BREEDING SCHEMES FOR IMPROVEMENT OF ADDITIVE GENE EFFECTS IN DAIRY CATTLE

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The dairy cattle industry of the world has undergone a radical change in technology, systems and structure during the past twenty-five years. Development and effective use of artificial insemination has been a major part of the change. The centralization of dairy bull insemination and progeny testing units, the evolution of milk recording and computerized sire evaluation methods, and a recognition of the tremendous genetic and economic impact of properly proven dairy sires has stimulated considerable research to determine breeding schemes that optimize the improvement of cattle.

WHAT CONSTITUTES A BREEDING SCHEME?

A. I. breeding schemes for additive gene effects in dairy cattle may be taken to embrace consideration of:

1. The development and maintenance of an accurate milk recording program for a significant number of artificially inseminated dairy cows

This is as basic to progress as good health and high conception rates. Other traits may be measured, but it is essential to recognize that increased milk yield is almost synonymous with higher profits in dairying (2). Certainly, growth rate largely dictates the profitability of enterprises developing male dairy calves for beef and, as it relates to mature size, the total yield of cow beef from culled dairy females. Consequently, performance testing for growth rate may also be
essential to the breeding scheme, especially in countries which do not have the extensive all-beef enterprises of Western North America, Russia and other regions of the world where beef cattle are the most effective means of harvesting protein and energy from vast grasslands.

2. The identification of potential bull dams and selection of young dairy bulls for progeny test

The milk recording scheme must provide, as a by-product, a list of potential bull dams which rank in the top one to two percent of the population for milk yield. Auxiliary traits such as milk constituent percentages, muscling, conformation of udder and feet and legs and milking qualities may be considered, provided they do not receive unwarranted emphasis (1) and wherever possible all data should be objectively measured, adjusted for important non-genetic factors and incorporated into one computerized list for use by sire analysts.

Dairy breeding researchers have been slow to apply the selection index to ranking cows on a combination of milk yield and constituent percent; a system which, theoretically, should yield optimum improvement. Some have argued that little advantage exists over selection for milk yield solely. However, information on the milk yield and constituent percentage of individual cows already exists in most data files and if a simple computerized selection index achieved even a slightly enhanced rate of improvement in the total production complex the additional improvement could have tremendous economic impact over large cow populations. Large cow populations can afford sophistication. The selection index concept needs application both in bull dam selection and in cow culling.

Once bull dams have been identified and screened, they must be planned to produce the next group of young bulls for entry. All research (10, 11, 19, 20, 21, 22) indicates the advantages of limiting the number (1 to 4 for most population sizes) of outstanding proven sires to sire young bulls. Some studies favour replacing them very slowly (10), so as to maximize selection differentials. Development and refinement of prediction equations for rates of inbreeding in A.I. progeny testing schemes is essential to avoid bottlenecks. Present approximation equations (19, 21) do not deal with the complexities of A.I. breeding schemes and, with world-wide use of semen from the same bulls it is essential to anticipate problems.

When young bulls with high genetic potential are purchased at relatively low prices, and the relative value of a unit of meat is high in contrast to a unit of milk, distinct economic advantages can be realized by performance testing young bulls for growth rate and culling the slow gainers prior to test mating them for milk. Early work (24) demonstrated the advantages of this approach over the progeny testing of bulls for growth, as well as optimum culling rates for varying ratios of meat: milk value. In countries such as Canada where demand for young bulls results in high prices for the top pedigreed calves, performance testing is a problem, and some improvement may be achieved by progeny testing for beef traits.
3. The test mating of young bulls

Size of the test population tends to dictate the optimum progeny group size, percentage of tested cows mated to proven bulls and number of young bulls to be progeny tested (11, 19, 20, 21, 22). As the population of tested cows increases, lower percentages may be mated to young bulls and with a progeny group of fifty or more, near optimum improvement can result (10, 11, 19, 20, 21, 22).

Once the young bull has completed test matings, he may be «laid off» until proven, or as in Scandinavia (14, 21), a large volume of semen may be drawn during his first year in the A.I. stud, and he may then be slaughtered. Viewpoints differ on this question and decisions are largely a function of volume of semen stored, and costs of semen processing and storage as compared to bull maintenance costs (8). There is no indication of a move towards the Scandinavian approach in North America, however, a recent study at our laboratory (4) which contrasted the two schemes above with the practise of leasing young bulls and returning them to the owner after a sizable volume of semen was drawn, clearly indicated that for most Canadian cost alternatives and for cow populations of 9,000 Guernseys, 16,000 Jerseys and 19,000 Ayrshires, the storage of a year's supply of semen from leased bulls has a profit advantage. Short-term leasing of bulls must be considered as an alternative to present schemes, particularly for small cow populations.

4. Use of the best proven bulls following the progeny test

The key factors for consideration are (a) accuracy of identification of the best bulls and (b) extent of use and rate of turnover of the proven bull stud. The outstanding contribution of Henderson, of Cornell University, in development of the Best Linear Unbiased Prediction method of ranking dairy sires must be emphasized as contributing materially to increases in accuracy of selection of proven sires with, however, a significant sacrifice in computational ease. This method is being applied to the National Sire Proving Program in Canada.

Slaughtering of bulls shortly after sampling limits the extent of use of individuals with outstanding proofs and tends to reduce selection differentials among sires of replacement cows (8, 10, 26). It does, however, tend to decrease generation length in the population. Further studies must give consideration to average fertility or non-return rates from living proven sires in contrast to semen from proven sires that has been bulk-stored for 6 years.

METHODS OF OPTIMIZATION OF BREEDING SCHEMES

Optimization methods may generally be divided into (a) genetic and (b) economic (5).

Genetic Optimization

The prediction of rates of genetic improvement in populations using progeny tests was attempted by Dickerson and Hazel (6) and Robertson (19). Dickerson and Hazel concluded that progeny tests would increase genetic progress only in
cases where the test information becomes available early in the tested animal's life, reproductive rates were low and early selections were inaccurate. Four kinds of opportunities for selection in an A.I. population were elucidated by Robertson (19) and it became appreciated that they might have quite different impacts on the rate of genetic improvement. Skjervold (20, 21) expanded the prediction equation for rate of genetic gain to consider variation in progeny group size, percent of cow population bred to young bulls, inbreeding depression and rate of use of proven sires.

The use of computers to predict the rate of improvement for hundreds of alternatives became commonplace after Skjervold's pioneering work in this area. He was also responsible for development of the concept of freezing up large supplies of semen from each young bull when it entered A.I., and slaughtering the bull rather than housing it until proven.

A considerable volume of research has been completed in this area to date by a number of workers (5, 9, 10, 11, 14, 19, 20, 21, 22) and the results suggest the following general conclusions:

1. The greatest opportunity for selection exists in choosing proven bulls to sire the next group of young bulls. The genetic gain will increase at a diminishing rate as the population size and number of young bulls sampled annually increases.
2. A desirable rate for replacement of sires of the next group of young bulls is about 50% per year.
3. The percent of first services to test young bulls in milk recorded herds should be equivalent to 10% of the total breedings in the population. Consequently, low levels of milk recording in a population require relatively higher percentages of milk recorded cows to be bred to young bulls.
4. The desirable progeny group size is between 30 and 50 tested daughters. The optimum progeny group is smaller in small test populations. A balance between number of young bulls sampled and number of tested daughters must be struck for each population size and level of milk recording.
5. Bull dams should be selected from about the top 1.6% of the population of milk recorded and indexed cows.
6. The best proven sires should be collected and used at maximum rates, so as to maximize selection differentials, and the proven bull stud should turn over at a relatively slow rate (e.g. 25%/year).
7. For populations of 50,000 cows or more, a genetically effective progeny testing program with extensive use of only the superior proven bulls should lead to more rapid progress than the Scadinavian system of testing and disposing of bulls after putting down semen.

**Economic Optimization**

Increases in rate of genetic change diminish as the maximum is approached; it naturally follows that costs may outweigh benefits at the higher rates of genetic progress. The concept of economic optimization of breeding schemes is founded on the assumptions:

(a) Genetic improvement of livestock for economically important traits leads to greater profits to primary producers through increased production of milk or meat or value of excess stock, or alternatively increased efficiency of produc-
tion associated with greater output of produce from the same inputs. This assumption has not been carefully examined and is presently under scrutiny in our laboratory.

(b) The benefits to the producer justify the extra capital outlay by government, A.I. studs and other institutions to expand milk recording, increase performance testing for meat traits or expand or improve sire proving programs.

(c) The fluctuations associated with costs over a 15- to 20-year period will be matched by similar changes in returns.

(d) The heavy capital outlay in early years will be recouped in later years.

These assumptions must certainly be carefully considered before undue emphasis is placed on economic optimization of breeding schemes, and there are many pitfalls. Assumption (a) is not met unless genetic potential is realized through use of good feeding and management. In cases where A.I. studs are privately owned and competing (25) there is considerable uncertainty under assumption (6) that large investments today will bring back a fair share of the profits associated with these investments tomorrow. These businesses must pay as they go, and this is difficult because of time lag. Assumption (c) encounters the problem that returns for perishable products such as milk and meat are subject to supply and demand fluctuations and also may vary in relative value. Unit input costs in the recent past have risen more rapidly than unit returns.

The early work of Poutous and Vissac (18) gave some stimulus to research to examine returns against costs when comparing various breeding schemes. Consideration of interest rates, discounting procedures to allow for time of investments and returns, as well as the way in which genetic improvement sifts through the population generation by generation were major innovations in this work. Lower intensities of bull selection were found to be optimal. Van Vleck (25) developed an expression for genetic superiority of the young bulls being tested and the proven bull stud and examined costs and returns to the dairy industry resulting from genetic improvement. He concluded that for the cost and return figures considered, maximum net returns will be achieved by programs maximizing genetic improvement. More recent work (12, 13, 14, 17, 18) differs with these findings. Cost and return factors considered in Van Vleck's study may indeed have been quite atypical, since as Cunningham (5) suggests for most situations, maximum profits seem to be achieved at considerably less than maximum genetic progress. Costs of young bulls, feed and maintenance may be major factors.

Other workers have expanded models to deal with dual purpose breeds of cattle in which both milk and meat traits are considered (3, 7, 8, 14, 24). Results suggested performance testing of prospective young bulls is economically advantageous and that as the ratio of value of a unit meat: milk increased, greater advantages could be achieved by culling more severely on growth, when young bulls terminate a performance test for growth (3, 24). Hinks (8) confirmed earlier findings of Soller et al. (24) in a study of the British Milk Marketing Board A.I. program. He argued, however, that an increase in relative value of meat: milk from 7:1 to 12:1 was desirable, before investment into performance testing of dairy bulls could be justified over investment in increasing the numbers of bulls progeny tested for milk.

A number of workers have been concerned with the time flow aspects of
costs, returns and genetic superiority (7, 8, 18, 24, 25). Discounting procedures have been used, although they may not be quite practical in many cases. In general, this approach assumes that interest rates do not fluctuate, and that adequate capital is available to finance programs on the year of initiation. Others have examined the impact of marginal increases in investment on returns at the time when fluctuations in genetic change, costs, and returns, settle down (4, 13).

NEW APPROACHES

The problem of optimization of breeding programs for the dairy populations of the world is an important, if difficult topic area, requiring multi-disciplinary inputs from economists, geneticists, A.I. stud accountants and management, and sophisticated computer programming. There is little indication that these resources have been effectively pooled and applied to the problem to date. This statement is substantiated by the lack of application of linear and dynamic (15, 23) programming principles to solution of these important problems. The approaches described herein will need extensive review and alteration if embryo transfer and cloning techniques expand to offer significant increases in the reproductive rates of females.

SUMMARY

Improvement of additive gene effects in dairy cattle is presently dependent on development of effective progeny testing schemes utilizing artificial insemination and milk recording. Progeny testing will be most effective in large cow populations and if sires and dams of young bulls are stringently selected, the best proven bulls are used extensively, 10% of the total cow herd is used to test bulls, and progeny group size is kept near 50 tested daughters. For populations of less than 50,000 cows, young sires may yield as rapid improvement and at lower costs. Economic considerations generally dictate as most profitable, programs that will generate less than maximum genetic progress. Since in most countries meat is relatively valuable in comparison to milk, performance testing of young bulls before a progeny test is economically sound. Further research in this area, employing programing techniques seems justified.

RESUME

L'amélioration des effets des genes additifs chez la vache laitière dépend présentement des méthodes de testage de progéniture par l'insemination artificielle et par le contrôle laitier. Lorsqu'on dispose d'un grand nombre de vaches, l'épreuve de progéniture des taureaux et des mères des taureaux, sévèrement sélectionnés, peut être faite intensivement en utilisant 10 % des vaches du troupeau. La progéniture à garder d'un taureau est d'environ 50 filles épreuées.
Pour les populations inférieures à 50,000 vaches l'utilisation intensive des jeunes taureaux pourrait donner une amélioration aussi rapide à moindre coût. Généralement les programmes qui donnent les meilleures améliorations génétiques ne sont pas nécessairement les plus rentables. Dans plusieurs pays la viande a une valeur relative supérieure à celle du lait donc il est préférable de tester les performances du taureau avant celles de sa progéniture. L'emploi de la programmation est justifié pour la recherche future dans ce domaine.

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REFERENCES


