SELECTION OF DAIRY CATTLE FOR LIFETIME PROFIT

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INTRODUCTION

Modern dairy cows are profitable if milk and beef income exceed feed, labor, housing, breeding, veterinary and other expenses over the cow's lifetime. In the beginning, cows produced milk only for their calves. After cattle were domesticated, specialized breeds were developed with improved dairy and/or beef production. Selection focused on hair color, other unique breed features, conformation, and simple phenotypic measures of production. Dairy Herd Improvement programs have recorded costs for nearly 100 years, but until recently only income traits were evaluated genetically. As more traits were measured and accuracy of evaluations increased, selection indexes grew in importance. USDA selection indexes provided since 1971 and Holstein Association USA Type-Production Index (TPI) provided since 1976 are summarized in Table 1. Selection for lower SCS is listed with positive values. Relative emphasis equals economic value times standard deviation (SD) divided by the sum of the absolute values of these products, then multiplied by 100. Relative values were obtained using SD of true transmitting abilities in USDA indexes and SD of predicted transmitting abilities (PTA) in TPI. Other U.S. breed associations publish Production-Type Indexes with different relative values.

Table 1. Relative emphasis on traits in USDA economic indexes (PD$, MFP$, CY$, and NM$) and Holstein Association TPI across time.

	Year Introduced and Index Name											
Trait	1971 PD$	1976 TPI	1977 MFP$	1980 TPI	1984 CY$	1987 TPI	1989 TPI	1992 TPI	1994 NM$	1997 TPI	2000 TPI	2000 NM$
Protein			27		53	40	34	50	43	50	41	36
Fat	48		46		45	40	34	17	25	17	16	21
Milk	52	60	27	60	-2				6			5
% Fat				20								
Longevity									20		13	14
SCS									6		1	9
Udder							17	17		11	9	7
Feet & Legs										5	5	4
Size												-4
Final Score		40		20		20	17	17		17	14	

Dairy cattle breeders in other countries also have developed increasingly accurate indexes to select for profit. Table 2 summarizes selection indexes for 11 other countries (Germany, France, New Zealand, Netherlands, Canada, Great Britain, Australia, Italy, Denmark, Sweden, and Spain) with the most Holstein cows in Interbull protein evaluations after the U.S., whose Holstein cows are 17.4% of the total Interbull population. All countries emphasize protein yield over fat yield and nearly all select against milk volume or for concentration. Most countries now select for longevity, health, and conformation traits, which often have differing definitions or are composite traits. Interbull provides evaluations for yield, conformation, and udder health traits, but only domestic evaluations for longevity, fertility, calving ease, and other traits may be available.

Table 2. Relative emphasis in selection indexes for other countries with many Holsteins.

	Country (Interbull Code)										
	DEU	FRA	NZL	NLD	CAN	GBR	AUS	ITA	DNK	SWE	ESP
% of Interbull Population	15.3	12.3	10.6	9.3	4.7	4.7	4.5	4.3	4.1	1.5	1.2
Index Name	RZG	ISU	BW	DPS	LPI	PLI	APR	PFT	S - I	TMI	ICO
Trait											
Protein	45	35	42	35	43	57	36	42	22	21	51
Fat	11	10	13	8	14	11	12	12	10	4	10
Milk			-22	-14		-19	-20		-3	-4	
% Protein		2						3			5
% Fat		2						2			
Longevity	6	13	10	12	8	15	12	8	6	6	
SCS / mastitis	14	13		11	3		7	10	13	12	
Fertility	4	13		7					10	10	
Other diseases									2	3	
Udder traits	8	8			17			13	9	12	17
Feet / legs	3	1		3	11			6	5	9	8
Size	2	2	-13		4		-4				
Dairy character	3										
Rump		1									
Final score	3							4	2		9
Calving ease				10					7	12	
Growth rate									4	6	
Temperament							5		1	3	
Milking Speed					<1		4		6		

This report describes the methods used to derive the Net Merit index introduced by USDA in August 2000 (VanRaden, 2000a). The index was developed in cooperation with scientists in multi-state project S-284 "Genetic Enhancement of Health and Survival for Dairy Cattle."

PROFIT

An economic value is the change in profit when a trait changes by one unit and all other index traits remain constant. Precise economic values are difficult to obtain because future prices are needed, expenses for individual animals are not always recorded and correlations between measured and non-measured traits may be unknown. Economic values are partial rather than simple derivatives of profit. For example, a breeder's preference for big cows if they give more milk does not imply that size should receive positive selection in an index that contains milk yield. The same breeder may decide to cull a big cow that eats more feed but produces no more milk than a small cow.

Lifetime profit includes some incomes and expenses that occur only once such as salvage value and replacement cost and others that repeat for each lactation such as milk sold and maintenance feed costs. Because costs per lactation are multiplied by number of lactations, the profit function is nonlinear. A simpler, linear function is used to calculate the U.S. Net Merit index by taking partial derivatives of the nonlinear function at population means for all traits. In 1978, scientists in multi-state research project NC-2 developed a similar profit function to compare genetic lines in experimental herds in which each cow's phenotypic data were combined directly into a measure of profit; an example is found in Bertrand *et al.* (1985). Index accuracy is greater, however, by combining PTA rather than combining phenotypic measures because trait heritabilities as well as genetic and phenotypic correlations differ and all phenotypes are not available at the same time.

Milk components have different values in different markets. For Net Merit, gross income = .022 (kg milk) + 2.54 (kg fat) + 5.62 (kg protein), which results in a base price of $0.28/liter for milk with 3.5% fat and 3.0% true protein. Cheese and Fluid Merit indexes also are released using a higher price or no payment for protein, respectively. Economic value of protein for fluid merit is negative because higher yields require more feed but receive no income. Over 80% of U.S. producers now are paid for both protein and fat content. Milk volume has a slightly negative value for Cheese Merit and a high positive value for Fluid Merit. Feed costs for an extra kilogram of milk, fat or protein were set at 30% of base prices. More exact feed costs are needed but are difficult to obtain. Fat requires more energy, but protein requires more expensive feed sources.

Many conformation traits are combined after genetic evaluation into composites based on relative weights from correlations with productive life. Holstein udder composite includes udder depth, fore udder, rear udder height and width, udder cleft and teat placement; feet-and-leg and size composites each include four traits. For other breeds, published PTA are standardized and combined into composites that are used in Net Merit calculation, but not published. Publication of data for more traits, composites and sub-indexes could be beneficial for selection decisions provided breeders do not get lost in all the numbers. Selection for improved udder traits and lower SCS can reduce labor and health costs (Rogers, 1993). Lower SCS also can increase milk price. Fetrow *et al.* (2000) found a mean price decrease of $0.004/liter for each SCS unit (each doubling of concentration). Relative emphasis on SCS is slightly greater than on udder composite and much greater than in TPI. Selection for higher udders and against larger body size can prevent undesired responses in those two correlated traits. Reducing cow size will generate higher profits if reduced feed and housing expenses exceed reduced income from beef. Costs of growing heifers included a fixed charge of $400 plus $1.32/kg of weight at first calving. Each lactation included maintenance feed cost, housing cost and income from heavier calves as a function of cow weight. Price received for culled cows was $0.77/kg. Body weight was estimated from conformation traits (Hansen, 2000).

Longevity has high value because several lactations of income are needed to exceed the cost of raising heifers. Mean profit was set to 0 by dividing the difference between culling income and raising costs by the mean number of lactations (3), to give the value of an additional lactation: $236. Expected number of lactations was 3.0 plus 0.12 times the productive life PTA. Increased longevity also increases mean yield because the herd will include more mature cows. Productive life is evaluated first from culling rate data using single-trait methods and then adjusted for correlated trait data using approximate multi-trait methods (VanRaden, 2000b).

PROGRESS

Expected genetic gains were calculated from genetic correlations with Net Merit. Gains from index selection as compared to single-trait selection were 83% for protein, 58% for productive life, 6% for SCS, 8% for feet-and-leg composite, and no change for udder composite or size. Net Merit measures the additional lifetime profit expected to be transmitted to an average daughter, but does not include profit expressed in granddaughters and more remote descendants. Gene flow methods and discounting of future profits could provide a more complete summary of profit. The linear profit function is much simpler to use than the nonlinear function and the two are correlated by 0.999. The profit function approach allows breeders to select for many traits by combining their incomes and expenses into an accurate measure of overall profit.

CONCLUSIONS

Dairy cattle are being selected for many economic traits. Breeding goals in many countries now include longevity, health and fertility traits in addition to yield and conformation. Selection indexes today are better measures of profit than those published three decades earlier. The methods used in USDA's Net Merit index provide an example of selection for lifetime profit.

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