ACCOUNTING FOR BOTH INCOME AND EXPENSE IN THE DEVELOPMENT OF BREEDING OBJECTIVES

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SUMMARY

The consideration of sources of income and expense (to the commercial producer) in the design of breeding programmes is examined. The consequences of ignoring costs in the development of breeding objectives are illustrated by examples involving Merino sheep and beef cattle. Feed represents a major cost in livestock enterprises, and problems found in assigning a monetary value to variations in feed requirements due to genetic change are discussed. It is concluded that neglecting important costs in the development of breeding objectives can result in losses of selection efficiency, and in gross over-estimates of the economic worth of genetic improvement.

INTRODUCTION

Although there have been exceptions (e.g. Dickerson 1970, Harris 1970) geneticists have traditionally focussed their attention on the genetic improvement of output traits (such as fleece weight or growth rate), without due consideration to input traits (such as feed intake). This general attitude has been more marked in the extensive livestock industries (e.g. beef cattle and sheep) than in the intensive industries (e.g. pigs and poultry). Consequently, many simplified and optimistic predictions have been made of the economic benefits of genetic improvement, often based on the genetic change of a single trait. Also, performance recording schemes were developed around the recording and reporting of values of a single output trait (e.g. weaning weight of terminal sire sheep breeds), or a series of very closely related traits (e.g. various live weights in beef cattle).

Recently, attention has been increasingly turning towards the development of comprehensive breeding objectives, accounting for both income and expense of the livestock enterprise (James 1982, 1986, 1987; Jones 1982; Ponzoni 1986ab). As a result, there is now a greater awareness of the fact that the development of a breeding objective should include the specification of each item of income and expenditure of the livestock enterprise.

In this paper I describe an approach which I believe facilitates the incorporation of all sources of income and expense to the commercial producer into the development of the breeding objective. I illustrate the consequences of ignoring costs in practical cases, and discuss some issues pertaining to the methodology used and assumptions made when accounting for costs. Comments on the difficulties encountered in some instances (e.g. with resistance to disease) are also raised. The main point I shall try to make is that, although neglecting costs may reduce selection efficiency, perhaps the resulting gross over-estimate of the economic worth of genetic improvement is of greater importance.

THE BREEDING OBJECTIVE IN THE CONTEXT OF A BREEDING PROGRAMME

A breeding programme can be viewed as consisting of the following five steps: (i) definition of breeding objectives; (ii) choice of selection criteria; (iii) organisation of the performance recording service; (iv) presentation and use of information for making selection decisions; (v) use of selected animals. The definition of the breeding objective is a crucial step in a breeding programme. If the objective is poorly defined, or not defined at all, the implementation of an effective system of genetic evaluation could result in genetic change in an undesirable direction. The breeding objective can be defined as the combination of economically important traits of animals in the production system. Breeding objectives should account for inputs, such as feed costs, husbandry costs and marketing costs, as well as for outputs, such as income from sale of surplus offspring and cull-for-age animals. The breeding objective is thus what we want to improve.

Decisions about which traits should be included in the breeding objective should be based purely on economic grounds, and not on whether they are difficult or easy to measure or to change genetically. The traits in the breeding objective are the ends, whereas the characters used as selection criteria are the means used to achieve the ends. The choice of selection criteria will, of course, be influenced by which traits are in the breeding objective, but the reverse should be avoided since it can lead to the omission of economically important traits. Feed intake is an example of a trait that has often mistakenly been left out of the breeding objective of grazing ruminants because it is extremely difficult to measure. This constitutes a major omission since feed intake accounts for a high proportion of the production costs of a grazing enterprise.

DEVELOPMENT OF THE BREEDING OBJECTIVE

The development of the breeding objective can be described in terms of the following four phases: (i) specification of the breeding, production and marketing system; (ii) identification of sources of income and expense in commercial populations; (iii) determination of biological traits influencing income and expense; (iv) derivation of the economic value of each trait. Ponzoni (1986b) and Ponzoni and Newman (1988) developed breeding objectives for Merino sheep and beef cattle, respectively, using this approach. Note that phase (ii) involves precisely the identification of all sources of income and expense in commercial populations.

It may be of help to draw up a table (such as table 1) to ensure that no important items are left out, or to express income and expense in equation form (as Ponzoni (1986b) and Ponzoni and Newman (1988)). If care and rigour are exercised in the identification of sources of income and expense, then the task of determining the biological traits influencing them (phase (iii)) will be facilitated. This is important, since as James (1986) points out, deciding on the level of detail with which income and expense are expressed as a function of biological traits may not be immediately obvious.

In table 1 a distinction is made between fixed and variable costs. Generally, fixed costs are those that the producer incurs no matter what the level of production of the livestock, and include rates, interest, labour, buildings, installations and machinery depreciation and repairs, sundries (electricity, telephone, etc.) and producer's margin. By contrast, other expenses are assumed to vary with the level of production, and are thus called variable costs. The distinction, however, is not always clear-cut, and there are cases in which a cost may be classified as fixed or as variable, depending on the particular cicumstances (see examples in Chapter 7 of Barnard and Nix 1979). Smith et al. (1986) note that all costs are variable with a long term perspective, given the freedom to vary the scale of the enterprise. Fixed costs can be ignored when economic values are derived from the difference between income and expense, but not if they are derived from the ratio.

Table 1 Sources of income and expense in commercial livestock populations

		Source
Income	Sale of:	Fibre (wool, mohair, cashmere)
		Milk
		Surplus offspring
		Culled animals (because of age or other reasons)
Expense	"Variable" costs	Feed
		Husbandry
		Veterinary treatments
		Sire replacements or semen
		Fibre harvesting
		Milking
		Marketing of fibre, milk and animals
	"Fixed" costs:	Rates, interests, business costs, etc.

CONSEQUENCES OF IGNORING EXPENSES - EXAMPLES

Merino sheep

WOOLPLAN is the Australian scheme designed to meet the performance recording needs of ram breeders of the Merino and other wool sheep breeds. One of the features of WOOLPLAN is a formal definition of the breeding objective, specifying five traits and assigning an economic value to each one of them. In the derivation of economic values (Ponzoni 1988a) sources of income and expense are taken into consideration. Thus, in the calculation of the economic value of clean fleece weight, not only the price of wool is considered, but also the cost of wool harvesting and marketing. Similarly, the economic value of reproductive rate includes the estimated cost of feeding more offspring as well as the extra income.

Table 2 illustrates the consequences of ignoring all expenses accounted for in the WOOLPLAN economic values. When all costs were ignored the economic value (in absolute terms) of all traits increased, but the increase was greatest for reproductive rate and weight of cast-for-age ewes. The genetic gains were based on a selection index which included clean fleece weight, fibre diameter, one record of reproduction of the candidate's dam, and hogget liveweight. Ignoring costs increased the gains in reproduction and live weight traits at the expense of gains in clean fleece weight. When costs were not considered the value of total genetic gain in economic units was 27 percent greater than predicted by WOOLPLAN. However, the correlation between corresponding indices was close to one.

Beef cattle

Ponzoni and Newman (1988) defined a breeding objective for beef cattle. In the calculation of the economic value of each trait they accounted for husbandry and marketing costs, and they included feed intake of each class of cattle as separate traits in the breeding objective. Table 3 compares their (P & N) economic values with corresponding ones derived ignoring feed costs, and ignoring all costs. When feed costs were ignored only the economic values of calving day and of feed intake traits were affected, whereas when all costs were ignored all economic values were affected.

Ignoring feed costs and ignoring all costs virtually had the same effect on the genetic gain in each trait (achieved using an index and selection intensity defined by Ponzoni and Newman 1988). In broad terms, ignoring costs had the effect of approximately halving the gain in calving day, while doubling the magnitude of the change in all other traits, except for the maternal component of calf carcase weight, in which case the sign of the change was reversed. When costs were ignored the total value of genetic gain was approximately two and a half times greater than predicted by Ponzoni and Newman (1988).

Table 2 Merino sheep economic values, genetic gain per generation in each trait (achieved by a selection intensity of one on the index), total genetic gain in economic units expressed as a percentage of that in WOOLPLAN, and correlation between a WOOLPLAN index and one derived ignoring all costs

		Traits†				
		CFW (kg)	FD (micron)	RR	SW (kg)	MW (kg)
Economic values ($)	WOOLPLAN	49.67	- 9.12	84.29	0.72	0.11
	Ignoring costs	57.92	-10.14	176.08	0.93	0.32
Genetic gain	WOOLPLAN	0.117	- 0.45	0.011	0.65	0.55
	Ignoring costs	0.096	- 0.45	0.018	0.91	0.75
Total gain in economic units (%)	WOOLPLAN			100		
	Ignoring costs			127		
Correlation between indices				0.98		

† CFW = clean fleece weight; FD = fibre diameter; RR = reproductive rate (no. lambs weaned); SW = sale weight of offspring; MW = weight of cast-for-age ewes

The correlation between indices indicates the loss of efficiency from selecting, say, for an index derived ignoring costs, when the "correct" index is that for P & N. The loss of efficiency appears large enough to justify careful consideration of costs in the development of breeding objectives for beef cattle.

Comments and conclusions from the examples

In the examples presented above, ignoring the expenses associated with the livestock enterprise increased the magnitude of the economic value of all traits, except of course, feed intake. In sheep the genetic gain in reproductive rate and growth traits increased at the expense of gains in clean fleece weight. In beef cattle the genetic gain in growth traits increased at the expense of reproductive rate (calving day), while feed intake increased considerably (note that once feed costs were accounted for, consideration of other costs had a

Table 3 Beef cattle economic values, genetic gain per generation in each trait (achieved by a selection intensity of one on the index), total gain in economic units as a percentage of that in Ponzoni and Newman's (1988) (P & N) objective, and correlations among indices

		Traits in the breeding objective									
		Calving day (days)	Carcase weight (kg)				Fat depth (mm)		Feed intake (kg dry matter)		
			Calf-direct	Calf-maternal	Heifer	Cull cow	Calf	Heifer	Calf	Heifer	Cow
Economic values ($)	P & N	-1454.95	606.32	454.05	359.42	84.25	-1243.74	-1198.08	-9.82	-9.82	-17.10
	Ignore feed cost	-1711.19	606.32	454.05	359.42	84.25	-1243.74	-1198.08	0	0	0
	Ignore all costs	-1864.96	638.23	477.94	378.34	88.69	-1309.20	-1261.14	0	0	0
Genetic gain	P & N	- 1.5	1.9	- 0.1	2.5	3.2	0.1	0.1	17.0	22.0	92.0
	Ignore feed cost	- 0.8	3.8	0.5	4.9	6.3	0.3	0.2	35.0	45.0	160.0
	Ignore all costs	- 0.8	3.8	0.5	4.9	6.3	0.3	0.2	34.2	44.1	158.4
Total gain in economic units (%)	P & N					100					
	Ignore feed cost					246					
	Ignore all costs					261					

Correlations among indices	P & N	Ignore feed costs	Ignore all costs
P & N – Ignore feed costs	0.83		
P & N – Ignore all costs		0.84	
Ignore feed costs – Ignore all costs			1.0

negligible effect). The loss of efficiency of index selection was small in sheep but substantial in beef cattle. Nevertheless, none of these features is as perturbing as the gross over-estimate of the economic worth of genetic gains which may result from ignoring the expenses of the livestock enterprise.

ACCOUNTING FOR INCREASED FEED REQUIREMENTS ASSOCIATED WITH GREATER REPRODUCTIVE RATE AND LIVE WEIGHTS

In the examples presented in the previous section likely changes in feed requirements were accounted for in different ways. In the case of Merino sheep the WOOLPLAN economic values for reproductive rate, sale weight of offspring and weight of cast-for-age ewes are "adjusted" for likely changes in feed intake associated with genetic change in those traits. James (1982, 1986) has in several instances pointed out the limitations of this approach, noting that it is preferable to include feed intake as a separate trait in the breeding objective, and this was done in the beef cattle example.

One of the reasons why feed intake has not been included as a separate trait in the breeding objective is the paucity of information regarding genetic parameters, particularly among grazing ruminants. Note, however, that the assumptions involved in "guessing" genetic parameters for feed intake are not any stronger than those made when traits such as reproductive rate or growth rate are "adjusted" for likely increases in feed intake. Furthermore, the inclusion of feed intake as a separate trait in the breeding objective enables us to test the model for sensitivity to our assumptions, and to identify areas in which our knowledge is deficient.

Despite the advantages of considering feed intake as a separate trait in the breeding objective, in practice there may be instances in which "adjustments" for feed intake are made to other traits in order to keep the number of traits in the breeding objective low. This may be a relevant consideration in performance recording services, so that interpretation of the information by breeders is facilitated by limiting the number of traits for which estimated breeding values are presented. In such cases, it would be desirable to have an elaborate model of the breeding objective, with feed intake as a separate trait (or group of traits), against which simpler but less rigorous definitions of the breeding objective could be compared.

For instance, the WOOLPLAN breeding objective described in table 2 may be considered a simplification of a more detailed definition of the breeding objective given by Ponzoni (1986b), which includes ten traits in the breeding objective. Using identical commodity prices and production costs, Ponzoni (1988a) compared WOOLPLAN indices with those derived for Ponzoni's (1986b) breeding objective. The correlation between indices was 0.999, indicating that the simplifications made in the WOOLPLAN breeding objective do not result in serious losses of selection efficiency.

PROBLEMS IN ASSIGNING A MONETARY VALUE TO VARIATIONS IN FEED REQUIREMENTS DUE TO GENETIC CHANGE

In intensive industries (such as pigs or poultry) the feed is usually purchased and therefore the determination of feed costs is a relatively simple matter. There are still problems of recording feed intake (Kennedy 1984), but these pertain more to feed intake as a selection criterion than to feed intake as a trait in the breeding objective. Among grazing ruminants the determination of feed costs and thus of the economic value of feed intake and of other traits that influence feed requirements is not as straightforward. Two different approaches have been taken when attempting to assign an economic value to such traits, but neither of them is free of problems.

One of the approaches involves calculating the value of the feed required (e.g. Ponzoni 1986ab; Ponzoni and Newman 1988). With this approach the value of the feed has been calculated in at least three different ways: (i) the price of pasture hay minus the production cost of such hay (Saoud and Hohenboken 1984); (ii) assuming land and input values to achieve a certain pasture productivity level (Ponzoni 1986b), and (iii) based on agistment rates (Ponzoni 1986a). Agreement among the three procedures depends, of course, on the assumptions initially made, but these can be "forced" within realistic bounds so that reconciliation is achieved. A limitation of this approach is that it assumes that the extra feed could be produced (or accessed via agistment) if required, or that there would be savings if less feed were needed. Thus, it implies a change in the scale of the operation.

The other approach that has been used assumes that pasture is a fixed resource. Thus, changes in feed requirements per head have to be matched with changes in stock numbers if stocking pressure is to remain constant. This is the approach taken by Jones (1982) and Atkins (1987). The economic value of feed intake calculated in this way is independent of the cost of the feed itself if economic values are derived from the difference between income and expense (i.e. P = I - E), but that is not the case if economic values are derived from ratios (i.e. 0 = I/E or Q = E/I).

Both of the approaches described above assume that the feed available is already being utilised in an optimal manner, so that any extra requirements have to be met either by having access to more feed, or by reducing stock numbers. Although this assumption may often be unrealistic, Smith et al. (1986) point out that it would be unwise to base long-term goals on the inefficiencies of existing production systems.

I feel that the determination of the best way of assigning an economic value to feed intake and to other traits that influence feed requirements in grazing livestock is still an unresolved matter. To illustrate this point I present an example which shows that different approaches can lead to somewhat different results. Table 4 shows the economic values for the traits in a breeding objective for Merino sheep, and the genetic gain per generation achieved by a selection intensity equal to one on an index including clean fleece weight, fibre diameter, hogget live weight and one record of reproduction of the candidate's dam as selection criteria. The correlations among indices are also shown, including those with a WOOLPLAN index that has the same selection criteria as listed above. When the economic value of feed intake and reproductive rate was calculated assigning a value to the feed (i.e. 2, 4, or 8 cents (c) per kg of dry matter) the methodology used was as in Ponzoni (1986ab). The values of 2c, 4c and 8c per kg of dry matter correspond to those based on agistment rates (Ponzoni 1986a), on the price of pasture hay minus the cost of hay production (Ponzoni 1986b), and on the price of pasture hay itself, respectively. The situations assuming the feed costs are 2c and 4c correspond to the options 'Base' and 'Fx2' of Ponzoni (1986a), respectively. When the economic values were calculated assuming a fixed amount of pasture the economic values of feed intake and reproductive rate were calculated as the change in profit resulting from the necessary adjustment of sheep numbers and flock structure to keep stocking pressure (total feed intake) constant. In addition to the sources of income and expense listed by Ponzoni (1986ab) I took into account variations in ram replacement requirements due to changes in ewe numbers.

Note that improved reproductive rate is associated with greater intake not only because of greater feed requirements of more prolific sheep (which is accounted for later by the correlations between intake and reproduction) but also because it results in a greater number of progeny to be reared.

Table 4 shows that the price assigned to the feed had a large effect on the economic values of reproduction and feed intake. The genetic gain in all traits was affected, changing in some cases not only in magnitude, but also in sign. The correlation between indices corresponding to the extreme values (2c and 8c) was low indeed.

Assuming that the total amount of pasture is fixed resulted in economic values for feed intake virtually identical to those corresponding to a feed cost of 4c, but the economic value of reproductive rate was nearly half. Despite the latter disagreement the genetic gains resulting from the two situations were remarkably similar, and the correlation between corresponding indices was almost equal to one.

Table 4 Merino sheep economic values, genetic gain per generation in each trait (achieved by a selection intensity of one on the index), and correlations among indices derived accounting for feed costs in different ways

	Basis of calculation	Traits in the breeding objective									
		Clean fleece weight(kg)			Fibre diameter (micron)		No. lambs weaned	Live weight (kg)		Feed intake (kg dry matter)	
		Lamb	Hogget	Ewe	Hogget	Ewe		Hogget	Ewe	Offspring	Ewe
Economic values ($)	Feed cost 2c/kg DM	2800.2	3238.2	4370.0	-518.7	-700.0	21266.5	210.1	73.5	-14.8	-20.0
	Feed cost 4c/kg DM	2800.2	3238.2	4370.0	-518.7	-700.0	12666.5	210.1	73.5	-29.6	-40.0
	Feed cost 8c/kg DM	2800.2	3238.2	4370.0	-518.7	-700.0	- 4533.4	210.1	73.5	-59.3	-80.0
	Fixed amount of feed	2800.2	3238.2	4370.0	-518.7	-700.0	6827.6	210.1	73.5	-29.2	-39.5
Genetic gain	Feed cost 2c/kg DM	0.018	0.119	0.103	-0.50	-0.40	0.017	0.83	0.75	8.6	8.4
	Feed cost 4c/kg DM	0.018	0.117	0.102	-0.63	-0.50	0	0.02	0.03	1.5	1.7
	Feed cost 8c/kg DM	0.008	0.046	0.042	-0.50	-0.39	-0.027	-1.31	-1.15	-10.9	-10.2
	Fixed amount of feed	0.019	0.117	0.103	-0.62	-0.49	-0.005	-0.17	-0.13	- 0.11	0.05

Correlations among indices

	Feed cost 4c	Feed cost 8c	Fixed amount of feed	WOOLPLAN
Feed cost 2c	0.88	0.18	0.81	0.98
Feed cost 4c		0.63	0.99	0.93
Feed cost 8c			0.72	0.33
Fixed amount of feed				0.88

The correlations between the appropriate WOOLPLAN index and those for the situations studied are presented as a reference in table 4. These were generally high, except when the feed cost was equal to 8c.

In view of these somewhat conflicting results, what should one do in practice? My preference would be for defining breeding objectives for the kind of production system for which the genetic improvement programme is intended. For example, if it is appropriate to assume that the total amount of feed available is fixed, then calculate the economic values accordingly. By contrast, if production or access to extra feed is feasible in the foreseeable future, then an appropriate value can be assigned to each unit of extra feed required. The consequences of using alternative approaches can be assessed as done in table 4, which shows that there is not much choice between the second (feed cost = 4c) and fourth (fixed amount of feed) options, whereas the first and third are very different from each other.

CONCLUDING REMARKS

Preceded by a brief description of a sequential approach which may assist in the identification of sources of income and expense in a livestock enterprise, I presented a rather partial coverage of a very broad area, leaving out of the discussion several important issues. For example, I did not address the problem of how (difference or ratio) income and expense are to be combined, since this topic has been thoroughly examined theoretically by Smith et al. (1986), and Ponzoni (1988b) conducted a case study with Merino sheep.

I concentrated largely on feed costs, but there are other costs, such as those related to prevention and treatment of disease, which could be reduced by selection. However, it has been pointed out (Piper 1987; Raadsma 1987) that the formal incorporation of disease resistance into the breeding objective is a very difficult task.

Feed costs constitute a major source of expenditure in livestock enterprises. Current procedures of accounting for feed costs in breeding objectives are far from perfect. Nevertheless, their use as a standard practice will lead to refinements and should be encouraged. Neglecting important costs can result in losses of selection efficiency, and, more importantly, in gross over-estimates of the economic worth of genetic improvement.

Note that here I have referred to production costs in the context of within breed programmes of genetic improvement. However, the consideration of production costs also should be an integral part of the examination of the benefits of crossbreeding, or of any other activity aimed at engineering "superior" livestock.

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