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Position paper

Genetic improvement in dairy cattle—an outsider's perspective

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Abstract

The author describes the improvement programmes that have normally been implemented for dairy cattle, and comments on these based on experience with other species. For the last half-century, most breeds have utilised two-stage schemes. Young sires have been given limited matings so that both future bulls and the majority of heifer replacements have been sired by older sires selected on progeny data for type, milk yield, and composition. Scientific methods of multiple trait selection have been only slowly accepted by commercial milk producers. The major genetic changes in Europe have, in any case, been brought in from other populations (North America). There are inevitable conflicts between the specific improvement goals of individual producers and those of the breeding organisations that control semen supplies. Numerically small populations should have different goals and should organise much simpler programmes based upon the widespread use of young sires. Inbreeding will become serious in all breeds unless current policies are modified.

Keywords: Dairy cattle; Genetic improvement; Progeny testing; Inbreeding

1. Introduction

The author has been professionally involved in animal improvement for over 30 years: in research with several species, teaching, commercial pig breeding, and consultancy; but only recently with dairy cattle. This position paper is intended to stimulate discussion on possible lessons from other species and experiences. The basic concern is with the average genetic merit of cows being milked in Europe's commercial dairy herds. In many countries, production is in surplus and quotas have been introduced.

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Creating genetic improvement involves trying to identify those animals with the best breeding values and then ensuring that the selected individuals become the parents of the next generation. Artificial insemination (AI) can allow the rapid dissemination of this improvement throughout a population or breed. The difficulties concern both the scope for selection, which is a function of reproduction and replacement rates, and the recognition of genetic superiority in time for it to be useful in the selection process. Most traits of interest can be measured on the female, but almost none on the male, though this could change in the future with tests for specific genes soon after birth.

Information on the female candidates is successively available from their ancestors (pedigree), sibs, own performance and eventually from progeny.

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Unfortunately the number of progeny per female is low (even when increased through embryo transfer) so that a high proportion of cows needs to be allowed to contribute daughters. The accuracy with which the females' true transmitting abilities can be predicted is often expressed as reliability (the squared correlation coefficient). Within a programme utilising progeny tested bulls, it may start at conception between 0.3 and 0.4 (for milk production) for the daughter of a mature cow and a thoroughly proven bull. This reliability may increase to around 0.65 if she survives to 6 or 7 years old.

In contrast, the reproductive potential of the male is much greater even with natural service, and when using AI it can become very high indeed. As a consequence, the reliability of predicted transmitting ability (PTA) starting at the same initial level can jump to around 0.85 when the bull's first proof (progeny test) arrives at, say, 6.5 years, and can even approach 1.0 when he has information from a larger (or second-crop) group of daughters.

But while almost all females can have a first lactation, and thus a reasonable proportion can achieve a reliability of 0.5 to 0.6, most males can never reach more than 0.3 to 0.4, since only a tiny fraction can be allowed to sire even a modest number of daughters. Herein lies the basic dilemma of dairy cattle breeding. In order to exploit the opportunity for discriminating accurately among bulls, it has to be accepted that the choice will be limited and the generation interval extended.

2. Historical development of modern dairy improvement schemes

2.1. Theory

The classic studies which explored this dilemma were carried out some 40–50 years ago and have influenced the structure of improvement programmes ever since. Dickerson and Hazel (1944) concluded that in a closed herd of only 120 cows there would be no advantage in waiting for a progeny test in order to select bulls to leave sons and a second crop of daughters. Robertson and Rendel (1950) then considered a unit (presumably a group of several herds) of 2000 cows using AI. They assumed that the young bulls used in a 3-year period would all be sired by the best two progeny-tested sires of the previous generation out of the best older cows. They calculated that genetic gain would be maximised if 40–60% of all cows were also mated to these proven sires (to produce replacement heifers). It is worth noting, however, that annual gain was predicted to be only 5% slower if all cows (other than bull dams) were put to young sires. In subsequent papers, Robertson (1957, 1960) continued to explore the optimum balance between choice and accuracy. Skjervold and Langholz (1964) also considered the inbreeding consequences of such programmes and showed how the optimum proportion of inseminations from young sires should increase in smaller populations (90% with 2000 recorded cows).

2.2. Development

Cattle breeding organisations throughout Europe and North America quickly evolved breed improvement programmes based on these studies utilising the new AI technology. Initially, young sires were offered by herdbook breeders and progeny tested by the AI cooperatives, but soon elite cows were being identified through the recording systems and contracted to produce sons by the newly proven sires. Bull selection thus became a two-stage process: the initial step involved a large choice among young males (or their dams) with predicted transmitting abilities of moderate reliability; the second stage was among older bulls newly proven through their first-crop daughters. In the best schemes, both the intensity and accuracy of selection could be high at this second stage so that a valuable genetic jump could occur from the mean of all the young sires to those finally chosen to breed sons and large numbers of second-crop daughters. This jump is necessary if it is to be worthwhile waiting for the proofs, since the generation interval is obviously increased.

2.3. Consequences

Several important consequences flowed from the universal adoption of progeny testing. First, the need to create large numbers of daughter records involved persuading many herds to participate and provide data via the recording organisations. This necessarily limited the proofs to those traits that every recorded herd was willing to measure, usually because the herd owners valued the information for short-term management decisions.

Second, by putting so much emphasis on the identification of the top bulls whose transmitting ability becomes known almost without error, such programmes automatically devalued the worth of semen from young sires. As a result these inseminations, upon which the whole programme depends, had often to be supplied free or discounted. Even then, it has sometimes been a struggle to persuade commercial milk producers to use young bull semen, rear the heifer calves and retain them through their first lactations.

A third consequence has been the pursuit of size in these progeny testing programmes (to improve precision and intensity of selection). The challenge of producing accurate and unbiased proofs from data collected so widely has thrown up complex statistical problems. Highly numerate scientists have been drawn in to solve them (in universities, research institutes and breeding organisations) so that dairy cattle improvement has been strongly influenced by people who think in terms of complex computational solutions. It is arguable that organisational changes could provide equally effective solutions. This suggestion was made by Bichard (1987) but was naturally not well received by academic dairy cattle geneticists, fascinated as they are by the latest mathematical applications. Nevertheless, it may be relevant that the most interesting alternative improvement systems in recent years have involved the radical change to a relatively small nucleus herd employing multiple ovulation and embryo transfer techniques, and that this MOET approach was first proposed by two other outsiders (Nicholas and Smith, 1983).

3. Choice of improvement goals

3.1. Evolution of indices

The overall goal of the breeder should be to produce future generations which are more profitable when kept by commercial milk producers. In practice, the producer hopes to maintain his competitive position while lower product prices cascade down the food chain and leave only the consumer permanently better off. Fifty years ago progeny tests gave predicted breeding values (or transmitting abilities) for milk yield, butterfat and protein for a few older bulls. When choosing herd sires, commercial producers applied their own weights for these three traits at the same time as considering type appraisals. Geneticists have long been convinced that more optimum weighting would only be achieved when the producer was presented with a total merit index for each candidate. Some progress towards these came after the imposition of quotas within EU countries since farmers were forced to consider both volume and composition when working out their permitted milk sales. Indices such as PIN (UK), INET (NL) and INEL (F) became popular, though somatic cell count and various type scores still had to be considered separately. Presented with these additional traits, producers seemed unwilling to allow superiority in one area to compensate for lower merit in another, but instead insisted on an independent culling level for type. McGuirk (1998) demonstrated that almost all semen offered in Britain came from bulls whose type proofs (not included in the popular milk profit index) were at least one standard deviation above the mean. Even with this assurance, producers continue to demand a photograph of a (highly selected) daughter, and breeding organisations oblige, thus perpetuating the myth.

A growing concern with so-called functional traits has been emerging in Europe. An EAAP working group (Groen et al., 1997) and a subsequent EU-funded project (GIFT—reported in Interbull Bulletins 12, 15, 18, 19, 21 and 23; Interbull 1996–1999) have brought together current thinking in this area. The main trait groups of concern are udder health, female fertility, foot and leg problems, and longevity. The Scandinavian countries have been recording many of these traits, calculating breeding values for more than a decade, and can be expected to be making progress in those breeds that have not been heavily influenced by North American blood (Christensen, 1998). Where such traits are not recorded, it may still be possible to include them as goals and predict breeding values through their covariances with other measured traits, though this does presuppose large and representative data sets from which to obtain good estimates of parameters. An example of predicting a functional trait was the 1995 ITEM index in the UK, which predicted longevity from several linear type traits and combined it with milk production into a merit index. A later version (LIFESPAN) utilised information from type traits and actual survival data as these became available, and was itself a component of the UK Productive Life Index (PLI).

3.2. Additional traits

Besides the main functional trait groups, other traits influence profits, and could be considered as improvement goals. These include calving ease, stillbirths, male fertility, milking traits, metabolic stress, feed efficiency, and beef production.

The fact that many commercial herd recording schemes only collect data on a limited range of traits need not preclude the direct assessment of test bulls on others which are considered valuable (as goals or as information traits). Large breeding organisations could contract with a limited number of commercial herds, chosen on size, location, management system, reliability and willingness to collaborate. These herds would agree to use a high proportion of young bull semen and then rear, milk, and record their daughters for all the necessary traits. Naturally, the herds would need some form of compensation, but there might be savings from having the recording concentrated on fewer sites, and from improved accuracy.

In theory, breeding values could be estimated for all traits which influence commercial herd profits, and these could be given objective weights within an overall merit index. But ever since geneticists have tried to do this, there has been a long-running debate on the appropriate methodology. In summarising this, Goddard (1998) claimed that a consensus had been reached on most issues. Nevertheless, it is evident from a careful reading of his paper that some are still under debate and others (e.g. FCE) have not so far received much attention. The subject is a minefield for the unwary or unsophisticated, and the provision of optimum weights demands much more information than is likely to be available in most situations.

3.3. Customised indices

Different milk producers may sell their entire output for liquid milk sales, for cheese or butter manufacture or to dairies that specialise in yoghurts, cream, or dairy desserts. The price received may be closely related to the specific market's needs. Again, within a single country and breed, different herds can be fed and managed in ways that appear to put quite different demands on the milking cows. Hence, there is naturally a strong interest from some commercial milk producers in indices that reflect their herd-specific goals based upon their physical and economic circumstances, and payment systems.

There are two sorts of problems with the provision of such customised indices. The first relates to the difficulties of deriving optimum indices that are highlighted in Goddard's (1998) review and the lack of parameter estimates appropriate to each situation. Second, and more fundamental, is that herd-specific indices are incompatible with an efficient improvement programme pursuing an industry-consensus breeding goal. Unfortunately producers continue to believe that they are substantially independent and in charge of their own genetic progress. The reality is that the key decisions are taken by those choosing first the young bulls and then the bull sires in the major breeding organisations. So long as semen is available from a large number of proven bulls, then an individual herd can pick bulls that deviate in its desired directions. These will leave useful daughters, but if they are not also being used to sire sons for future testing, then such improvement will not be cumulative. It might be useful for someone to model just how far from the mainstream direction an individual herd can be maintained by the use of a customised index before too much effort is put into its development.

3.4. Breed-specific indices

A much more appropriate use of specialised indices would seem to be for specific breeds (or sub-populations). The so-called coloured breeds in Britain illustrate this situation. Together the Jersey, Guernsey, Ayrshire and Dairy Shorthorn breeds probably represent under 5% of commercial dairy cows, compared with over 50% in the mid-20th century. None of them has yet sunk to rare breed status (and both Jerseys and Ayrshires have substantial numbers in other countries with effective breed improvement programmes), but their plight is mirrored by many other once important breeds throughout Europe. There is also a significant number of producers who would like to retain the former British Friesian genotypes, and not replace them by imported Holsteins. Governments and FAO are committed to maintain biodiversity in domestic livestock, yet they are unlikely to provide sufficient funding to persuade farmers to maintain these old breeds in direct competition with the major breeds. It would seem preferable to try to identify, or create, a viable commercial market for their products, so that some farmers can make an adequate living from them based upon their differences; thus effectively maintaining biodiversity at no cost.

Such a scenario probably has to start with a defined production system to which all herds subscribe, and which is likely to appeal to consumers of their 'niche' products. An obvious route is to base this firmly on the breed's traditional system, and to avoid those cost-saving technologies which most milk producers have adopted, but which disturb a proportion of consumers. Thus, grazing might be required for part of the year with conserved forage at other times rather than heavy reliance on purchased cereal and oilseed feeds. Products would be close to the breed's traditional output: milk of characteristic composition; specific local cheeses and other processed items. All this is more easily achieved if the farms are within a defined locality or region. A successful example is the Reggiana breed producing the traditional hard Parmesan cheese of Central Italy. Rosati (2000) has also described efforts to conserve the Sicilian Modicana breed and develop cheese production from its native region.

Improvement goals for such breeds will often be different from those for breeds supplying the commodity milk markets. They will put even more emphasis on the traits that enable cows to walk easily to their pastures, to obtain most of their nutrients from roughage, to rebreed easily, and to survive for a long herd life. Of course, milk yield within the defined production system will be important, but not to the point where changed milk composition causes serious changes in the characteristic products. The English Guernsey Cattle Society and the organisations in the breed's Guernsey Island home have recently accepted a Guernsey Merit Index to achieve agreed improvement goals in a revised breeding programme to be illustrated in a later section.

4. Creation of genetic improvement in large populations

4.1. Recent practices

The generally accepted method of improving dairy cow populations has been outlined earlier. For the past 50 years, most have relied on the two-stage gains achieved by first selecting among all possible young bulls (pedigree selection) to create the annual group of young sires, and then, several years later, selecting within that group the surviving bulls with the best daughter proofs. Owen (1975) proposed selecting on half-sister rather than daughter proofs, but this system was not adopted. These proven bulls then sire the next generation of candidate young bulls and large numbers of second-crop daughters. There are many papers dealing with optimising this process in large populations and these topics will not be explored here except for one comment on control. It might be more efficient if more care were taken to confirm parentage, and collect records from test-groups of daughters, instead of leaving this information gathering to recording organisations which survive by offering management information to their commercial milk producer clients.

This discussion will be concerned with some situations where other methods may be more appropriate. Almost all European black and white populations have been going through a period when commercial milk producers changed their goals. In essence, they decided that the simultaneous pursuit of milk and meat was no longer appropriate. Their reasons, and the validity of their decisions need not be discussed, since this review is concerned with how the genetic change was realised. Progressive breeders and the largely cooperative breeding organisations began to appreciate that, for their new goals, there already existed superior populations in North America, and they eventually received veterinary approval to import them.

After the initial importations of bulls and semen, when their daughters had been milked in the different countries of Europe, it might have become obvious that what was needed was a grading-up programme, designed to increase the proportion of North American Holstein blood as rapidly as possible. What actually happened was that the European progeny testing programmes (with all their associated costs) continued. Groups of young bulls with less than 100% Holstein blood were evaluated, but the programmes naturally failed to identify individuals that could compete with the latest proven sires from the USA. Only when young sires were sourced directly from North America, or taken out of European cows with a high proportion of USA blood, did these organisations begin to identify European proven bulls of world-ranking status that could be used to sire large numbers of second-crop daughters. Even today non-US programmes are handicapped in international markets since many farmers favour bulls tested in their home country or in USA, though this could change if Europeans put more emphasis on the additional traits.

4.2. Future progress

For most milk producers who keep the numerically large breeds, their needs for continuing genetic improvement might seem reasonably assured, providing their production systems are in line with the majority. They are likely to be serviced by a number of competing breeding programmes, all operating internationally. Some will be private (shareholder) companies, others may remain producer-owned cooperatives, but their behaviour could be very similar.

Most cows will be inseminated by progeny tested bulls, proven to high accuracy. The current two-stage selection process may be extended to three, with a larger group of young bull calves (selected on pedigree index) being reduced shortly after birth on the basis of DNA tests for specific genes of interest. This will be similar to the initial beef performance test conducted in some (dual purpose) breeds before the survivors are progeny tested for milk production traits. Today's system involves every programme assembling its annual choice of young bulls, then waiting for many herds and recording agencies to collect records on their daughters, and finally the national and international (Interbull) data centres provide bull proofs. This arose in a previous era of cooperation, which may be disappearing, as more of the breeding organisations become private sector companies or at least international players on behalf of their farmer owners. One feature is that any competitive advantage which one company may gain from a clever or lucky choice of a young bull is bound to be short lived. Semen from the 'winning' bulls is immediately made available to all rival organisations to breed new crops of sons.

This system has been likened to that operated by pharmaceutical companies which carry out public testing of new patented products and hope every year to identify a few winners whose subsequent sales will finance their research laboratories to produce the next generation of drugs. The missing element for cattle breeders is of course patent protection. A drug company has the sole right, in exchange for making public its active ingredients, to sell the successful product for an extended period or receive royalties from licensing production to others. In contrast, the breeding organisation remains ignorant of its successful new bull's genotype, and only retains the rights to lifetime semen sales while making samples available immediately to its competitors for their contract matings. In poultry and pigs (and many plant species), most of the commercially released material is crossbred. Purebred lines only given to contracted partners. With poultry, deliberate steps may be taken to prevent mis-sexed chicks being sold or identified within consignments of females.

Unfortunately, most international cattle breeding organisations are currently not very profitable. This may be because their mainly cooperative origins have set semen prices too low based upon a small margin over direct costs rather than on the value to the producer in the new situation where governments have largely withdrawn their support for service organisations and producers are forced to question all their costs it might be better if all activities, including the routine running of national and international genetic evaluations, were truly privatised. Consolidation would then be likely and the remaining companies would be forced to distinguish themselves through competitive and different breeding programmes.

An alternative system might be for each international breeding organisation to try to establish an individual brand. This would involve using contracted test-herds to evaluate very thoroughly all first-crop daughters for many additional traits. The resultant proven bulls could be marketed as a team, or even as mixed semen getting away from the cult of the individual bull. Such a development might encourage more investment in the testing and selection processes to the advantage of both commercial milk producers, and the milk consuming public.

5. Creation of genetic improvement in numerically small populations

5.1. The misuse of progeny testing

The same system of progeny testing has been accepted as the only possible method of genetic improvement by nearly all dairy cattle breeds, no matter what their numerical size. This is even more unfortunate where several different breeding organisations have each had only a share of the semen market for a numerically small breed dispersed through their traditional territories—for example in USA, Canada and UK. It is obvious that such a breed only has a small number of heifers milking each year to provide the proofs for young sires. This problem is the conflict explored by the early researchers, but here there is no satisfactory compromise between choice and accuracy when the total number of daughters is too small. Either a large number of young bulls is tested so that the second stage selection has low reliability; alternatively, few young sires are used and there is no opportunity to apply intense selection among them when their daughter proofs eventually appear.

The classic papers of 50 years ago showed that, in such situations, progeny test programmes have little or no advantage over young bull schemes in terms of annual rates of genetic progress. Presumably they were adopted and have persisted because commercial herd owners have been educated to believe in the merits of proven bulls, and hence demand them. Furthermore, if a superior sire is discovered, then there may be good short-term profits to be made by the AI organisation from semen sales. These organisations ran the tests alongside the much larger programmes for the majority breeds, and there was little extra planning or work involved. Today, however, as the minority breeds have decreased in importance, in part owing to their much slower progress, the AI companies are having to review their involvement. Responsibility for future progress is likely to return quite clearly to the breed society, or at least the influential breeders, and this provides opportunities for new thinking.

5.2. Alternative improvement programmes: the young sire schemes

In a young sire scheme almost all matings are carried out with semen from the latest batch of yearling bulls. Only the contract matings of bull dams might use semen from a smaller group: perhaps 2.5-year-old bulls with a paternal half-sib proof; or an occasional 6.5-year-old bull with a good progeny test if he had not been previously over-used. Young bulls may even be used a bull sires. Very little semen needs to be stored, but the bulls themselves are redundant before 2 years of age or could be returned to the breeders for natural service with heifers.

Herd owners who have been accustomed to think in terms of accurately proven bulls may regard this as a high-risk strategy. But while the young sires' individual breeding values will have relatively low reliability, a team of such bulls is expected to deliver close to their mean value. Hence the commercial producer needs to concentrate on the team and not the individual members. Furthermore, what genetic superiority they do possess is injected very quickly into the whole breed since they sire all the heifers as soon as they are old enough to work. Dissemination is rapid and the genetic lag is short so that future bull dams are likely to be discovered throughout the breed and not only in a few breeders' herds.

Such a system contrasts with conventional progeny testing programmes, which permit very accurate decisions among tested bulls, but involve delays of several years before the proven sires have a major impact on the breed. When these points are carefully explained, it is quite possible to persuade commercial dairy farmers to stop demanding proven sires, though this must be easier when all semen suppliers agree to cooperate. The organisations representing the Guernsey breed in England and in Guernsey have increasingly been utilising young sires as the supply of USA-bred proven bulls diminished. In the past, herd owners retained the hope that some outstanding proven bulls would emerge and could be used to sire second-crop daughters and sons. Recently the breeding societies have taken the decision to move completely to the young bull programme and try to build this into a global programme involving another six small Guernsey populations around the world. A sound theoretical basis has been provided by research funded by the UK Milk Development Council, the States of Guernsey, and the World Guernsey Cattle Federation; the work was carried out by Dr J.A. Woolliams at the Roslin Institute, Edinburgh. Dempfle and Jaitner (2000) also evaluated the relative merits of young sire and progeny testing programmes within a herd of N'Dama cattle in The Gambia, and chose to implement the former based both on genetic efficiency and simplicity. Syrstad and Ruane (1998) came to similar conclusions, and Nitter (1998) favoured young bull systems for developing countries based on cost effectiveness.

6. Inbreeding considerations

The creation of genetic improvement in poultry and pigs has increasingly been carried out within more or less closed nucleus populations without the need for involving other cooperating flocks or herds. Nicholas and Smith (1983) first showed how the same concepts could be used with dairy cattle through the application of reproductive technology to greatly enhance the cow's reproductive rate. The theory of such MOET methodology has been much explored since then (Woolliams, 1989), but it is essential to make comparisons among alternative approaches when the expected rates of inbreeding have been equalised.

A nucleus herd, either real (assembled in one place) or virtual (dispersed among many herd owners) does indeed have theoretical advantages. It may be a useful way of measuring additional traits and eliminating preferential treatment among potential bull dams. But it is essential that it should succeed in achieving its planned increase in female reproduction. This is only possible through a high level of reproductive intervention that demands very close supervision, and so will be expensive, particularly where cows are dispersed among many owners. It may therefore be preferable for a new programme in a numerically small breed to begin rather simply, and a young sire scheme has advantages here.

Throughout the last century, most breeders have regarded inbreeding as a wholly bad process. Geneticists have also advised them to avoid it on the grounds that it leads to a loss in just that genetic variation on which future progress depends. Today it is perhaps time to change that view, in much the same way that economists have begun to view the rate of monetary inflation in a national economy as needing to be kept closely within both upper and lower limits. Too high a rate of inbreeding warns of trouble ahead. Too little implies a lack of effective selection in the preceding generations. Fortunately there are now methods available to simultaneously maximise selection pressure while limiting the rate of inbreeding to a predetermined level (perhaps 1% per generation) (Meuwissen, 1997), and these have been comprehensively developed and reviewed by Bijma (2000).

Such procedures should be perfectly possible in programmes where the key selection decisions are controlled by a single person or by a specific group. It is less obvious how they might be achieved where competing breeders (individual or corporate) are working independently within a single population. Wickham and Banos (1998) used the Interbull database to show that only five Holstein bulls were the sires of 50% of all 1990-born Holstein bulls that had been progeny tested worldwide, and that the effective population size in the breed had decreased sharply in the previous 20 years. Weigel (2001) has provided more recent analyses for several breeds, and highlighted the necessity for international breeders to balance their desire to offer sons of the best proven bulls with the need to limit inbreeding. At present this seems unlikely and one is reminded of the situation in the world's sea fish stocks where voluntary restraint failed to stop over-fishing until drastic international action became necessary.

7. Conclusions

7.1. Organisation

Practical improvement programmes in the different species of farm livestock have remained surprisingly isolated from each other. There are undeniable differences in reproductive rates, and in the ability to measure performance traits in both sexes, and before breeding age. Nevertheless not only does the organisation rest with separate bodies, but breeding scientists have also tended to concentrate upon a single species both in their academic studies, and in their consultancy. The author believes that greater sharing of ideas and experiences could have been beneficial since the underlying principles are common.

7.2. Data collection

Dairy cattle breeding is usually characterised by the great complexity and sophistication of data processing and breeding value estimation. This is superimposed upon livestock populations where no one is really in control, and where performance information is only collected on a few of the many traits influencing producer profitability. More emphasis upon structure and control within the breeding pyramid will be necessary if there is to be improvement in traits other than milk yield. The collection of performance data on which to base selection decisions should be seen as a vital task for a breeding organisation, rather than merely a cheap by-product of recording systems primarily designed to assist short-term management.

7.3. Multi-trait selection

A great deal of theory exists to aid selection for multiple objectives, but there is too large a gulf between this and the way most producers choose their herd sires. More effort will be needed to derive acceptable indices of overall merit and then to persuade milk producers of their value so that they are actually used.

7.4. Numerically small breeds

If these breeds are to survive, they must have quite different improvement goals from those for the dominant breeds supplying commodity milk. Breed associations need to realise that they will have to take charge of, and organise, scientifically designed programmes appropriate to their resources. These are likely to be based upon the use of young bulls rather than accurately proven sires, and such schemes will be much cheaper to run.

7.5. Inbreeding

The lack of overall control in the major breeds is leading to rates of inbreeding that will be harmful in future. The competing international breeders need to accept the responsibility for implementing measures to keep these rates below agreed maxima.

References

Bichard, M., 1987. Problems of across-population genetic evaluation within improvement schemes. In: Proc. 6th Conf. Austr. Assoc. Anim. Breeding and Genetics, Perth, pp. 103–111.

Bijma, P., 2000. Long-term genetic contributions: prediction of rates of inbreeding and genetic gain in selected populations. Ph.D. thesis, Wageningen University.

Christensen, L.G., 1998. Possibilities for genetic improvement of disease resistance, functional traits and animal welfare. Acta Agric. Scand. Sect. A Suppl. 29, 77–89.

Dempfle, L.K., Jaitner, J., 2000. Case study about the N'Dama breeding programme at the International Trypanotolerance Centre in The Gambia. In: Galal, S., Boyazoglu, J., Hammond, K. (Eds.), Workshop on developing breeding strategies for lower input animal production environments. ICAR Technical Series No. 3, 347–354.

Dickerson, G.E., Hazel, L.N., 1944. Effectiveness of selection on progeny performance as a supplement to earlier culling of livestock. J. Agric. Res. 69, 459–476.

Goddard, M.E., 1998. Consensus and debate in the definition of breeding objectives. J. Dairy Sci. 81, 6–18.

Groen, A.F., Steine, T., Colleau, J.J., Pedersen, J., Pribyl, J., Reinsch, N., 1997. Economic values in dairy cattle breeding with special reference to functional traits. Report of an EAAP working group. Livest. Prod. Sci. 49, 1–21.

Interbull, 1996–1999. Proceedings of International Workshops on

EU Concerted Action. Genetic improvement of functional traits in cattle (GIFT), Bulletins 12, 15, 18, 19, 21, 23.
McGuirk, B.J., 1998. Developments in the dairy cattle breeding industry. Interbull Rep. 19, 21–28.
Meuwissen, T.H.E., 1997. Maximising response of selection with a predefined rate of inbreeding. J. Anim. Sci. 75, 934–940.
Nicholas, F.W., Smith, C., 1983. Increased rates of genetic change in dairy cattle by embryo transfer and splitting. Anim. Prod. 36, 341–353.
Nitter, G., 1998. Considering cost effectiveness in dairy bull selection schemes. Proc. 5th W. Cong. Gen. Appl. Livest. Prod. 23, 435–438.
Owen, J.B., 1975. Selection of daily bulls on half-sister records. Anim. Prod. 20, 1–10.
Robertson, A., 1957. Optimum group size in progeny testing and family selection. Biometrics 13, 442–450.
Robertson, A., 1960. On optimum family size in selection programmes. Biometrics 16, 296–298.
Robertson, A., Rendel, J.M., 1950. The use of progeny testing with artificial insemination in dairy cattle. J. Genet. 50, 21–31.
Rosati, A., 2000. Breeding strategies for the Mediterranean Modicana cattle breed. In: Galal, S., Boyazoglu, J., Hammond, K. (Eds.), Workshop on developing breeding strategies for lower input animal production environments. ICAR Technical Series No. 3, 503–510.
Skjervold, H., Langholz, H.-J., 1964. Factors affecting the optimum structure of AI breeding in dairy cattle. Z. Tierzucht. ZuchtBiol. 80, 25–40.
Syrstad, O., Ruane, J., 1998. Prospects and strategies for genetic improvement of the dairy potential of tropical cattle by selection. Trop. Anim. Health Prod. 30, 257–268.
Weigel, K.A., 2001. Limiting the consequences of inbreeding in dairy cattle breeding programs. European Association for Animal Production Book of Abstracts No. 7, 74.
Wickham, B.W., Banos, G., 1998. Impact of international evaluations on dairy cattle breeding programmes. Proc. 6th W. Cong. Gen. Appl. Livest. Prod. 23, 315–322.
Woolliams, J.A., 1989. Modifications to MOET nucleus breeding schemes to improve rates of genetic progress and decrease rates of inbreeding in dairy cattle. Anim. Prod. 49, 1–14.