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Major Advances in Determining Appropriate Selection Goals

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ABSTRACT

Substantial increases of 3,500 kg of milk, 130 kg of fat, and 100 kg of protein per cow per lactation have resulted from improvements in genetics, nutrition, and management during the past 20 yr. At the same time, the interval from calving to conception increased (unfavorable) by 24 d. Genetics has accounted for about 55% of gains in the yield traits and about one-third of the change in interval to conception. Genetic gains in the yield traits and productive life have accumulated to around 1.7 and 1.2 genetic standard deviations since 1980. Unfavorable genetic changes in conception interval since 1980 and somatic cell score since 1990 have accumulated to 1.0 and 0.12 genetic standard deviations. The most important advance in selection indexes has been the introduction of nonyield traits. Advances in selection indexes have gone hand in hand with advances in data collection and genetic evaluation. As new traits were recorded in dairy management databases and as genetic evaluations were developed for these traits, they were incorporated into selection indexes. Until 1994, when somatic cell score and productive life were introduced, selection indexes provided by USDA included only yield traits. In 2000, composite type indexes for udder, feet and legs, and body size were added. Daughter pregnancy rate and service sire- and daughter-calving ease were included in 2003. The lifetime merit indexes introduced in 2003 have, for the first time, resulted in theoretical selection responses in the desired direction for all traits. During this time, the percentage relative economic weights in selection indexes increased from 0 to 45% for the nonyield traits. Selection emphasis on nonyield traits should continue to increase as additional traits (e.g., calf survival, metabolic disease, and male fertility) are introduced in the future. Wide variation exists among countries in traits included in selection indexes and in relative economic weights. Molecular genetic studies have identified many chromosome regions with potentially important major genes for economic traits. Use of DNA markers for genetic improvement is currently limited by lack of precision in marker location. Discovery of major genes will be accelerated by the availability of the bovine genome sequence, comparative genome maps and genome sequences across species, and increased use of breed crosses in molecular studies. As major genes are identified, their effects will be incorporated into genetic evaluations and selection indexes.

Key words: selection index, total economic merit

INTRODUCTION

"Turn your attention towards reducing the cost of production so that there is a margin of profit even at low prices." This admonition from W. D. Hoard, founder of Hoard's Dairyman magazine in 1885, characterizes the most important change in selection index formulation during the past quarter-century. Since 1994, selection indexes in the United States have evolved from being entirely based on milk revenues to now including 8 traits that represent production costs.

In the United States, selection indexes are developed by the breed associations and by the USDA Animal Improvement Programs Laboratory (**AIPL**). The AIPL indexes and comparisons with indexes published in other countries are the focus of this article. Although AIPL staff coordinates formulation of selection indexes, broad input is sought from the AI industry, breed associations, DHIA organizations, researchers, extension specialists, and producers. Advances in selection indexes have gone hand in hand with advances in data collection and genetic evaluation. As new traits were recorded in dairy management databases and as genetic evaluations (predicted transmitting ability, **PTA**) were developed for these traits, they were incorporated into selection indexes. Advances in genetic evaluations are outlined in a companion article. The American Dairy Science Association observed the 50th anniversary of publication of the founding article on selection index by L. N. Hazel with a symposium in 1993.

BACKGROUND

A selection index in its simplest form is a prediction of animals' breeding merits for total economic merit

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Table 1. Holstein breed averages by year of birth[1]

Trait[2]	Year of birth 1980	1985	1990	1995	2000
Milk,[3] kg	8,003	8,616	9,458	10,605	11,505
Fat,[3] kg	290	312	346	384	419
Protein,[3] kg	241	253	280	314	345
PL, mo	25.8	24.8	24.1	23.8	24.7
DPR, %	27.5	26.3	25.2	22.3	21.2
SCS	NA[4]	NA	3.2	3.1	3.1

[1]Animal Improvement Programs Laboratory. Genetic and phenotypic trends, November 2004. http://aipl.arsusda.gov/dynamic/trend/current/trndx.html. Accessed Jan. 4, 2005.

[2]PL = Productive life; DPR = daughter pregnancy rate.

[3]Adjusted to twice-daily milking and 305 d in milk at mature age.

[4]NA = Not available.

Table 2. Gain in Holstein average breeding value for selected years of birth relative to cows born in 1980[1]

Trait[2]	Year of birth 1985	1990	1995	2000	SDBV[3]
Milk,[4] kg	466	980	1545	2083	1220
Fat,[4] kg	17	38	54	70	42
Protein,[4] kg	10	25	41	59	32
PL, mo	1.2	1.8	2.6	3.1	2.5
DPR, %	−0.8	−1.6	−2.1	−2.1	2.1
SCS	NA[5]	0	0.02	0.04	0.34

[1]Animal Improvement Programs Laboratory. Genetic and phenotypic trends November 2004. http://aipl.arsusda.gov/dynamic/trend/current/trndx.html. Accessed Jan. 4, 2005.

[2]PL = Productive life; DPR = daughter pregnancy rate.

[3]SDBV = Standard deviation of breeding value. Genetic gain divided by SDBV measures accumulated selection intensity.

[4]Adjusted to twice-daily milking and 305 d in milk at mature age.

[5]NA = Not available.

(**TEM**). Total economic merit is a combination of an animal's (denoted by i) predicted transmitting abilities (PTA_{ij}) for all economically important traits, with each trait (j) weighted by its net economic value (a_j):

$$TEM_i = a_1 \times PTA_{i1} + a_2 \times PTA_{i2} + \ldots + a_n \times PTA_{in}.$$

The economic value for a trait represents the contribution to change in profit per unit change of a trait, given no change in any other trait. It is not necessary to use the actual economic values in TEM, but the relative economic values, e.g., $(a_j)/(a_1)$, should be correct. Predicted transmitting ability measures the average value of genes transmitted from the individual to progeny and is derived from performance of the animal and known relatives.

Effective selection indexes depend on proper formulation of TEM in terms of the measure of TEM, appropriate relative economic weights, and inclusion of the most important traits. The TEM may be measured in terms of profit per month of herd life, lifetime profit, economic efficiency (revenues/costs), or production efficiency (costs/revenues). Selection indexes have their utility in combining the PTA values for several traits into a single summary value for each animal. Ranking animals on TEM values should be the first step in selecting breeding animals from among candidates. This ensures that the animals ultimately selected are among the highest in TEM.

Relative economic weights determine how selection pressure and selection response are distributed among traits. Increasing percentage weights on some traits requires decreasing weights on others with consequent changes in trait responses. A properly formulated index directs selection intensity toward traits in a way that optimally exploits the economic values, heritabilities, and genetic variances of traits as well as the genetic and phenotypic correlations among traits. When the correct relative economic weights are used, the rate of genetic improvement in TEM is maximized.

GENETIC AND PHENOTYPIC TRENDS

Remarkable increases in yield traits have occurred since 1980. Holstein breed averages are given in Table 1 for cows on DHI, included in the national genetic evaluation program, and born in selected years. These increases reflect improvements in genetics, nutrition, management, and animal health. Among the nonyield traits, a small improvement in SCS and a decline of 1 mo in productive life occurred.

The decline in reproductive performance in US Holsteins has been well documented. Table 1 shows a 6% decline in pregnancy rate since 1980. This is equivalent to an increase of 24 d open (interval from calving to conception). A study of herds with continuous reporting from 1976 to 1999 in 10 southeastern states is characteristic of national trends. Average days open increased by more than 40 d between 1982 and 1999 in Holsteins and by more than 30 d between 1988 and 1999 in Jerseys. These trends increased by an increasing amount from year to year. Conception rates in both breeds decreased from about 50% in the early 1980s to about 34% in 1999.

Genetic improvement in dairy cattle is driven primarily by the array of bulls provided by the AI industry and secondarily by the choices producers make among the bulls available. Selection indexes influence selection decisions at both levels. Other factors that play into these decisions are advertising and popularity, semen cost, and individual type and production traits. Genetic gains since 1980 are shown in Table 2. Genetics has accounted for more than 55% of phenotypic gains in the yield traits and about one-third of the