Retrofitting genetic-economic indexes to demonstrate responses to selection across two generations of Holsteins

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Summary

Three U.S. genetic-economic indexes for dairy cattle were retrofitted to demonstrate the progress that would have been made for currently evaluated traits if selection had been based on those indexes across 2 generations. Holstein bulls were categorized by quintile for each index, and 25 cow groups were formed based on sire and maternal grandsire quintiles. Data included records from 1 756 805 cows in 26 106 herds for yield traits, productive life, pregnancy rate, and somatic cell score; 692 656 cows in 9 967 herds for calving ease; and 270 564 cows in 4 534 herds for stillbirths. For each index, least-square differences between the 25 cow groups were examined for 8 first-parity traits (milk, fat and protein yields; productive life; somatic cell score; pregnancy rate; calving difficulty; and stillbirth) that had been standardized to mature equivalence. Analysis was on a within-herd basis with cow birth year in the model. When cow groups were combined by selection intensity (low, medium and high), the highly selected group based on the 2006 net merit index had an advantage of 219 kg more milk, 21 kg more fat, 11 kg more protein, 6.3 months longer productive life, 0.21 lower somatic cell score, 1.2 percentage units higher pregnancy rate, 0.19 lower calving difficulty score and 5 percentage units lower stillbirth rate over the group with low selection intensity. Corresponding differences for the 1976 index, which included only milk, fat and protein yields, were larger for yield traits but were less favorable for other traits. The 1994 net merit index had differences intermediate to the 1976 and 2006 indexes. Selection based on the 2006 net merit index should provide phenotypic improvement for all traits included in the index and result in a dairy population that performs more satisfactorily for a number of health and fitness traits.

***Key words**: Genetic-economic indexes, Selection, Yield, Fitness, Health.*

Introduction

Throughout most of the 20th century, considerable emphasis in dairy cattle populations was directed towards yield traits (volume and component percentages). A consequence was some decline in other traits with a negative genetic relationship with milk yield. A large decline in cow fertility and a small increase in somatic cell score were particularly unfortunate.

With more comprehensive data recording, genetic evaluations for health and fitness traits were developed. To address the growing list of evaluated traits on which breeding decisions could be made, genetic-economic indexes were developed to combine estimates of genetic merit for various traits so that breeders could base selection decisions on a single trait. Choosing parents of the next generation based on such indexes helps produce cows with fewer functional deficiencies and thus a greater capacity for efficient performance over a longer herdlife. Most countries that evaluate several traits update their genetic-economic indexes periodically, either when genetic evaluations for new traits become available or when economic values to weight the traits are no longer appropriate (International Bull Evaluation Service, 2008).

The U.S. Department of Agriculture (USDA) has used 6 major genetic-economic indexes (Table 1) since the first "predicted difference dollars" index was introduced in 1971 (Norman and Dickinson, 1971). The economic weights used in USDA's current net merit index (VanRaden and Multi-State Project S-1008, 2006) were expected to lead to genetic improvement for all 10 traits included if selection decisions were directed exclusively toward net merit. Breeding values per decade are predicted to increase by 486 kg for milk yield, 34 kg for fat yield, 24 kg for protein yield, 6.0 months for productive life, 0.80 for udder composite, 0.60 for feet/legs composite, 1.4 percentage units for daughter pregnancy rate and $25 for calving ability and to decrease by 0.34 for somatic cell score and 0.80 for body size (smaller body size now is considered to be an asset). Based on June 2006 economic weights and genetic and phenotypic parameters for U.S. Holsteins, Cunningham and Täubert (2007) reported that an index with only yield traits overstated economic gain from selection by 4.4%, an index with yield and type traits understated gain by 1.7% and an index with yield, type, health, and fertility traits had an improvement of 3.4% in economic gain.

The objective of this study was to retrofit 3 USDA genetic-economic indexes that have been used over the last 37 years to demonstrate the progress that would have been made for currently evaluated traits if the alternative indexes had been the basis for selection decisions across 2 generations.

Materials and methods

The 1976 milk-fat-protein dollars (MFP$76) and 1994 and 2006 net merit indexes (NM94 and NM06, respectively) were used to categorize artificial-insemination Holstein bulls with ≥35 daughters into quintiles (1 = low, … 5 = high). For each index, 25 cow groups were formed based on sire and maternal grandsire (MGS) quintiles. For example, $group_{11}$ contained cows with both sire and MGS in the lowest quintile, where the first subscript refers to sire quintile and the second subscript refers to MGS quintile. Only cows with birth dates from 1993 through 1999 and calving dates from 1995 through 2005 were included. Cows that changed herds or had missing lactation records within their first 5 parities were excluded as were those in herds with <5 cows. Data included records from 1 756 805 cows in 26 106 herds for yield traits, productive life, pregnancy rate, and somatic cell score; 692 656 cows in 9 967 herds for calving ease; and 270 564 cows in 4 534 herds for stillbirths.

For each index, least-square differences between the 25 cow groups were examined for 8 first-parity traits (milk, fat and protein yields; productive life; somatic cell score; pregnancy rate; calving difficulty; and stillbirth) that had been standardized to mature equivalence. Analysis was on a within-herd basis with cow birth year in the model.

Table 1. Relative emphasis (%) on traits included in U.S. Department of Agriculture genetic-economic indexes for dairy cattle and year introduced[1].

Trait	Predicted difference dollars, 1971	Milk-fat protein, 1976	Net merit			
			1994	2000	2003	2006
Milk yield	52	27	6	5	0	0
Fat yield	48	46	25	21	22	23
Protein yield	…	27	43	36	33	23
Productive life	…	…	20	14	11	17
Somatic cell score	…	…	-6	-9	-9	-9
Udder composite	…	…	…	7	7	6
Feet/legs composite	…	…	…	4	4	3
Body size composite	…	…	…	-4	-3	-4
Daughter pregnancy rate	…	…	…	…	7	9
Service sire calving difficulty	…	…	…	…	-2	…
Daughter calving difficulty	…	…	…	…	-2	…
Calving ability index[2]	…	…	…	…	…	6

[1]Source: VanRaden and Multi-State Project S-10082, 2006.
[2]Includes calving difficulty and stillbirth forboth service sire and daughter.

Results and discussion

Because 600 least-squares means (25 cow groups × 8 traits × 3 indexes) were generated, only results for low ($group_{11}$ + $group_{12}$), medium ($group_{32}$ + $group_{33}$ + $group_{34}$) and high ($group_{54}$ + $group_{55}$) levels of selection intensity are presented (Table 2). For NM06, the highly selected group over 2 generations had an advantage of 219 kg more milk, 21 kg more fat, 11 kg more protein, 6.3 months longer productive life, 0.21 lower somatic cell score, 1.2 percentage units higher pregnancy rate, 0.19 lower calving difficulty score and 5 percentage units lower stillbirth rate over the group with low selection intensity. Least-square means for the group with medium selection intensity were intermediate to means for the groups with high and low selection intensities for all traits. Although the differences for milk, fat and protein yields were low (and, therefore, disappointing), favorable differences were evident for the other traits.

When selection was based on MFP$76, which placed emphasis only on milk, fat and protein yields, differences in least-squares means between the high and low selection intensity groups were impressive for yield traits (1 127 kg more milk, 50 kg more fat and 37 kg more protein) and considerably higher than corresponding NM06 differences. However, MFP$76 differences for other traits (2.1 months longer productive life, 0.12 higher somatic cell score, 1.4 percentage units lower daughter pregnancy rate, 0.06 lower calving difficulty score and 0.9 percentage units lower stillbirth rate) were less favorable than NM06 differences. Although selection on MFP$76 increased productive life, larger increases were realized by selection on net merit indexes, which include productive life directly in the index. The increase in somatic cell score and decrease in pregnancy rate likely are due to the negative genetic correlation between milk yield and those traits.

Table 2. Least-square means for first-parity traits standardized to mature equivalence for cows selected for 2 generations based on the 1976 milk-fat-protein dollars (MFP$76), 1994 net merit (NM94) or 2006 net merit (NM06 index) by selection intensity.

		Selection intensity[1]			Difference between high and low selection intensity
Trait	Index	Low	Medium	High	
Milk (kg)	MFP$76	10 443	11 053	11 570	1 127
	NM94	10 443	11 012	11 417	973
	NM06	10 961	11 083	11 180	219
Fat (kg)	MFP$76	374	400	424	50
	NM94	384	400	411	27
	NM06	391	401	411	21
Protein (kg)	MFP$76	299	319	336	37
	NM94	304	318	328	24
	NM06	314	320	325	11
Productive life (mo)	MFP$76	29.8	30.7	31.9	2.1
	NM94	27.8	29.9	33.6	5.8
	NM06	27.9	30.5	34.2	6.3
Somatic cell score	MFP$76	2.83	2.91	2.95	0.12
	NM94	2.99	2.92	2.86	-0.13
	NM06	3.03	2.91	2.82	-0.21
Pregnancy rate (%)	MFP$76	29.5	28.5	28.1	-1.4
	NM94	28.7	28.3	28.7	0.0
	NM06	27.9	28.3	29.1	1.2
Calving difficulty (1–5 scale)	MFP$76	1.76	1.75	1.70	-0.06
	NM94	1.81	1.75	1.68	-0.13
	NM06	1.85	1.72	1.66	-0.19
Stillbirth (%)	MFP$76	12.1	11.6	11.3	-0.9
	NM94	14.5	13.3	11.2	-3.3
	NM06	13.6	11.9	9.0	-4.6

[1]Selection intensity based on sire and maternal grandsire quintiles for 25 cow groups: low = $group_{11}$ + $group_{12}$, medium = $group_{32}$ + $group_{33}$ + $group_{34}$ and high = $group_{54}$ + $group_{55}$, where first subscript refers to sire quintile and second subscript refers to maternal grandsire quintile.

Selection on NM94, which includes yield traits, productive life and somatic cell score, resulted in differences that were intermediate to those from selection on MFP$76 and NM06. Relative trait emphasis (Table 1) and assigned economic values affected whether the NM94 difference was closer to the MFP$76 or NM06 difference for individual traits. The NM94 milk yield difference was closer to the MFP$76 difference, but the NM94 differences for fat yield, somatic cell score and stillbirth were closer to NM06 differences. The NM94 differences for protein yield, pregnancy rate and calving difficulty were almost exactly intermediate to differences for the other indexes.

Conclusions

First-parity least-squares means for cows that had sires and MGS selected based on NM06 demonstrate that selection based on the current USDA genetic-economic index for dairy cattle should provide phenotypic improvement for all traits included in the index. Such selection will result in a dairy population that performs more satisfactorily for a number of health and fitness traits. Some of the expected improvements are large enough that they will be noticeable to producers in a single generation (e.g., increases in productive life and pregnancy rate and declines in somatic cell score and stillbirths). Future concern by consumers about animal welfare issues should be reduced substantially through the use of a comprehensive composite index that includes health and fitness traits even though progress for yield traits will be slowed. Profit from selection on NM06 was greater than from selection on indexes with fewer traits or on individual traits.

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