g., birth live weight), yearling traits (e.g., yearling live weight) and slaughter traits (e.g., carcass conformation). The vectors and matrices previously defined were used to build equations for predicting CDEs for the six trait categories.

Case study (Ireland)

This case study represents the Irish system of cattle farming where a strong relationship exists between dairy (Breed A) and beef (Breed B) enterprises. A large proportion of dairy farms either supply animals to or operate a beef enterprise. Initial parameters required for the calculations were obtained from national data. An additional vector summarising the proportion of self-replacing dairy females of different ages mated to beef males was created based on national data. In a situation of complete market failure the benefits to the dairy farmer of generating superior crossbred replacement females for the beef herd are not realised through premium prices. Sensitivity analyses were performed by altering the various input parameters including the degree of market failure and recalculating the CDEs.

Results and Discussion

The CDE for each of the six trait categories following an initial mating between either a dairy male (Breed A) or a beef male (Breed B) with a dairy female are summarised in Table 1. A contributing factor to the difference in CDE between annual and replacement heifer traits is because heifer replacement traits are only expressed once per lifetime. Cumulative discounted expressions of cull cow traits are in turn lower than the CDE for replacement heifer traits because a cow is only culled once, while only a proportion actually exhibit the trait. Additionally culling occurs after a time delay and so cull cow expressions are discounted accordingly. Poorer cow longevity and/or lower cow mortality reduced the relative difference between the CDE for replacement heifer and cull cow traits.

The difference between the CDE for birth traits and yearling/slaughter traits arises because females destined to become replacements were not counted as expressing yearling or slaughter traits. Greater discounting and mortality also contribute to the difference in CDE between birth and yearling/slaughter traits. Differences in the CDE for yearling and slaughter traits reflect mortality from yearling to slaughter and higher discounting to age at slaughter.

Table 1. *Cumulative discounted expressions for annual, replacement heifer, cull cow, birth, yearling and slaughter traits.*

	Initial breed mating	
Trait	A x A	B x A
Annual	0.89	0.24
Replacement heifer	0.28	0.06
Cull cow	0.19	0.04
Birth	1.05	0.66
Yearling	0.66	0.45
Slaughter	0.59	0.41

It is important to realise that some annual traits may be economically relevant in dairy enterprises but not in beef enterprises, and vice versa. For example, the genetic merit of a dairy sire in Ireland for lactation milk yield will be irrelevant to a beef farmer; hence the expressions of these traits in beef herds should not be included in the CDE of a dairy sire for lactation milk yield.

Assuming that shortly after birth crossbred (AB) females destined to become replacement females (in Ireland this represents 12% of AB progeny) enter a beef herd, then less than 13% of the total CDE for all trait categories (using current input parameters) are expressed in the beef herd when the initial mating is between a dairy male and a dairy female. However, a number of the purebred dairy expressions for yearling and slaughter traits may also occur in the beef herds since a large proportion of surplus purebred and crossbred dairy progeny in Ireland will be finished in beef herds.

When no crossbred progeny enter beef herds the intensity of market failure is irrelevant. Under complete market failure the CDE of a dairy sire's genes for birth traits when mated to a dairy female decreased as the proportion of crossbred females entering the beef herd increased. The opposite was true when no market failure existed. Market failure does not exist if a farmer operates both a dairy and beef enterprise or a dairy farmer has a reputation for producing superior crossbred replacement females. For example, an Irish beef farmer may actively seek crossbred females from dams with favorable beef characteristics. However, in the majority of countries the full economic benefits of crossbred animals and their descendants are rarely realised by the generating farmer. This questions the (full) inclusion of such expressions in the CDE of the original sire. Nevertheless, the fundamental aim of all national breeding organisations should be to maximise genetic gain and profitability across all cattle. Thus, a national breeding organisation may choose to ignore market failure thereby servicing the entire cattle industry as a whole.

The CDE of a beef sire for all traits when mated to a dairy female were lower than for a dairy sire mated to a dairy female because of the low proportion of resulting progeny that enter the beef herd as beef replacements. Based on the parameters used in the present study, the CDE of yearling/slaughter trait genes of a beef sire are greater than the discounted expressions of annual cow traits of the sire. The difference between birth and yearling/slaughter traits was low because very few self-replacing female replacements were sourced from this breed type.

Conclusions

Absolute and relative differences in CDE existed among trait categories. The calculated CDEs were sensitive to the input parameters used especially cow survival. Relative differences in CDE observed following sensitivity analyses of alternative input parameters reveal that the relative emphasis of traits within a profitability index may alter thereby increasing the probability of identifying genotype by environment interactions for economic efficiency across alternative production systems. Nevertheless, results from the present study highlight the necessity to investigate the economic value of beef merit (or other auxiliary traits) in dairy breeding objectives in Ireland.

References

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