Economic values of functional traits in dairy cattle

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1. Introduction

Integration of functional traits into breeding programmes requires among others knowledge on economic values of these functional traits. The economic value of a trait expresses to what extent economic efficiency of production is improved at the moment of expression of one unit of genetic superiority for that trait (Groen, 1989c). The cumulative discounted expression of a trait reflects time and frequency of future expression of a superior genotype originating from the use of a selected individual in a breeding programme (Brascamp, 1978). Multiplication of the economic value by the cumulative discounted expression gives the discounted economic value. Discounted economic values are used (1) to aggregate genotypes for several traits to the 'aggregate genotype', in other words, to weight genotypes in a specific breeding goal (Hazel, 1943), and (2) to value predicted genetic superiorities in a breeding goal in order to calculate economic revenues of this programme. Relative levels of discounted economic values of traits are important for an accurate definition of the breeding goal, giving optimum levels of genetic improvement according to future production circumstances (Groen, 1990). To obtain an accurate calculation of economic revenues of breeding programmes (in order to optimize the structure of breeding programmes), primarily the absolute levels of economic values are important.

The aim of this paper is to discuss methodology in deriving economic values, with special emphasis on functional traits. A summary of literature on estimated economic values for functional traits is included.

2. Methodology

Objective versus non-objective methods

At first, one might distinguish between objective and non-objective methods to derive economic values.

The principal tool used in objective methods to derive economic values is a model. A model is an equation or a set of equations that represents the behaviour of a system (France and Thornley, 1984). Modelling is also refered to as '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, economic results 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. For data simulation models, often the terms 'profit function' and 'bio-economic model' are used. There principally is no difference between profit functions and bio-economic modelling. A profit function is a single-equation model (e.g., Miller and Pearson, 1979). Regarding the strict definition of profit as being output minus input, probably the more general term 'efficiency function' better represents this type of modelling. A multi-equation simulation model is refered to a a bio-economic model (e.g., Tess *et al.*, 1983; Groen, 1988). Using simulation models, economic values are derived by studying the behaviour of the system as a reaction to a change in level of an (endogenous) element that represents 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, levels and sizes of the production system ar 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 reason called upon in practically applying non-objective methods is 'difficulties' to perform an objective calculation; insufficient knowledge to model (all) relevant aspects involved. Specific non-objective methods are desired or restricted gain indices. These methods assign economic values in order to achieve a desired or restricted amount of genetic gain for each trait (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 other breeders (Schultz, 1986). 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 (see also notes by Yamada, 1995). 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 gains indices allow stabilization of base population averages only at the expense of considerable losses in economic selection response. A good example of a multi disciplinary effort to objectively assign economic values is the method for incorporating competitive market position in economic values, as presented by De Vries (1989). Ollivier *et al.* (1990) considered the method of De Vries (1989) together with the desired gains index. The competitive index appeared to have better properties than the desired gains index, not only with respect to saleability but also in economic terms. Of course an important aspect of comparisons performed by Gibson and Kennedy (1990), Ollivier *et al.* (1990) and Groen *et al.* (1994), is that they define a 'true' efficiency function and an appropriate (optimal) objective index. In that situation, any subjective index can only perform equally or less efficient. In practice, 'true' efficiency functions are unknown, and breeders applying subjective economic values argue that they have a better 'expert' insight in future development than an objective model.

In conclusion, objective methods are prefered in deriving economic values to define breeding goals. Modelling is not an easy job, requiring multi-disciplinary effort. Some basic choices to be made in modelling when deriving economic values are discussed below.

Biological versus economic definition

Efficiency of production is a function of costs and revenues of the production system. Costs can be defined as the total value of production-factors required for production within the system; revenues as the total value of products resulting from production within the system. In calculating costs and revenues of a production system, two aspects are important:

- the physical amounts (and qualities) of each production-factor required and product produced,
- the values per unit of production-factor and per unit of product.

Differences between biological and economic efficiency are restricted to differences in the way of defining costs and revenues. In the biological definition, costs and revenues are expressed in energy and/or protein terms; in the economic definition this is done in terms of money. The major problem arising with the biological definition is that not all costs and revenues can be expressed in terms of energy and/or protein. The economic definition largely deals with this problem. A disadvantage of the economic expression is weakness in stability in time and place of monetary units (Schlote, 1977). Notwithstanding imperfectness, money is 'the standard for measuring value' (Stonier and Hague, 1964). Therefore, efficiency of production is usually considered to be economic efficiency, and the contribution of improvement of a trait to improvement of efficiency is called 'economic value'.

System level

A system is considered to be a finite number of elements, together with relationships between elements and their environment (Gal, 1982). Genetic merit is tied up to the level of an individual animal, not just an organ or tissue. Therefore, the animal level is the lowest system level considered in deriving economic values, but higher levels (farm, sector, or inter-national) may be considered as well.

Improvement of genetic merit of animals increases efficiency of production. Long run effects of greater efficiency will be lower market prices (Cochrane, 1958). Yet, a cyclic interaction is observed. Economic values (and hence level of improvement of traits) are influenced by product and production-factor prices, and level of improvement of a trait will itself influence future prices. Therefore, derivation of economic values ideally requires knowledge of future levels of improvement of genetic merit and their price effects (Niebel, 1986). The theoretically appropriate level to be used in deriving economic values in animal breeding is the one for which limited resources and prices of products and production-factors are influenced by an improvement of a trait (Fewson, 1982). A good example is given in a dairy industry with a milk quota system limiting the amount of product at farm level. Improvement of genetic merit for milk production per cow will result in a reduction in the number of cows at a farm. To include the effects of a reduction in the number of cows (reduced costs of housing, feeding, labour and so on), derivation of economic values should be performed at farm level. Another example is the effect of genetic improvement on product market prices. Amer and Fox (1992) denote, within the framework of neoclassical production theory, how to assess the distribution of benefits from genetic improvement between producers and consumers. This distribution of benefits will depend on the elasticity of demand curves for products.

Although theoretically appropriate, national or international levels or sector level are rarely chosen because of methodological problems. Most calculations of economic values are restricted to the animal, herd or farm level (Groen and Ruyter, 1990). The potential bias as a result of simplifications made can be tested by a sensitivity analysis for market prices and production levels.

Planning term

The choice of a planning term should be included in deriving economic values regarding (1) the choice of (exogeneous) price parameters, and (2) the distinction between variable and fixed costs. In dairy cattle breeding, usually, the strategic planning term is chosen, because future expression of genetic superiority originating from a selected animal will mainly be more than five years after the moment of selection of this animal. Two comments on this choice are to be made. First, it is problematic to distinguish between a strategic and tactical term in estimating future price parameters. Secondly, selection sometimes has major influence on short term efficiency of a single farm (e.g. value of new born calf to be sold for beef production).

The choice of a planning term is related to the choice of production level; an improvement of a trait will only at the longer term influence limited resources and prices of products and production-factors at sector level.

Perspective

Three different interests of selection can be distinguished (Harris, 1970): (1) to maximize profit (= revenues - costs), (2) to minimize costs per unit product, and (3) to maximize revenues/costs. In animal breeding, mainly the first and second interest are considered (Groen and Ruyter, 1990). The base of evaluation establishes size of the system considered in deriving economic values, according to social and economic production circumstances. The three possibilities are (Groen, 1989c): (a) a fixed number of animals within the system, (b) a fixed amount of input of a production-factor into the system, and (c) a fixed amount of output of a product out of the system. Groen (1989c) presented the concepts of economic production theory regarding different perspectives (combinations of interests of selection and bases of evaluation) in deriving economic values (Table 1). Concepts are derived for a situation with one product and one variable production-factor per animal. However, concepts can easily be extended to situations with more products and more variable production-factors. The costs of other production-factors with a variable input are always to be considered in average variable or average total costs. When the inputs of other variable production-factors are influenced by the level of genetic merit, the marginal costs of production will contain more terms. Analogously, the revenues of other products are always to be considered in average revenues. When the output level of other products is influenced by the level of genetic merit, marginal revenues will contain more terms. When the output level of other products is not influenced, within the profit interest average variable costs are extended. In the latter case, the revenues of other products are 'negative costs' components. For the cost price interest, consideration of the revenues of other products to be negative costs is optional. For example, in dairy cattle productio the gross or net cost price of milk can calculated. The net cost price considers all co minus revenues of beef production per unit milk. Theory given is based on a single base of evaluation. Situations with multiple quota systems are dealt with by Gibson (1989).

Table 1 Economic values for different perspectives (base of evaluation and interest of selection) expressed in concepts of economic production theory (From: Groen, 1989c).

Base of evaluation	Interest of selection *Profit*	*Cost price*
Fixed number of animals	Marginal revenues[i] - marginal costs[ii]	Average total costs[i] - marginal costs[ii]
Fixed input	Marginal revenues[i] - average (revenues - fixed costs per animal)[iii]	Average total cost[i] - average fixed cost farm[iii]
Fixed output	Average variable costs[i] - marginal costs[ii]	Average variable costs[i] - marginal costs[ii]

i : per δy units of product
ii : per δy units of product, corresponding to δx_v units production-factor
iii : per δx_v units of production factor

The essence of improvement of efficiency of a production system is: saving inputs of production-factors per unit product and/or a change towards use of cheaper production-factors. Saved production-factors can either be used in the system where they are saved from (and thus extend product output of this system) or can be transferred to another system (via the market) (Willer, 1967). Likewise, additionally required production-factors are either to be drawn from the market or from an alternative use in the system. Obtained differences in concepts of production theory originate directly from differences in assumed use of saved production-factors. Example given, for the 'profit, fixed number' perspective, saved production-factors are sold at the market. In other words, differences in concepts between perspectives (Table 1) will only lead to differences in economic values when the values of (saved) production-factors differ between alternative uses. Assuming (1) markets of products and production-factors to be purely competitive markets and (2) industry and all individual firms to be in equilibrium, market prices will equal average total costs of production (Stonier and Hague, 1964). This is the approach considered by Brascamp *et al.* (1985) in proposing to set profit to zero. In terms of Table 1, economic values on base of fixed number of animals are equivalent when derived within profit and cost price interests. On base of fixed output, economic values within a profit interest are equivalent to economic values within a cost price interest. These economic values will also be equivalent to economic value 'fixed number, cost price' when (3) all costs of the farm are considered to be variable per unit product. This equivalence was pointed out by Smith *et al.* (1986), who proposed to express fixed costs per animal or per farm, like variable costs, per unit of output.

Concluding, assuming that all costs are variable and that also the costs of producing the variable production-factor at the farm equals the market price, all perspectives are equivalent. However, in agricultural industries, products and production-factors are commonly heterogeneous and not fully divisible. Heterogenity of products and production-factors leads to division of markets (Dahl and Hammond, 1977), and cause the average costs of production to be different for individual firms. Given (equilibrium) market prices, some firms will have a lot of profit; other firms will be just efficient enough to continue production (Stonier and Hague, 1964). As an important result, the equivalence of perspective may hold under certain conditions for the sector as a whole, but will not be valid from an individual producer's point of view. In defining breeding goals, definition of efficiency function has to correspond to the individual livestock producer's interest of selection; the producer's primary reason to buy a certain stock at a certain price, will be based upon his assessment of how animals will contribute to the efficiency of his firm (Harris, 1970). These concepts form the theoretical base for a diversification of breeding goals among (groups of) farms (Smith, 1986; Groen, 1990), and impose the question of the usefullness of customised indices for (individual) farms (Bowman *et al.*, 1996).

Optimum management

Bio-economic modelling allows for the implementation of mathematical programming techniques to optimize management variables in dependence on genetic levels. Van Arendonk (1985) applied a dynamic programming model to determine the optimum replacement policy of dairy cows. Reducing involuntary (reproductive failure, health problems) disposal rates increased optimum voluntary disposal. Ignoring these changes in (optimum) management variables would bias the economic advantage of reducing involuntary culling (Dekkers, 1991). Steverink *et al.* (1994) applied linear programming to derive economic values in dairy cattle in dependence on governmental environmental policies. As future governmental policies are yet unknown, different alternatives were studied, and linear programming allowed for the definition of optimum farm management for each of these alternatives, given multiple restrictions. Steverink *et al.* (1994) denoted that linear programming allowed for the best (given farm characteristics, like kg milk quota per ha) use of saved production-factors, in others words, the appropriate choice of (marginal) prices for (marginal) feed requirements. Zeddies *et al.* (1981) used linear programming in a sector model in order to define structural developments (farm sizes, number of farms) based on profitability of individual farms. Other studies using mathematical programming are among others Adelhelm *et al.* (1972) and Harris and Freeman (1993).

The question of optimizing farm management given farm structure should not be confused with optimizing farm structure. Animal breeding is part of strategic (long-term) planning of production. Therefore, it is appropriate to consider all costs to be variable in time, in deriving economic values. However, costs may be fixed (constant or discontinously variable) with respect to size of the farm (Horring, 1948). Considering these fixed to be variable per unit product requires an assumption on (optimum) size of the farm. Smith *et al.* (1996) proposed to express all fixed costs per animal or per farm per unit of output, thereby assuming a given optimum farm structure or size, with efficient use of resources. Assuming all farms to have same size, and that changes in output and input are accomplished by change in number of farms, the condition of fixed cost to be constant per unit of product is arithematically correct. However, structural developments in industry are detached from improvements in efficiency of production, which is not correct considering long term effects of the implementation of new techniques (Groen, 1989c; Amer and Fox, 1992).

Functional traits

After giving these general aspect on the methodology to derive economic values in animal breeding, I will denote some aspect specifically related to functional traits.

In deriving economic values of functional traits, especially reproductive and health traits related to animal welfare, it is important to consider public opinion and consumer attitude towards animal production. A basic model for the economic appraisal of diseases including these aspects is given by McInerney (1992). Constructing such a model requires knowledge on (agricultural) economics and marketing principles as well as actual values on required parameters that reflect the elasticity of the demand and supply curves for agricultural products (see Amer and Fox, 1992). Avoiding such a multi-disciplinary objective modelling, one might restrict genetic gain in health traits to zero or any other arbitrarily choosen (low) level, refering to public opinion and consumer attitude. However, I consider this problem in deriving economic values for functional traits as a major challenge for animal breeders in the near future. Constructing models at sector level, including mathematical programming techniques is, therefore, highly relevant in deriving economic values for functional traits.

As denoted in the introduction, weighing factors in the aggregate genotype should be discounted economic values, and not economic values as such. However, often only economic values are considered in deriving practical selection indices. Under the assumption of cumulative discounted expressions to be equal for all genotype traits considered (e.g., correct for only milk production traits), this simplification (economic values in stead of discounted economic values) will not influence relative emphasis on index traits. However, when considering both production traits and functional traits in the breeding goal, the assumption on equal cumulative discounted expressions will not hold. For example, Groen (1990) gives cumulative discounted expressions for milk production traits, live weight and mature body weight, showing apparent differences. Ignoring cumulative discounted expressions in breeding goals that consider both production and functional traits is incorrect and will lead to bias in relative selection emphasis on traits, and thus to non-optimum genetic responses.

Functional traits are phenotypically and genetically related to production traits. For example, incidences of mastitis are more frequent with high genetic potential for milk production in early lactation, but will result in lower milk production during the remaining part of lactation. If both milk production and mastitis are included in the aggregate genotype, index calculations using an appropriate correlation structure account for these aspects. To avoid double counting, in this situation reduced milk production as a result of mastitis incidence should not be accounted for in the economic value of mastitis. Specifically in situations with composite traits like residual feed intake capacity, it is important to adequately attune choice of genetic parameters, economic values and aggregate genotype traits chosen (Kennedy *et al.*, 1993).

Another point raising attention when considering functional traits is non-linearity of economic values. The economic value of a trait may depend on the level of the trait itself, or on the level of other traits. The theoretical basis for the application of non-linear (linear and quadratic component) indices was given by Wilton *et al.* (1968). Relative efficiency of non-linear indices versus regularly updating economic values according to new population averages was recently studied by Groen *et al.* (1994) and Dekkers *et al.* (1995), using examples in dairy cattle (days open) and poultry (egg weight), respectively. Weller *et al.* (1996, this workshop) extensively discusses properties of different methods to select for non-linear profit functions.

Table 2 Functional traits considered as breeding goal traits and examples of possible information index traits (From: Strandberg *et al.*, 1996). Traits in *italic* are considered in this summary.

Functional traits		Possible information index traits for selection
Efficiency	*Body weight* *Feed intake capacity*	Linearly scored type traits, body measurements
Fertility	Showing heat	Interval calving to first heat, interval calving to 1st insemination
	Pregnancy rate	Non-return, interval 1st insemination to pregnancy, number of inseminations per pregnancy
	Calving ease Stillbirth	Rump angle
Health	*Mastitis*	Teat placement, suspensory ligament, udder depth, SCC, milking speed, *longevity*
	Feet and legs Other diseases	Rear legs set, claw diagonal, longevity Longevity
Milkability	*Milking speed* Behaviour	

3. Literature

In this chapter, a summary of literature on estimated economic values for functional traits is given. Functional traits considered are summarized in Table 2. Absolute figures on derived economic values depend strongly on price parameters and methodology and are, for that reason, not presented here. Also relative importance of traits towards production traits is not denoted: only index weighing factors fully account for differences in heritability and genetic variance, genetic correlations, differences in discounted economic values, and the amount of information recorded in the breeding programme.

Only original references are included. I know this summary is not complete, and I would like to encourage people having other sources to inform me. A review on economic values of milk production traits is given by Groen and Ruyter (1990). Recently, a broad review on breeding for profit in livestock is publisched by Harris and Newman (1994).

Body weight

Mature body weight of dairy cattle has a negative economic value; marginal costs associated with increased energy requirements for raising female stock and increased maintenance requirements for lactating cows exceed marginal revenues from increased body weight of disposed young female stock and lactating cows (Groen, 1989a). Economic values for body weight are usually derived without considering changes in body composition. The economic value of mature body weight is mainly dependent on assumed feed prices and beef prices (Groen, 1989a).
Given their impact on marginal feed cost, farming intensity (kg milk quota per ha) and environmental legislation will also influence the economic value of mature body weight (Steverink *et al.*, 1994). The economic value of mature body weight for pasture based dairy production systems in Australia, restricting input of roughage at farm level, was derived by Visscher *et al.* (1994). When restricting roughage input, the economic value of mature body weight tends to decrease, as the average revenues over fixed costs per unit roughage in practical situations exceed marginal costs of roughage production (Groen, 1989b, see Table 1). Ignoring the rearing period only slightly influences the economic value of mature body weight (Morris and Wilton, 1977; Groen, 1989a). Economic values for (mature) body weight are also presented by VanRaden (1988) and Alborn and Dempfle (1992).

Feed intake

Feed intake is a very complex trait, which in fact can not be treated on its own, but should always be considered in relation to milk production and body weight. An important question is whether a reduction or an increase in (residual) feed intake (capacity) should be considered. Increasing (residual) feed intake at constant production levels and body weight would allow for a more efficient production; less nutrients required per unit of product. An increase in feed intake capacity would allow for more (and cheaper) fibrous feed intake and probably a lower negative energy balance in early lactation.

Groen and Korver (1989) derived the economic value of feed intake capacity assuming that nutrient intake is determined by nutrient requirements: an increase in feed intake capacity allowed for a cheaper composition of nutrient intake, and their model allowed for a change in genetic value of feed intake capacity without changing levels of body weight and milk production. Increasing feed intake capacity as defined, might be a change in body composition and/or an increased rumen outflow rate of particles (Orskov *et al.*, 1988). The economic value of feed intake capacity was found to be highly sensitive to feed and animal factors influencing the feed intake of dairy cows, and to the difference between concentrate and roughage price. This sensitivity corresponds to results by Zeddies (1985).

Health

Financial losses from diseases at the farm level can be attributed to one or more of the following factors (Schepers and Dijkhuizen, 1991): (1) less efficient production and more veterinary costs before disposal (decreased milk yield, changed milk composition, decreased milk quality, discarded milk, decreased feed intake, drug costs, veterinary fee, labour costs), (2) reduced slaughter value and idle production factors at disposal, and (3) lost future income when replacing animals before reaching there optimal economic age for culling (loss is difference between (a) income that a particular animal could earn during her remaining expected life and (b) expected average income from replacement animals. These losses do not include costs of (national) disease control programs (Schepers and Dijkhuizen, 1991), nor do they consider effects of increased disease incidence on public health and consumer behaviour (McInerney, 1992). My personal feeling is, that the latter point, consumer behaviour, is the main incentive to consider health (and reproductive) traits in cattle breeding programmes. A lot of work is to be performed in this area.

A critical analysis of estimates of economic losses from mastitis at farm level is given by Schepers and Dijkhuizen (1991).

Fertility

Variables used to denote the fertility of a dairy cow are calving interval or days open, and conception or non-return rates, or number of inseminations to obtain pregnancy. It is obvious, that these variables are strongly related, and directly depend on insemination and replacement policy of the farmer. The consequences of a decrease in fertility include (Boichard, 1990): additional insemination and veterinary costs, increased length and persistency of the current lactation, increased culling rate, and modifications to subsequent lactations. A basic study quantifying these aspects is described by Dijkhuizen *et al.* (1985).

The economic value of prolonged calving interval or period with days open depends on relative prices for milk and beef. Thereby, the persistency of lactation is an important factor in determining relative production level at the end of lactation (with prolonged days in milk) versus production level at the beginning of (next) lactation. The economic value of days open was recently calculated by Groen *et al.* (1994). A literature review, summarizing cost components included in modelling economic losses of prolonged calving interval, is given by De Boer (1990).

Van Arendonk and Dijkhuizen (1985) used dynamic programming techniques to optimize replacement policies when quantifying the effects of changes in probabilities of conception. Boichard (1990) used a similar model to derive the economic value of conception rate in dairy cattle. Amer *et al.* (1995) introduced an alternative approach to derive economic values of reproductive traits, combining partial budgeting of the economic costs of a barren cow with a model of the herd calving distribution whcih is driven by assumed levels of reproductive parameters. Specificity of the model is that it accounts for non-normal distributions of e.g. days open. Economic values of conception rate are also given by Dekkers (1991).

Calving ease

Meijering (1986) presented a model for the derivation of the economic value for dystocia, assuming recording of dystocia as a categorial trait. Meijering (1986) included veterinary fee, farmer labour calf losses, reduced milk yield, reduced fertility and increased culling as cost components. This model was also applied by Bekman and Van Arendonk (1993), Dekkers (1994), and Groen *et al.* (1995). In dependence on other breeding goal traits considered, these authors applied different sets of cost components. The economic value of calving ease is mainly determined by the frequency of animals in classes like veterinary help, caesarian, and fetotomy, and the costs of veterinary fee and calf loss in these classes.

Milking speed

Dekkers (1993) and Stegink (1994) derived the economic value of milking speed, including the following cost components: labour, electricity, and milking parlour (interest and depreciation). Labour cost were about 90-95% of total costs. Therefore, the level of labour cost per hour and the number of milking machines per person were the most important parameters determining the economic value of milking speed.

Longevity

According to Rendel and Robertson (1950), a longer productive life in dairy cattle increases profit at farm level in four ways: (a) by reducing the annual cost of replacements per cow in the herd, (b) by increasing the average herd-yield through an increase in the proportion of cows in the higher producing age-groups, (c) by reducing the replacements which have to be reared, and therefore allowing an increase in size of the milking herd for a given acreage, and (d) by an increase in the culling possible. Including all these components requires extensive models using mathematical programming techniques to optimize replacement policies, like the model by Van Arendonk (1985). The optimum replacement policy and the economic importance of longevity strongly depends on the relative magnitude of costs of growing (or buying) a replacement heifer versus the salvage value of a cow (Van Arendonk, 1985). There are two main approaches considered in deriving the economic importance of longevity: calculate either the economic value of increased productive life (Van Arendonk, 1991; Allaire and Gibson, 1992) or the economic value of reducing involuntary culling rates (Van Arendonk, 1985; Rogers *et al.*, 1988). Recently, Dekkers and Jairith (1994) summarized the role of longevity in the breeding goal. Economic values of longevity are recently calculated by Harris and Freeman (1993), Reinsch (1993), Böbner (1994), and Stott (1994).

Concluding remarks

Integration of functional traits in dairy cattle breeding goals, with a correct weighing relative to milk production requires economic values of these funtional traits. Derivation of objective economic values of functional traits, including physiological modelling of animal production, farm economic and social aspects (like price development, consumer behaviour) is still a major challenge for animal breeders, requiring a multi-disciplinary effort.

References

Adelhelm, R., Böckenhoff, E., Bischoff, T., Fewson, D. and Rittler, A., 1972. Die Leistungsmerkmale beim Rind. Teil A: Wirtschafliche Bedeutung. Hohemeimer Arbeiten, Tierische Produktion. Heft 64. Verlag Eugen Ulmer, Stuttgart.

Ahlborn, G. and Dempfle, L., 1992. Genetic parameters for milk production and body size in New Zealand Holstein-Friesian and Jersey. Livest. Prod. Sci., 31: 205-219.

Allaire, F.R. and Gibson, J.P., 1992. Genetic value of herd life adjusted for milk production. J. Dairy Sci., 75: 1349-1356.

Amer, P.R. and Fox, G.C., 1992. Estimation of economic weights in genetic improvement using neoclassical production theory: an alternative to rescaling. Anim. Prod., 54: 341-350.

Amer, P.R., Lowman, B.G. and Simm, G., 1995. Economic values for reproduction traits in beef suckler herds based on a calving distribution model. Paper G3.5. Book of Abstracts of the 46th Annual Meeting of the EAAP, Prague, September 4-7th, 1995. pg. 36.

Bekman, H. and Van Arendonk, J.A.M., 1993. Derivation of economic values for veal, beef and milk production traits using profit equations. Livest. Prod. Sci., 34: 35-56.

Böbner, C., 1994. Schätzung wirtschaftlicher Gewichte für sekundäre Leistungsmerkmale bei Schweizerischen Zweinutzungsrindern unter Anwendung der dynamischen Optimierung. PhD Thesis, Technische Hochschule, Zürich.

Boichard, D., 1990. Estimation of the economic value of conception rate in dairy cattle. Livest. Prod. Sci., 24: 187-204.

Bowman, P.J., Visscher, P.M. and Goddard, M.E., 1996. Customised selection indices for dairy bulls in Australia. Accepted for publication in Animal Sciences.

Brascamp, E.W., 1978. Methods on economic optimization of animal breeding plans. Report B-134, Research Institute for Animal Husbandry "Schoonoord", Zeist.

Brascamp, E.W., 1984. Selection indices with constraints. Anim. Breed. Abstr., 52: 645-654.

Brascamp, E.W., Smith, C. and Guy, D.R., 1985. Derivation of economic weights from profit equations. Anim. Prod., 40: 175-180.

Cochrane, W.W., 1958. Farm prices: myth and reality. University of Minnesota Press, Minneapolis.

Dahl, D.G. and Hammond, J.W., 1977. Market and price analysis. The agricultural industries. McGraw-Hill, New York

De Boer, H.J., 1990. Een model op de personal computer ter berekening van de economisch optimale tussenkalftijd bij melkvee. MSc Thesis Department of Farm Management, Wageningen Agricultural University, Wageningen.

Dekkers, J.C.M., 1991. Estimation of economic values for dairy cattle breeding goals: bias due to suboptimal management policies. Livest. Prod. Sci., 29: 131-149.

Dekkers, J.C.M., 1993. Breeding strategies for milking speed. Memo, Centre for Genetic Improvement of Livestock, University of Guelph, Guelph.

Dekkers, J.C.M., 1994. Optimum breeding

strategies for calving ease. J. Dairy Sci., 77: 3441-3453.

Dekkers, J.C.M., Birke, P.V. and Gibson, J.P., 1995. Optimum linear selection indexes for multiple generation objectives with non-linear profit functions. Anim. Sci., 61: 165-175.

Dekkers, J.C.M. and Jairith, L.K., 1994. Requirements and uses of genetic evaluations for conformation and herd life. Proceedings 5th World Congress on Genetics applied to Livestock Production, Guelph. Vol. 17: 61-68.

De Vries, A.G., 1989. A method to incorporate competitive position in the breeding goal. Anim. Prod., 48: 221-227.

Dijkhuizen, A.A., 1983. Economische aspecten van ziekten en ziektebestrijding bij melkvee (with English summary). PhD Thesis. Veterinaire Faculteit, Utrecht.

Dijkhuizen, A.A., Stelwagen, J. and Renkema, J.A., 1985. Economic aspects of reproductive failure in dairy cattle. I. Financial losses at farm level. Prev. Vet. Med., 2: 351-363.

Fewson, D., 1982. Influence of economic weights and population structure on selection response of milk and beef traits. In: G.J. More O'Ferrall (ed.), Beef production from different dairy breeds. M. Nijhof publishers, The Hague.

France, J. and Thornley, J.H.M., 1984. A quantitative approach to problems in agriculture and related sciences. Butterworths, London.

Gal, T., 1982. Betriebliche Entscheidungsprobleme, Sensitivitätsanalyse und Parameteriscshe Programierung. Walter de Gruyter, Berlin.

Gibson, J.P., 1989. Economic weights and index selection of milk production traits when multiple producton quotas apply. Anim. Prod., 49: 171-181.

Gibson, J.P. and Kennedy, B.W., 1990. The use of constrained selection indices in breeding for economic merit. Theor. Appl. Genet., 80: 801-805.

Groen, A.F., 1988. Derivation of economic values in cattle breeding. A model at farm level. Agric. Systems, 27: 195-213.

Groen, A.F., 1989a. Economic values in cattle breeding. I. Influence of production circumstances in situations without output limitations. Livest. Prod. Sci., 22: 1-16.

Groen, A.F., 1989b. Economic values in cattle breeding. II. Influence of production circumstances in situations with output limitations. Livest. Prod. Sci., 22: 17-30.

Groen, A.F., 1989c. Cattle Breeding goals and production circumstances. PhD Thesis, Departement of Animal Breeding, Wageningen Institute of Animal Sciences, Wageningen.

Groen, A.F., 1990. Influences of production circumstances on the economic revenue of cattle breeding programmes. Anim. Prod., 51: 469-480.

Groen, A.F., Brandts, A.G.B.M., Jansen, H.H. and Kanis, E., 1995. Economic value and genetic parameters for calving performance in Dutch dairy cattle breeding. Proceedings of the open session of the Interbull annual meeting , Prague. September 7-8, 1995.

Groen, A.F. and Korver, S., 1989. The economic value of feed intake capacity of dairy cows. Livest. Prod. Sci., 22: 269-281.

Groen, A.F., Meuwissen, T.H.E., Vollema, A.R. and Brascamp, E.W., 1994. A comparison of alternative index procedures for multiple generation selection on non-linear profit. Anim. Prod., 59: 1-9.

Groen, A.F. and Ruyter, T.P.L., 1990. Derivation of economic values of milk production traits: a literature review. Proceedings 4th World Congress on Genetics applied to Livestock Production, Edinburgh. XIV: 191-194.

Harris, D.L., 1970. Breeding for efficiency in livestock production: defining the economic objectives. J. Anim. Sci., 30: 860-865.

Harris, B.L. and Freeman, A.E., 1993. Economic weights for milk yield traits and herd life under various economic conditions and production quotas. J. Dairy Sci., 76: 868-879.

Harris, D.L. and Newman, S., 1994. Breeding for profit: synergism between genetic improvement and livestock production (a review). J. Anim. Sci., 72: 2178-2200.

Hazel, L.N., 1943. The genetic basis for constructing selection indexes. Genetics, 28: 476-490.

Horring, J., 1948. Methode van kostprijsberekening in de landbouw. Ten Kate, Emmen.

aspects of longevity in dairy cattle. Emp. J. Exp. Agric., 18: 49-56.

James, A.D. and Ellis, P.R., 1979. The evaluation of production and economic effects of disease. Proceedings 2nd International Symposium on Veterinary Epidemiology and Economics. Canberra, pp. 363-372.

Kempthorne, O. and Nordskog, A.W., 1959. Restricted selection indices. Biometrics, 15: 10-19.

Kennedy, B.W., Van der Werf, J.H.J. and Meuwissen, T.H.E., 1993. Genetic and statistical properties of residual feed intake. J. Anim. Sci., 71: 3239-3250.

McInerney, J., 1992. Economic aspects of diseases in poultry production. Proc. XIX World's Poultry Congress, Amsterdam. Vol. 2: 561-566.

Meijering, A., 1986. Dystocia in dairy cattle breeding. PhD Thesis, Department of Animal Breeding, Wageningen Agricultural University, Wageningen

Miller, R.H. and Pearson, R.E., 1979. Economic aspects of selection. Anim. Breed. Abstr. 47: 281-290.

Morris, C.A. and Wilton, J.W., 1977. The influence of body size on the economic efficiency of cows: a review. Anim. Breed. Abstr., 45: 139-153.

Niebel, E., 1986. Economic evaluation of breeding objectives for milk and beef production in temperate zones. Proc. 3rd World Congress on Genetics applied to Livestock Production. Lincoln, pp. 18-22.

Ollivier, L., Guéblez, R., Webb, A.J. and Van der Steen, H.A.M., 1990. Breeding goals for nationally and internationally operating pig breeding organisations. Proc. 4th World Congress on Genetics applied to Livestock Production, XV: 383-394. Edinburgh.

Orskov, E.R., Ojwang, I. and Reid, G.W., 1988. A study on consistency of differences between cows in rumen outflow rate of fibours particles and other substrates and consequences for digestibility and intake of roughages. Anim. Prod., 47: 45-51.

Reinsch, N., 1993. Berechnung wirtschaftlicher Gewichtungsfaktoren für sekundäre Leistungsmerkmale beim Fleckvieh. PhD Thesis, Institut für Tierwissenschaften, Technische Universität, München-Weihenstephan.

Rendel, J.M. and Robertson, A., 1950. Some

Rogers, G.W., Van Arendonk, J.A.M. and McDaniel, B.T., 1988. Influence of involuntary culling on optimum rates of annualised net revenue. J. Dairy Sci., 71: 3463-3469.involuntary culling

Schepers, J.A. and Dijkhuizen, A.A., 1991. The economics of mastitis and mastitis control in dairy cattle: a critical analysis of estimates published since 1970. Prev. Vet. Med., 10: 213-224.

Schlote, W., 1977. Choix et pondération économique des caractères en sélection animale. Ann. Génét. Sél. Anim., 9: 63-72.

Schultz, F.T., 1986. Formulation of breeding objectives for poultry meat production. Proceedings 3rd World Congress on Genetics applied to Livestock Production. Lincoln, pp. 215-227.

Smith, C., 1986. Variety of breeding stocks for the production-marketing range, and for flexibility and uncertainty. Proc. 3rd World Congress on Genetics applied to Livestock Production, Lincoln, pp. 14-20.

Smith, C., James, J.W. and Brascamp, E.W., 1986. On the derivation of economic weights in livestock production. Anim. Prod., 43: 545-551.

Stegink, J., 1994. De plaats van melkbaarheid in het fokprogramma: fokdoel, index en selectiestrategie (with English summary). MSc thesis Department of Animal Breeding, Wageningen Institute of Animal Sciences, Wageningen.

Steverink, M.H.A., Groen, A.F. and Berentsen, P.B.M., 1994. The influence of environmental policies for dairy farms on dairy cattle breeding goals. Livest. Prod. Sci., 40: 251-261.

Stonier, A.W. and Hague, D.C., 1964. A textbook of economic theory. Longmans, Green and Co Ltd., London.

Stott, A.W., 1994. The economic advantage of longevity in the dairy cow. J. Agric. Econ., 45: 113-123.

Strandberg, E., Groen, A.F. and J. Sölkner, 1996. General Introduction. Proceedings International Workshop on Genetic Improvement of Functional Traits in Cattle. Gembloux.

Tess, M.W., Bennett, G.L. and Dickerson, G.E., 1983. Simulation of genetic changes in life cycle efficiency of pork production. I. A bio-economic model. J. Anim. Sci., 56: 336-353.

Van Arendonk, J.A.M., 1985. Studies on the replacement policies in dairy cattle. II Optimum policy and influence of changes in production and prices. Livest. Prod. Sci., 14: 101-121

Van Arendonk, J.A.M., 1991. Use of profit equations to determine relative economic value of dairy cattle herd life and production from field data. J. Dairy Sci., 74: 1101-1107.

Van Arendonk, J.A.M. and Dijkhuizen, A.A., 1985. Studies on the replacement policies in dairy cattle. III. Influence of variation in reproduction and production. Livest. Prod. Sci., 13: 333-350.

Van Raden, P., 1988. Economic value of body size in Holsteins. J. Dairy Sci., 71 (Suppl. 1): 238 (abstract).

Visscher, P.M., Bowman, P.J. and Goddard, M.E., 1994. Breeding objectives for pasture based dairy production systems. Livest. Prod. Sci., 40: 123-137.

Weller J.I., Pasternak, H. and Groen, A.F., 1996. Selection indices for non-linear breeding objectives, selection for optima. Proceedings International Workshop on Genetic Improvement of Functional Traits in Cattle. Gembloux.

Willer, H., 1967. Technische Fortschritt und Landwirtschaft. Verlag Paul Parey, Hamburg.
Wilton, J.W., Evans, D.A. and Van Vleck, L.D., 1986. Selection indices for quadratic models of total merit. Biometrics, 24: 937-949.

Yamada, Y., 1995. Are economic selection indices always superior to a desired gains index? Theor. Appl. Genet., 91: 655-658.

Zeddies, J., 1985. Die wirtschafliche Bedeutung der Leistungsmerkmale beim Rind nach der Milchkontingentierung. Polykopie. Institut für landwirtschafliche Betriebslehre, Universität Hohenheim, Hohenheim-Stuttgart.

Zeddies, J., Waibel, H. and Zickgraf, W., 1981. Nutzen züchterischer Fortschritte in der Rindviehhaltung im strukturellen Wandel der Produktions- und Absatzbedingungen. Polykopie. Institut für landwirtschafliche Betriebslehre, Universität Hohenheim, Hohenheim-Stuttgart.