ACCOUNTING FOR FEED INTAKE IN DAIRY CATTLE EVALUATION

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SUMMARY
Selection of dairy cattle in New Zealand is based on an economic index known as Breeding Worth (BW). BW is a linear combination of economic weights (EW) and estimated breeding values (EBV) for lactation yields of milk, fat and protein, mature cow liveweight, longevity and fertility. The objective of this paper is to demonstrate that an equivalent index can be constructed whereby feed intake is included as a trait in the selection objective using information from the existing traits included in the selection objective. Trait EBVs and BWs for a small sample of bulls were obtained from the animal evaluation unit. The economic weights used to construct these index values were back solved by multiple regression of the trait EBVs on the index values from the sample data. Estimated breeding values for feed intake for each bull were derived directly from the EBVs for the production traits using standard formulae to calculate dry matter requirements for lactation, maintenance, pregnancy and (proportional) growth of replacements. Given the EW for feed intake (-\$0.32), economic values for the other traits that did not include their previous contribution for feed intake were found by back solving to obtain the original bulls' BWs. This ensured double counting of feed costs was avoided. The equivalent index resulted in different EWs but identical BWs. The EW for liveweight changed from -\$0.923 including feed costs to \$0.725/kg excluding fed costs. The EWs for milk volume increased from -\$0.074 including feed costs to -\$0.024 excluding feed costs.
Keywords: breeding objective, economic value, feed intake, dairy cattle

INTRODUCTION
Dairy cattle improvement programmes in New Zealand have a profit focus. Many farmers make primary use of the index values, known as Breeding Worth (BW) and expressed in \$ profit per 4.5 tonnes DM with little regard to the individual traits that constitute the index. The index is constructed as a linear function of estimated breeding values (EBV) for lactation yields of milk, fat and protein, mature cow liveweight, longevity and fertility and corresponding economic weights (EW), that is,

$$BW = \mathbf{x'v} \quad [1]$$

where **x** is a vector of order six with EBVs for the six traits and **v** is a vector of the corresponding EWs. These EWs are calculated using an economic model of a dairy farm, parameterised to national average production and economic circumstances. The management circumstances that underpin the economic model assume that any genetic change results in a modification to animal numbers such that total farm feed utilisation is not changed. That is, feed consumption is not a trait in the objective, but the opportunity cost of changes in feed consumption is taken account of in deriving economic weights.

The EWs for lactation traits reflect the impact of a marginal change in that trait on milk revenue, feed consumption and other costs. For example, the value of milkfat is dictated by the increased income from a unit increase in fat production, minus the opportunity cost of the increase in pasture consumption required to meet the changed nutritional demand of the increased fat production. In the case of milk volume, farmers are charged a penalty per litre, associated with the extra costs of transporting and processing milk on a volume basis. The economic value is more negative than the price penalty reflecting the feed requirements for lactose production. In respect to liveweight, the economic value reflects both the positive impact of heavier cattle on beef revenue and the negative effect of increased maintenance costs associated with heavier cows. The net effect at current beef prices is that this economic value is negative. Although producers have generally accepted and adopted the BW system, most do not understand the intricacies of the economic model and therefore cannot explain the reason why: the ratio of EWs for fat to protein is much lower than the market prices for these components; the volume penalty in the index is greater than the company penalty for volume; or why liveweight has a negative EW when they know that larger cows tend to produce more milk. In part, these difficulties result because the calculation of economic values requires both economic knowledge (related to costs, prices, opportunity costs and discounting) and biological knowledge for example relating animal performance to nutritional requirements. It is easier to understand the construction of EWs when the biological and the economic aspects can be kept separate. Garrick (2002) demonstrated from a theoretical basis that an equivalent index can be constructed whereby feed intake is included as a trait in the objective and an EBV for this trait can be derived directly from the EBVs for the production traits. The index is equivalent in the sense that given appropriate EWs for feed intake, and adjusting the EWs for production traits to exclude the feed costs component leads to identical index values for all animals. Although this index could be considered to be overparameterised (because an additional trait has been added that is a function of the other traits in the index), we believe it may be easier for producers and other interested parties to understand. The objective of this paper is to demonstrate the application of this methodology to the New Zealand BW index via a small example.

MATERIALS AND METHODS

Trait EBVs and BWs were downloaded from the web (www.aeu.org.nz) for a small sample of $b=10$ bulls (Table 1). The economic weights used to construct these index values were back solved by multiple regression of the trait EBVs on the index values from the sample data. That is

$$\mathbf{v} = (\mathbf{X'X})^{-1}\mathbf{X'y} \quad [2]$$

where $\mathbf{X}$ is matrix of order $b \times 6$ with each row representing a bull's EBVs and $\mathbf{y}$ is a vector of order b containing corresponding bulls' BWs. Note that b must be at least equal to the number of traits in the index.

An EBV for feed intake was constructed as a linear function of the lactation trait EBVs and a non-linear function of liveweight EBV as follows:

EBV feed intake = [EBV milk × DM milk] + [EBV fat × DM fat] + [EBV protein × DM protein]
+ fn[EBV liveweight × (DM maintenance + DM pregnancy + DM growth of replacements)]

Calculation of DM was based on the requirements of metabolizable energy according to standard formulae (AFRC, 1993). The resultant function can be closely approximated by the following linear function:

EBV feed intake = [EBV milk × 0.155] + [EBV fat × 6.175] + [EBV protein × 3.463]
+ [EBV liveweight × 5.138]

Table 1. Sample of dairy sires and their estimated breeding values and breeding worths (BW) from the national genetic evaluation of New Zealand dairy cattle (www.aeu.org.nz)

		Estimated Breeding Values [A]						
Bull code	Bull name	BW ($)	Prot (kg)	Fat (kg)	Milk (*l*)	Lwt (kg)	Fert (%)	Long (days)
97472	WILLAND ADS SAMUAL	234	27	46	261	-40	-0.8	-2
663962	WHINLEA MAGLEY EXTASY	219	60	54	1571	86	-3.7	-68
97507	CHEERS JOY OMEGA GR	177	24	31	319	-15	3.2	-6
92420	KIRKS DUNDEE GR	175	15	30	118	-56	4.4	25
99316	WAIAU EMINENCE LOTUS	174	41	39	982	54	3.7	-25
95421	ROYALS GREEN DAYBREAK	174	13	36	-294	-28	-0.5	113
98405	MONABRETT DOYLES IMAGE	173	23	39	212	-4	3.5	-54
99298	HAZAEL EMINENCE DEAN	173	49	43	1416	70	-1.8	-69
664164	BLACKDEE FOR HOGAN	172	13	37	10	-49	2.9	11
99351	GLENMEAD R E HOLIDAY-ET	199	55	48	1546	66	-6.8	-151

[A] Prot = protein, Lwt = live weight, Fert = Fertility, Long = Longevity.

The EW corresponding to [1] but excluding feed intake is obtained

$$\mathbf{v}^{\mathbf{equivalent}} = (\mathbf{X'X})^{-1}\mathbf{X'}\left(\mathbf{y}\text{-}v_f \times \mathbf{x_f}\right) \quad [3]$$

where $\mathbf{x_f}$ is the vector of feed intake EBVs and v_f is a scalar representing the EW of feed intake. The economic index of [3] augmented by the EW for feed intake will give identical index values and does not double count feed costs. For any EW assumed for the feed intake EBV, there is a unique set of EWs for the other traits that guarantees the same BW index of Equation 1. The derivation of the appropriate feed intake EW is beyond the scope of this paper.

RESULTS AND DISCUSSION

The resultant feed intake EBVs for the bulls in Table 1 are 210, 1224, 244, -34, 810, 76, 330, 1012, 21 and 1063 kg DM. The EWs for the six traits included in the national selection index used to rank dairy cows and bulls in New Zealand derived from back calculation as in [1] are in Table 2, along with the equivalent index EWs from [3] when feed intake is included at a cost of $0.32 per kg DM. The EWs for fat and protein when feed was separately taken into account are much closer to values currently used in milk payment. The EWs for fertility and longevity were hardly changed with the most drastic change being to the EW for liveweight which increased from -$0.923 to $0.725/kg, because the negative impact of extra feed required for maintenance was removed.

Table 2. Economic weights (EW) for milk traits, liveweight, fertility, longevity and feed intake used to calculate breeding worth of New Zealand dairy cattle

Trait	Official EW ($/unit)	Modified EW to include feed intake estimated breeding value
Fat (kg)	1.226	3.196
Protein (kg)	5.968	7.053
Milk (kg)	-0.074	-0.024
Live weight (kg)	-0.923	0.725
Fertility (%)	1.500	1.501
Longevity (days)	0.031	0.031
Feed intake (kg DM)		-0.320

Veerkamp (1996) indicated that if there is genetic variation in food utilisation and the goal is to improve net efficiency then feed intake needs to be included in the selection index. In this situation, EW for milk traits have to be recalculated to avoid double counting for feed costs. Veerkamp (1996) proposed adjusting DM intake genetically for milk yield traits already included in the breeding goal (milk, fat and protein) to produce EWs for the milk yields and adjusted feed intake. The relative EWs obtained using the methodology in this paper were similar to those obtained by Veerkamp (1996).

Correlated responses in feed intake from selection for yield is expected to cover less than 50% of the requirements needed for the extra milk yield (Veerkamp, 1998). Such trends suggest breeding programmes might benefit for increased feed capacity to reduce negative energy balances, specially in mid lactation where reproductive performance can be adversely affected.

The example calculations show that feed intake can be included in the selection index with a negative EW to produce equivalent BW to that calculated without considering feed intake. It remains to be seen whether this modification to the construction of the index is more readily understood and customised by dairy farmers. The index with food intake included will facilitate future modifications when individual intake capacity can be measured and used to improve the accuracy of feed intake.

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