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Economic aspects of defining breeding objectives in selection programmes

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SUMMARY – The breeding objective in any livestock species is to increase the profit by improving production efficiency. Breeding objective is described by a profit function that takes genetic values as input and produces profit as outcome. This profit may be a bioeconomic model of the farm. The traits in the profit function should be related as directly as possible to all sources of income and costs. The profit function can include variables controlled by management decisions if these interact with genetic merit. Cumulative discounted expressions should be multiplied by the economic value to give the discounted economic values. Development and implementation of selection criteria are also presented.

Key words: Breeding objective, profit function, economic values, selection index.

***RESUME –** "Aspects économiques dans la définition des objectifs des programmes de sélection". L'objectif de sélection de toute espèce animale est l'augmentation du bénéfice à travers une amélioration de l'efficience de production. L'objectif de sélection est décrit par une fonction d'utilité qui considère les valeurs génétiques comme input et le bénéfice produit comme output. Ce bénéfice peut être un modèle bioéconomique au niveau de la ferme. Les caractères inclus dans la fonction d'utilité doivent être en relation directe avec toutes les sources de recettes et de coûts. La fonction de bénéfice peut inclure des variables contrôlées par des décisions de gestion technique si elles interagissent avec la valeur génétique. Les expressions cumulatives escomptées doivent être multipliées par la valeur économique pour avoir les valeurs économiques escomptées. Le développement et la mise en place des index de sélection sont aussi présentés.*

***Mots-clés :** Objectif de sélection, fonction d'utilité, valeurs économiques, index de sélection.*

Introduction

A breeding programme is an organization in which information on performance of potential breeding animals is used to estimate breeding values, and superior animals are selected to breed the next generation. Designing comprehensive animal breeding programme with a specific objective involves economic considerations. However the incorporation of economic factors into research and practice of animal breeding occurred only recently.

Failure to consider economics aspects in breeding decisions may be, in part, due to a lack of economic training on the part of animal breeders, and to the difficulties and uncertainties of predicting the future production and economic conditions which will exist for progeny generations. The lack to provide an economic assessment of genetic alternative leads that breeding in many programmes is guided by the recommendations of industry or the desires of breeders, that may be not the most profitable available.

Harris *et al.* (1984) presented a procedure for arranging choices, decisions and other relevant information to develop a breeding programme, which involves eight different steps:

Step 1. Describe the production system(s)
Step 2. Formulate the objective: both simplified and comprehensive
Step 3. Choose a breeding system and breeds
Step 4. Estimate selection parameters and (discounted) economic values
Step 5. Design an animal evaluation system
Step 6. Develop selection criteria
Step 7. Design mating for selected animals
Step 8. Design a system for expansion – dissemination – of genetic superiority

Harris *et al.* (1984) stressed, that the ideal steps outlined should be carried out sequentially starting with the first and continuing till the last one. Groen *et al.* (1997) summarized all these steps in three major steps. First, the breeding goal definition: setting up the aggregate genotype and deriving cumulative discounted expressions and economic values. The second step is the breeding value estimation: deciding what traits to be included in the information index, derivation of the regression coefficients to be included in the information index, estimation of the information index value, i.e. the estimated breeding value for each potential breeding animal. The final third step is the breeding programme optimization: optimizing the organization to routinely gather information on potential breeding animals and/or their relatives, and to select and mate breeding animals to breed the next generation.

To be able to judge and discuss the structure of breeding programmes, one has to understand how choices and decisions in different steps interact, and what is considered to be relevant information within each step (Groen, 1997). Three major factors influence the design of breeding programmes: reproduction capacity, social infrastructure and optimization meaning (Groen *et al.,* 1997). The reproduction capacity of individual animals is very important in determining the structure of breeding programmes. It has a direct effect on the choices of designs of animal evaluation system, mating programmes and dissemination of genetic superiority. Social infrastructure is a very broad and confused term. Information on social structure should be concentrate mainly on the following four aspects: (i) average and distribution of farm size and location of farms; (ii) degree of information network with regard to animal identification, pedigree recording and performance recording; (iii) state of technology; and (iv) structure and behaviour of the market. The last aspect mentioned largely influences the breeding objective and the design of the programme. In sheep and goat, overcoat in meat breeds, social factors largely determine the type of products. For that almost self-evident, but regretfully not always practised, the demand of product from consumers should determine the breeding goal.

The aim of this review is to describe some concepts, methods and techniques employed to include economic aspects in the process of establishment an animal breeding programme. Therefore, this review does not attempt to summarize details of objectives or economic aspects expressly of sheep breeding programmes, but will discuss the derivation of economic values, the concept of discounting and the formulation of the selection index in general. Due that I work habitually in dairy cattle area, I will refer to dairy cattle programmes in many parts of this review. Even though dairy cattle programmes can be more skilled than sheep ones, both of them can be compared.

Derivation of economic values

The economic value of a trait can be defined as the change in the profit of the farm, as a consequence of one unit of change in the genetic merit of the trait considered.

Groen *et al.* (1997) affirm that it is not possible to come up with the best methodology in deriving economic values. The best method from a theoretical point of view is not necessarily the method that is most practical to implement. It is, however very important that people deriving economic values would be aware that genetic improvement can be considered as a technological development. Awareness of these aspects might help choosing appropriate method to derive economic values.

Objective and non objective methods

First of all, one might distinguish between objective and non-objective methods.

The principal tool used in objective methods is modelling. A model is an equation or a set of equations that represent the behaviour of a system (France and Thornley, 1984). Modelling is also referred to "systems analysis". Two approaches of systems analysis can be distinguished: positive approach or data evaluation and normative approach or data simulation (James and Ellis, 1979).

When applying data evaluation, observed economic and technical data are used to derive economic importance of animal traits. A major drawback of economic data evaluation is that it uses historical prices, while breeding is future oriented. Gabiña *et al.* (this volume) used data evaluation analysis to define the relative economic importance of several traits in Latxa dairy breed. By means of a regression approach, they employed a field data to estimate a multiple regression equation that predicts profit. Due that the objective is genetic improvement, the regression should use genetic, not phenotypic, covariances. The regression approach seems to be confusing breeding objectives and selection criteria.

For data simulation models, the terms "profit function" and "bio-economic model" are used. There is no basic difference between profit functions and bio-economic modelling. A profit function is a single equation model (e.g. Miler and Pearson, 1979). Regarding the strict definition of profit as output minus input, the more general term "efficiency function" better represents this type of modelling. A multi-equation simulation model is referred to a bio-economic model (e.g. Tess *et al.*, 1983; Groen, 1988). Using simulated systems, economic values are derived by studying their reaction to a change of production factors related with the genetic merit of the animal for a specific trait, without changing other traits. With efficiency functions, this is performed by partial differentiation. With data simulations, possibilities of applying different prices, level and sizes of the production system are numerous.

Non-objective methods, as opposed to objective methods, do not derive economic values by direct calculation of influences of improvement of a trait on the increase in efficiency of the production system. A major justification of this method is an insufficient knowledge to model relevant aspects involved. Specific non-objective methods are that used to establish desired or restricted gain genetic indices. These methods assign economic values in order to achieve a desired or restricted amount of genetic gain for some traits (Kempthorne and Nordskog, 1959; Brascamp, 1984). These methods may be useful in commercial pig and poultry breeding because commercial breeders tend to calculate economic values according to the performance of their stock relative to those of competitors (Schultz, 1986). Moreover, these methods may be useful to examine the borders of the possible solution area for genetic improvement. Gibson and Kennedy (1990) illustrated the in-efficiency of desired gains indices relative to objective indices, and argued that multi-disciplinary scientific effort is needed to derive reliable objective efficiency functions rather than to rely on desired gains. Groen *et al.* (1994) compared linear, quadratic and desired gains indices for multiple generation selection response in a non-linear profit function, and concluded that desired gain indices allow stabilization of base population averages only at the expense of losses in economic selection response.

Profit functions

The first steps of development of breeding programme are the definition of production system and the establishment of the selection goal. The goal for individual animals should be to maximize the economic benefits of the production enterprise. Yet, in some cases, selection goals are established almost by default. The primary goal of most livestock producers is to make money. To obtain maximum economic gain from selection, an expression of the goal for individual animals is needed. Most workers begin by formulating a profit equation (Harris, 1970; Groen, 1988; Ponzoni, 1988; Van Arendonk and Brascamp, 1989; Bekman and Van Arendonk, 1993; Charfeddine and Alenda, 1997, etc.).

A profit function is a procedure or rule that describes the change in net economic returns as function of a series of physical, biological and economic parameters (Gibson, 1992). The use of the profit function in animal breeding is principally to define economic weights of traits contributing to economic genetic improvement. Therefore profit should be defined as a function of additive genetic values of aggregate genotype traits. In some cases, for simplicity, and because it does not affect results, other inputs such as management contributions and economic parameters are considered as fixed. Therefore a profit is a function of genotypic values for a given set of management and economic parameters as:

$$P = f(g_1, g_2, g_3, \ldots, g_n)$$

For the profit equation to be useful in animal breeding the following minimum criteria should be met:

(i) Change in profit should be a function of genetic change not other changes of phenotype.

(ii) Management conditions assumed should be relevant to the population in which genetic change is to be used at the time genetic change is used.

(iii) Economic parameters should reflect the marketing and management system in which genetic improvement is to be used at the time genetic improvement is used.

On time to define the profit equation three interlocking issues have been widely debated:

(i) Should profit be viewed from the perspective of the farmer, the industry or the consumer?

(ii) Should profit be expressed per farm, per animal or per unit of product (e.g. kilogram of milk)?

(iii) Should the objective be:
- to maximize profit $P = R - C$
- to maximize return on investment $\Phi = R/C$
- to minimize cost per unit production $Q = C/R$

where, R: return and C: cost.

Logically, the perspective depends on who is being asked to invest in the breeding program. Fortunately the type of investor should make little difference. Therefore, Groen *et al.* (1997) suggest that the derivation of economic values should be performed at farm level, where the profit is expressed per animal.

About the three interests of selection, in animal breeding, mainly the first and second interest are considered (Groen and Ruyter, 1990).

Traits to be considered in the profit function

In nearly all animal breeding situations, the selection goal is defined as an objective function of several traits, each with its own discounted economic value, called aggregate genotype and used to represent the genetic merit of an animal.

Hazel (1943) defined the aggregate genotype, *H*, for a given individual as the sum of its genotypes for several traits (assuming a distinct genotype for each economic trait), each genotype being weighted by their predicted contribution to the increase in the overall objective. This contribution is determined by so-called cumulative discounted expressions and economic values. The cumulative discounted expression of a trait reflects time and frequency of the future expression of a superior genotype originating from the use of a selected individual in a breeding programme (Brascamp, 1978). Multiplying the economic value by the cumulative discounted expression gives the discounted economic value. The following equations illustrate the principles used:

$$H = a_1\, BV_1 + a_2\, BV_2 + \ldots + a_n\, BV_n \qquad (1)$$

where,

BV_i : is the breeding value for trait i
a_i : is the discounted economic value for trait i

$$a_i = c_i\, v_i$$

where,

c_i : is a cumulative discounted expression for trait i
v_i : is the economic value of trait i

It is important to distinguish between traits in the breeding objective and traits in the selection criterion. The traits in the breeding objective determine profit but may not be the same as those traits that are actually recorded in practice (selection criteria) and used to make selection decisions. The conventional approach to selection of breeding livestock is to define an objective and then use knowledge of genetic and phenotypic covariances to choose a selection criterion. In the strict application of this approach, covariances have no place in the definition of the objective. Therefore, the traits in the profit function should relate as directly as possible to sources of income and costs (Harris and Newman, 1994). The profit function should be as close to true profit as possible. Traits should not be left out because information about them is lacking but should be excluded only if there is no genetic variation in them. Profit functions that leave out some traits can lead to suboptimal decisions. For instance, ignoring fertility, health costs and feed costs may exaggerate the economic benefits to be expected from selection for increased milk yield. Similarly, a trait should not be replaced by a prediction unless that prediction is 100% accurate.

In dairy cattle, traits influencing the efficiency of production are roughly characterized as production traits (milk and beef) and functional traits. The term functional traits is used to summarize those characters of an animal which increase efficiency not by higher output of products but by reduced costs of input. Major groups of breeding goal traits belonging to this category are health, fertility, calving ease, efficiency of feed utilization, and milkability (Groen *et al.,* 1997).

In sheep, breeding objectives depend on breed, local situation and type of flock. Barillet *et al.* (1997) classify traits with economic interest in dairy sheep breeds into production traits and functional traits. The production traits correspond to milk and meat income, while functional traits involve traits that support an efficient production like reproduction, milkability, and udder health traits. Martyniuk and Olech (1997) advise to address separately breeding objective for ewe flock and lamb production. In ewe flock reproduction performance, hardiness, fitness and longevity should be the main traits of the breeding objective, while to improve efficiency of lamb production breeding objectives should focus on high growth rate and carcass yield in prime lambs.

Production factors

Economic values depend on production circumstances in terms of production levels and market conditions. Definition of the production system in deriving economic values includes definition of level and size of the system. A system is considered a finite number of element together with relationships between them and their environment (Groen, 1997). Therefore, the animal level is the lowest system level considered in deriving economic values, but higher levels (farm, sector, or international) may be considered as well (Groen *et al.,* 1997).

In more practical terms, estimation of economic values requires a description of the production system, sources of income and expense, and the relationship between them, and with traits included in the breeding goal. Costs should be defined as fixed and variable costs. Fixed costs are those that the producer judge no change with the level of production of the flock or herd. By contrast, other expenses are assumed to vary with the level of production of the flock or herd, and are thus called variable costs.

In dairy cattle, Charfeddine (1998) developed a farm model, where the herd enterprise was modelled in detail, addressing separately dairy cows and young replacement stock. Profit was estimated by accounting for the total net values of milk, fat and protein produced; net value of calves born, salvage value; and the total fixed and variable costs of rearing heifers and lactation cows. Fixed costs involve medicines and veterinary application, insemination and semen, labour and other operation costs. Variable costs were originated mainly by feed costs. Figure 1 shows input and output components of this model, and their relationship with traits included in the breeding goal.

In sheep, Ponzoni (1988) estimated economic values for several traits in Australian Merino sheep. He developed a farm model, where income derives from lamb and ewe wool, surplus offspring and culled age ewes, and costs originates from feed, husbandry, wool harvesting and marketing, and marketing of slaughter animals. Costs was defined as fixed and variables costs.

Gabiña *et al.* (this volume) analysed the influence of some yield and reproduction traits on the profitability of flocks of the Latxa dairy breed in Basque country, autonomous region of the north of Spain. They used a positive approach to calculate the profit at ewe level. Incomes are provided by the sales of milk and cheese, lambs slaughter, ewes and ram sold to other farm, and culled ewes and rams. Costs are calculated taking account all feed and forage expenses, veterinary fees, bedding, marketing expenses and other operating costs.

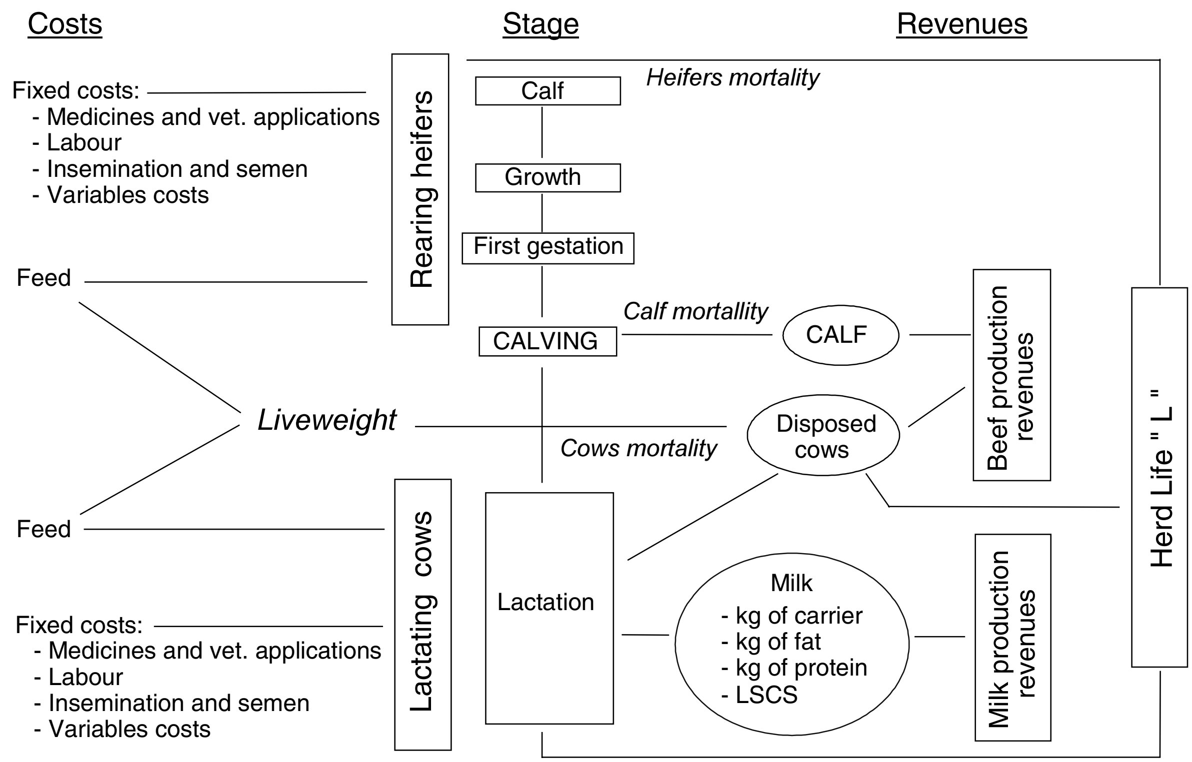

Fig. 1. Representation of milk production system and their major components.

The concept of discounting

Cumulative discounted expressions may differ between groups of traits. Assuming cumulative discounted expressions to be equal for all genotype traits considered (e.g., correct for only milk production traits), this simplification (economic values instead of discounted economic values) will not influence relative emphasis on index traits, and thus not genetic superiorities obtained. However, when considering different groups of traits, the assumption of equal cumulative discounted expressions will not hold.

Examples on cumulative discounted expressions are given by Groen (1990, milk production traits, live weight and mature body weight) and Dekkers (1994, direct and indirect effect of calving performance).

Ignoring cumulative discounted expressions in breeding goals is incorrect and will lead to bias in relative selection emphasis on traits and to non-optimum genetic responses.

Development of selection criteria

Once a linearized breeding goal has been developed and economic values of economic traits have been estimated, selection index theory (Hazel, 1943) can be used to derive a linear selection index, that predicts the breeding goal as accurately as possible, given the information that is available in the form of EBV for individual traits:

$$I = b_1\, EBV_1 + b_2\, EBV_2 + \ldots + b_m\, EBV_m \qquad (2)$$

where,

EBV_i : is the estimated breeding value for trait i
b_i : is the index weight on EBV_i

Traits in I may not be the same as traits in T. EBV in I can be from a single or multiple trait evaluation models. If EBV for all traits in I are from a joint multiple trait evaluation model, selection index weights can be derived as:

$$b = G_I^{-1} G_{IT} v \qquad (3)$$

where,

G_I : is a matrix with genetic (co)variances among traits in I
G_{IT} : is a matrix of genetic (co)variances between traits in I and traits in T

Equation (3) allows for different traits in I and T, If traits in I are the same as traits in T, then $b=v$.

Exact methods to derive selection index weights when EBV are from single trait BLUP evaluation methods are not available (other than conducting a multiple trait evaluation). In this situation, optimum index weights differ from animal to animal and depend on accuracy of EBV and sources of information that contribute to an animal's EBV. Standard index weights can, however, be approximated by deriving (co)variances among EBV based on given sources of information, for example, by considering EBV based on considerable number of daughter records for sires. Index weights can then be derived based on:

$$b = P^{-1} G v \qquad (4)$$

where,

P : is a matrix with approximate (co)variances among single traits EBV in I
G : is a matrix with approximate (co)variances between single trait EBV in I and BV in T

If accuracy of EBV is high, index weights from (3) approximate weights from (4) (Van Vleck, 1988). Depending on genetic parameters among traits and variability of accuracy of EBV among animals, the impact of using a standard index for all animals on accuracy of selection may be small. For example, Gibson and Dekkers (1992) found that an index of production traits derived based on sire ETA with 50 daughter records was close to optimum also for cows.

In general, derivation of selection indexes requires availability of accurate estimates of genetic parameters among traits in T and I, which are frequently lacking. Use of poor estimates in derivation of selection indexes results in overestimation of the accuracy of the index (Gibson and Dekkers, 1992).

With a large number of traits evaluated and included in I, the resulting index may become quite complicated and difficult to explain to farmers, who are targeted as the main users of the index. A possible solution is a stepwise building of the overall index, in which first subindexes are developed for components of the breeding goal, which are subsequently combined into an overall index.

In dairy cattle, Charfeddine (1998) Developed a total economic merit index. Three steps:

(i) Development of three breeding sub-goals, mastitis resistance, functional herd life and productivity.

(ii) Development of subindexes pertaining to these breeding sub-goals.

(iii) Development of an overall selection index based on subindexes (Fig. 2).

Conclusion

A genetically and socio-economically balanced selection requires correct economic values. Correct relative levels of economic values of traits should give optimum levels of genetic improvement according to future production circumstances.

Derivation of economic values requires a sound theoretical basis, proper methodology in terms of models including physiological modelling of production, farm economics and social aspects, and appropriate assumptions on future production circumstances. Even though, social aspects generally are not considered.

Breeding goal definition is of ongoing interest, because knowledge on modelling is improving, and production circumstances are continuously changing. Research and integration of economic aspects in sheep breeding goal are still a great challenges.

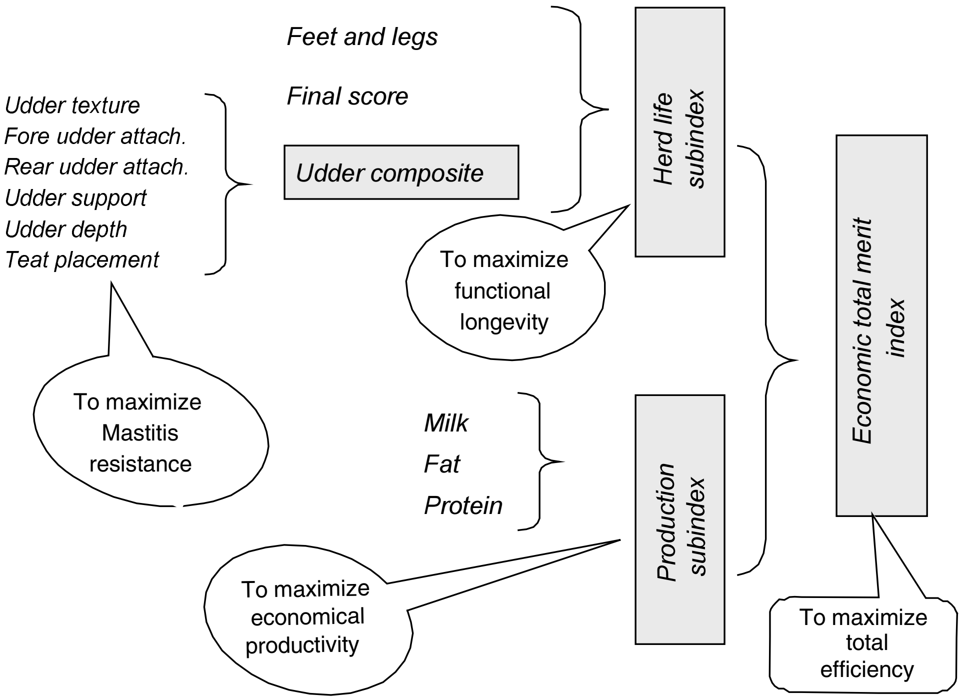

Fig. 2. Development of an overall index for total economic merit.

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