Veterinary Epidemiology: Principles and Methods

Part 3: Animal Health Economics
Chapter 9: Animal Health Economics

CHAPTER 9

Animal Health Economics

The nature of the veterinary service provided to animal production, whether at the national or individual herd level, characteristically evolves with the stage of development of the community served. Thus, in the early part of this century, major emphasis was placed on the control of diseases that decimated animal populations over large geographic areas. Decisions on whether to control these diseases could usually be made without the aid of formal economic appraisal, because generally the losses greatly exceeded control costs. As epidemic diseases of this latter type were brought under control, emphasis increasingly shifted to the individual property and to the treatment of endemic, clinically-recognizable disease. While this latter approach met with a great deal of success, it suffered because it depended on the initial recognition of an abnormality by the farmer and was too heavily dependent on qualitative and subjective assessment.

In recent years a number of trends (including an increase in the scale of operation, intensification of resource utilization, and the substitution of labor with other usually capital-intensive resources) have typified animal production, particularly in those areas where intensive agricultural methods are practiced. These trends have resulted in those diseases or disease complexes that manifest themselves primarily through a decrease in productive efficiency and that in most cases are endemic becoming the most significant with respect to decreasing farm incomes (Morris 1975). These disease conditions often have a complex multifactor etiology that is intimately related to the production system. Also, since various intensities of control are often possible, it is necessary to determine the level of control that is economically optimal. In this regard, the feature of disease control that makes it such a valuable investment is that it generally increases the efficiency of the production process, and hence it is unlike most other goods and services the farmer may use that generally increase output without changing the nature of the process. This is one of the reasons why returns on funds invested in disease control are usually very high.

In a rapidly changing environment, decisions regarding animal health activities can rarely be made solely on biologic grounds. Rather, a dynamic integrated approach combining epidemiologic and economic analyses is required to determine the nature and scope of the health problem and the implications of intervention. As will be seen later, this is because economic appraisal is highly dependent upon the underlying technical appraisal. In general, economic analysis should be regarded as a tool providing additional information on which to base a decision, rather than a definitive method on which to base the final policy decision.

At the herd level, veterinarians are becoming increasingly aware that they work for farmers whose financial welfare is their interest. They are also realizing that whether their animals have a particular health problem (or have it at a particular level) is largely immaterial, unless it is economically advantageous to do something about it. Exceptions would include zoonotic diseases or the control of disease for humane reasons, where the intensity of control may be greater than that which would be economically optimal. Thus, the choice between the available control techniques is a function of their economic and biologic efficiency. Also, because farmers' participation is usually voluntary, they must be convinced that it is profitable to change their current management practices.

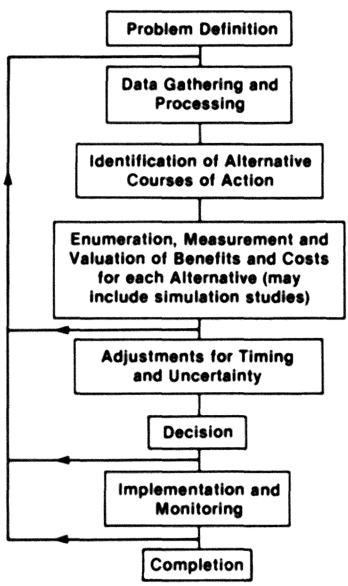
The above principles also apply at levels of organization beyond the farm, and most governments or agencies involved with disease control require that an economic analysis be completed so a rational choice can be made among alternatives competing for the same limited resources.

9.1 Value of Economic Analysis

The majority of the early reports utilizing economic techniques concerned themselves primarily with estimating the cost of a particular disease to an individual producer or a nation. However, this approach is undesirable because it incorrectly suggests that this amount of money is completely recoverable. In recent years the emphasis has moved to an evaluation of the economic benefits of control procedures. Not only is this approach more in accord with economic theory, but it also places a more positive orientation on the information by drawing attention to the benefits of action rather than the costs of inaction (Morris and Meek 1980).

The principal purpose of economic analysis is to aid decision making regarding limited resource allocation. Hence, it provides a basis for making rational choices from among alternative preventive or control actions under various circumstances. Monetary values are used only as a common denominator for the value of particular resources in society. Economists are aware of the limitations of this approach to valuation and have searched for a measure of satisfaction provided by a particular resource. The term "utility" is frequently used as a measure of this. A complete analysis should also indicate the confidence one can have in the monetary and/or utility ranking of the various strategies.

The objective of this chapter is to introduce some of the common methods that are used for the economic assessment of animal health activities and to place these in the context of the decision-making process, a schematic representation of which is presented in Figure 9.1. The first step in solving any disease control problem is to clearly define it and the criteria or goal(s) that will be used to choose between alternative control measures (including no action). One such criterion is economic efficiency. This implies that choices in health care should be made to result in the greatest average return or benefit from the resources available. At the farm level it is frequently assumed that this point is where profit is maximized; however, many other factors (such as risk aversion) may contribute to the final decision. The next steps in the decision-making process are data gathering and processing and the identification of alternative courses of action. To reach a decision as to which alternative to pursue, it is necessary to enumerate, measure, and value the benefits and costs for each alternative and to com-



9.1. Schematic representation of decision-making process including economic appraisal.

pare these. As indicated in Figure 9.1, this may include simulation or optimization studies (see Chapter 8). At this stage it may be necessary to consider and account for uncertainty in the results and the timing of cash flow. The economic evaluation can then be completed using the appropriate technique, the results integrated with other pertinent data, and a decision made. The chosen alternative may then be implemented and monitored. The latter phase may again involve computer simulation studies.

The actual method of economic appraisal used in any given situation will depend upon a number of factors such as the type of health problem under consideration and the scope of the control program. A number of the common techniques are outlined in the remainder of this chapter.

9.2 Partial Farm Budgeting

In economic analyses, one must consider how variation in input to the animal production process influences the quantity and quality of output. If the intensity of control can be raised over a continuous spectrum so that a mathematical equation can be used to represent the data, this can be interpreted as a production function and the optimum level of control determined. It can be shown with the aid of such a production function that farmers should continue to increase inputs until reaching the point where marginal (additional unit) costs (i.e., expenses) equal marginal (additional unit) benefits (i.e., revenues). However, in health related matters, sufficient information is rarely available to produce a full production function and hence calculate values from it. Because of these difficulties, partial farm budget analysis may be used as it does not presuppose the estimation of a continuous function. It only requires the knowledge of two or more combinations of factors and their discrete input-output relationships.

While the partial farm budget technique can be applied to a number of different situations, a common application is to assess programs aimed at disease problems that can be assumed to occur on a farm with a high degree of certainty (e.g., bovine mastitis and internal parasitism) (Morris 1969).

The technique only considers those components of enterprise income and costs that are likely to be influenced by the proposed disease control procedure. In general, fixed costs (e.g., taxes) are largely ignored. The technique therefore differs from whole farm budgeting in that the latter is usually reserved for the assessment of a change that will affect the total farm operation (such as the purchase of additional property) whereas the former is usually reserved for assessment of small changes that do not affect total farm management.

A partial farm budget describes the economic consequences of a change in farm procedure. To achieve this, the budget items are categorized as: (1) additional monetary returns received due to adoption of the proposed control procedure (e.g., increased yield of product at possibly higher prices); (2) foregone returns (e.g., reduced numbers of culled animals); (3) additional costs incurred due to the control procedure (e.g., expenditure for drugs and management procedures); (4) costs no longer incurred if the program is implemented (e.g., salvage treatment procedures).

The change in net return is then calculated by summing the returns and costs, calculated under headings 1 and 4 above and subtracting from that the amounts calculated under headings 2 and 3. This net return is an estimate of the additional profit that will accrue to the producer as a result of adopting the disease control procedure and is usually expressed in terms of some basic unit (e.g., per hectare).

The virtue of this procedure is that it permits a realistic appraisal to be made of the consequences of various actions without necessitating the keeping of complete financial records for the farm. One of the inherent difficulties with the technique is that arbitrary decisions must be made about which items to include. The simplest solution is to include any item that may be affected, since if there is no effect it will not influence the outcome. Caution must be taken not to "double count"; that is, measure and include the same effect in two ways. Another limitation is that it allows comparisons to be made between the strategies tested but does not necessarily provide optimum solutions. When possible, it is also advisable to determine how sensitive the conclusions from the analysis are to changes in product price and biological response. (The subject of sensitivity analysis will be discussed later in this chapter, 9.4.)

An example of partial farm budgeting is presented in Table 9.1. The field trial from which these data were taken was designed to assess the economic benefits from two schemes, namely, traditional and critical strategies for helminth control in weaned lambs (Anderson et al. 1976). The traditional scheme was based on a survey of local control procedures, whereas the critical scheme was based on strategic treatments applied in the late spring and early summer period and was based on an objective appraisal. The latter schemes were also compared to no strategic treatment and bi-weekly drenching. The same information presented in the form of a partial budget and comparing the critical to the no strategic treatment schemes only would appear as:

1. Additional Returns	
Additional fleece wool shorn ($227 − $187) (see Table 9.1)	$40
Capital value of additional sheep surviving to March 1, 1971 ($263 − $222)	$41
Increased value of crutchings ($13 − $11)	$ 2
	$83

2. Foregone Returns	
Difference in wool value from sheep which died ($5 − $5)	$ 0
3. Additional Costs Incurred	
Extra anthelmintic and labor ($19 − $6)	$13
4. Costs No Longer Incurred	
Nil	$ 0
Net return ($83 + $0) − ($0 + $13)	$70

In examining data such as that presented in Table 9.1 a question arises as to whether net return or percentage return on marginal invested funds most accurately reflects the most profitable option. In general, if the farmer has unlimited funds available, the scheme with the highest net return is the most profitable and should be adopted (the critical scheme in Table 9.1). If funds are limited, those available should be progressively invested in uses that yield the highest marginal return (Morris 1969). Here, the percentage return on invested funds gives an imprecise assessment of marginal returns; however, it does facilitate comparisons between the investment alternatives. In the example cited, the critical scheme is the option of choice regardless of the availability of funds. Very often this is not the case.

Examination of the actual experimental results, from which these data were derived, revealed the factor that produced the main financial difference between the control strategies was the variation in mortality rate. The group of sheep receiving no strategic treatments suffered a 26% mor-

Table 9.1. A comparison of the returns from various control strategies for ovine helminthiasis (values adjusted to a flock of 100 sheep)

	Strategy			
Item	(1) No strategic treatment	(2) Traditional scheme	(3) Critical scheme	(4) Biweekly drenching
Fleece wool shorn February 1971 ($)	187	199	227	268
Wool from dead sheep ($)	5	4	5	1
Crutched wool ($)	11	13	13	13
Capital value of surviving sheep 1 March 1971 ($)	222	233	263	342
Gross return ($)	425	449	508	625
Cost of labor and anthelmintic ($)	6	18	19	170
Marginal cost over strategy 1 ($)	. . .	12	13	164
Strategy net return ($)	419	432	489	455
Marginal return over strategy 1 ($)	. . .	13	70	36
Percentage return[a] on marginal invested funds	. . .	108	538	22

Source: Anderson et al. 1976, with permission.

[a]Calculated as marginal return divided by marginal cost and expressed as a percentage (e.g., 13/12 × 100 = 108%).

tality rate compared to 12% in the critical scheme group. The mortality rate in the no treatment group would need to be as low as 13% before the benefit from adopting the critical scheme would be reduced to zero (i.e., the break-even point). The individual farmers could assess how plausible this would be under their own particular situations when making their final decisions.

9.3 Gross Margins Analysis

In attempting to determine whether a farmer has benefited or will benefit from an improvement in herd health, the analysis may be carried out by means of a partial farm budget, particularly if only one health problem is under consideration, or by assessing the change in some economic index of performance with time. One such index is the gross margin, usually expressed relative to some unit of production (e.g., gross margin per cow, per hectare, or per person). Gross margin analysis is the most practical method for assessing enterprise profitability, and it is widely used in farm management economics. It can also be used for comparing the profitability of different enterprises on a farm and for estimating the effect of changes within the limits of fixed assets and other resources available to the farmer (Ellis and James 1979b). With regard to animal health activities, gross margin analysis perhaps finds its greatest application in assessing the effectiveness of integrated health management programs. The general format for calculating the gross margin of an animal related activity is presented in Table 9.2.

Table 9.2. General format for calculating the gross margin of a food animal activity

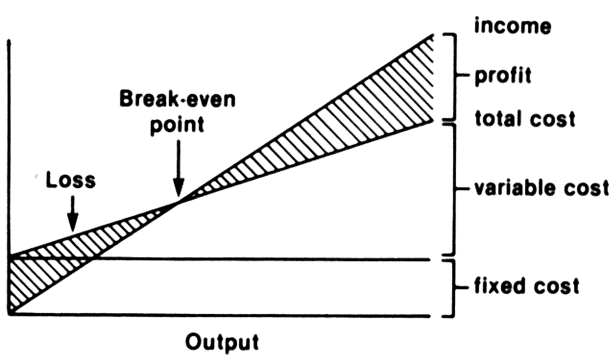
Stock inventory value beginning of year	+	cost of animals bought	+	cost of: feed husbandry marketing breeding and replacements (where not raised on farm) health care, etc.	=	total of beginning value and all costs
(1)	+	(2)	+	(3)	=	(4)
Value of stock at end of year	+	sales of animals and animal products	+	sale of by-products	=	total of end of year value and all sales
(5)	+	(6)	+	(7)	=	(8)

Total of (8) minus total of (4) = gross margin

In gross margin analysis, all actual income from the enterprise in question is totaled, and all variable costs directly attributable to operating that enterprise are subtracted. The resultant figure is known as the "enterprise gross margin" or "profit before fixed costs". Variable costs, as the name implies, vary as the size and/or level of an activity varies. If cattle numbers are doubled, variable costs such as feed, husbandry, and marketing costs will also increase. (Purchases of animals can be either a variable or capital cost. Annual purchase of stock to maintain a flock or herd at a constant level is a variable cost, but purchase of stock to increase the permanent numbers is treated as a capital investment.)

As well as being directly associated with the level of intensity of each activity, many variable input costs determine the yield or level of output of the activity. With crops, the amount and kind of fertilizer, seed, or sprays influence crop yield. Similarly, with animal activities, the level and type of feed, drenches, and vaccines used may have a major effect on animal production. Very little output would occur on farms unless money was spent on variable cost items. Fixed costs in the short run are incurred regardless of the level of output and include such things as taxes, insurance, and depreciation. Figure 9.2 illustrates in simplified linear form the relationship between fixed and variable costs and income.

Identifying the variable costs of an activity gives the farmer an idea of the size of the change in costs that would occur if one or more activities expands or contracts. For example, if the farmer decides to decrease the area of oats and increase the area of wheat, the variable costs will change, but the fixed costs are likely to remain about the same. Knowing the likely variable costs and gross income, the farm operator is in a position to assess the merit of making a change in activities. Operating profit can be calculated by subtracting fixed costs from the total gross margin.



9.2. Hypothetical example relating fixed and variable costs to income.

Gross margin analysis was used to assess the results of a 4-year controlled study designed to investigate the impact of a dairy herd health and management program on dairy farms (Williamson 1980). The analysis involved 59 program farms and 47 surveillance farms. The gross margin consisted of three main parts: a livestock inventory, a section for dairy enterprise income (milk sales, livestock sales, and the value of milk or livestock transferred to other enterprises), and a cost section including supplementary feeds, livestock purchases, artificial insemination, and veterinary costs. Other benefits or costs directly attributable to the study were also included for the program group of herds. On a mean whole-farm basis, the program resulted in an improvement (as measured by gross margin) of $23.58, $65.56, and $90.30 per hectare respectively, in the second, third, and fourth year when compared to year one.

As previously mentioned, partial farm budgeting and gross margin analysis find their principal application in the assessment of control procedures for endemic diseases (such as bovine mastitis) and integrated health management programs. Difficulties arise when consideration is given to sporadic diseases (such as hypomagnesemia or enterotoxemia). Diseases of this latter type must be viewed for planning purposes as not certain to occur within the immediate planning period; there is a strong chance or risk component. One technique that can be applied to decision making about disease control under such conditions of risk is the payoff table.

9.4 Payoff Table

The use of the payoff table entails the calculation of the payoff (returns minus costs) for each of the strategies under consideration, given that an outbreak of the disease does or does not occur. An expected monetary value for each strategy is then calculated by multiplying each payoff by its probability, and summing these values over all possible outcomes for that strategy. The general form of the payoff table is presented in Table 9.3. The assigned probability of disease occurrence is best based on objective data, but subjective estimates frequently must be used. The usual decision criterion is to choose the strategy with the highest expected monetary value.

Table 9.3. General format for a payoff table

Possible outcomes	Probability of occurrence	Economic result of alternative strategies 1	2
Disease occurs	X	a	b
Disease does not occur	Y	c	d
Expected monetary value (strategy 1) = $(a \times X) + (c \times Y)$			
(strategy 2) = $(b \times X) + (d \times Y)$			

However, veterinarians should remember that not withstanding the above calculations, the final decision on what strategy to implement rests with the farmer, because the decision is made under risk of financial loss if incorrect (Morris 1969).

A practical example of the use of the technique for decision making regarding control strategies for thromboembolic meningoencephalitis (TEME) is shown in Table 9.4 (Davidson et al. 1981). The calculations are based on a feedlot situation where: the price of cattle is $1.32/kg; average weight of cattle is 300 kg; number of cattle per pen is 350; number of pens per year is 67; and the probability of a pen becoming infected with TEME is 15%. The alternatives investigated were: (1) no action, assumed to result in a 3% mortality rate if TEME occurred; (2) vaccination of all cattle, assumed to give perfect protection at a cost of $2 per head; and (3) mass treatment of all cattle at a cost of $114 per pen if a case occurs. In the last case an overall mortality rate of 1% is assumed. The dollar values presented in Table 9.4 are gross returns under each circumstance minus any vaccine or treatment costs. In this case and given the above assumptions, strategy 3 resulted in the highest expected monetary value and hence would be the option of choice.

The same data can be presented in the form of a decision tree (Fig. 9.3) in which choices (decision nodes) are represented by squares, probability events by circles, and outcomes are given at the right of the tree. Tree diagrams can become much more complex in nature as other dimensions (such as time) are added to the problem. Another example of the use of decision analysis relates to the treatment of ovarian cysts in dairy cattle (White and Erb 1980).

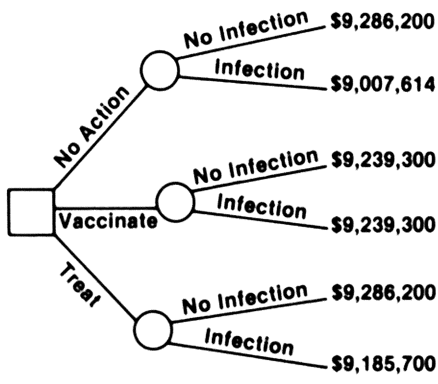
The importance of uncertainty as a factor influencing decisions about disease control has been underestimated. The environment in which practi-

Table 9.4. Payoff table for various action-outcome combinations for thromboembolic meningoencephalitis (TEME)[a]

Possible states	Probability of TEME	(1) No action ($)	(2) Vaccinate all cattle ($)	(3) Treat after first case of TEME ($)
		TEME control alternatives		
No infection	.85	9,286,200	9,239,300	9,286,200
TEME infection	.15	9,007,614	9,239,300	9,185,700

EMV[b] (1) = (0.85)(9,286,200) + (0.15)(9,007,614) = $9,244,412.10
EMV (2) = (0.85)(9,239,300) + (0.15)(9,239,300) = $9,239,300.00
EMV (3) = (0.85)(9,286,200) + (0.15)(9,185,700) = $9,271,125.00

Source: Modified from Davidson et al. 1981, with permission.
[a]See text for explanation and derivation of financial returns.
[b]Expected monetary value.



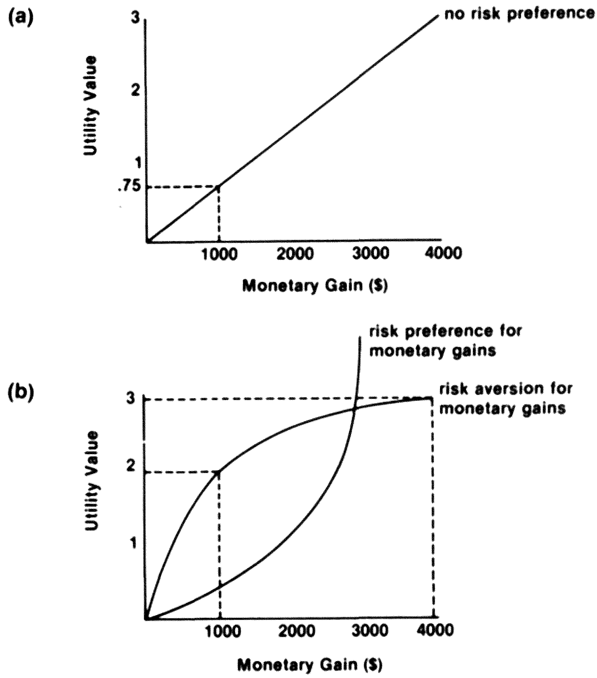
9.3. Decision tree representation of data presented in Table 9.4.

cal decisions are made is usually uncertain and involves complex relationships among many factors. In fact, farmers usually tend not to invest large sums of money purely on the basis of expected return when they are uncertain of the outcome (Anderson 1976).

There are a number of methods for dealing with uncertainty, one of which is to conduct a sensitivity analysis. In such an analysis, the sensitivity of the outcome to variation over the likely range of the items used in the calculations (e.g., costs, prices, probabilities, etc.) is assessed. The decision maker can then integrate these outcomes with one's own personal aversion to risk and subjective assessment of the likelihood of various combinations (such as extremes of price or mortality) in making a final decision.

Another dimension that can be used when making decisions under uncertainty is the concept of utility. If the decision maker has no risk preference (indifferent to risk), the expected monetary value approach and the expected utility approach are the same. (Fig. 9.4a.) However, if the decision maker has preference or aversion to risk as illustrated in Figure 9.4b, maximization of expected utility may be the appropriate approach. The approach is based on the fact that monetary amounts may not provide a measure of the relative value a person attaches to different sized gains or losses. The risk-aversion curve illustrated in Figure 9.4b implies that its owner values an extra $1000 at two-thirds the value of an extra $4000; whereas the individual with no risk preference (Fig. 9.4a) values a $4000 gain at 4 times a $1000 gain. The latter case is not characteristic of many people, especially when large sums of money (gains or losses) are involved.

As an example, suppose one has a choice between two costless alternatives: (1) tossing a fair coin for $100,000 if a head appears or $0 if a tail appears; or (2) a certain gift of $50,000. Which alternative would you



9.4. Example of utility curves for monetary gains.

choose? (Note that both have the same expected monetary value of $50,000.) Most people would accept the sure alternative; the value they attach to the 50% chance of $100,000 is more than offset by the 50% chance of receiving $0. People differ in their utility because of things such as their past experience or psychological makeup. As circumstances change over time (e.g., if a person becomes rich playing the stock market) the shape of their utility curve may also change.

In the expected utility approach, utility values are derived from the utility function. The latter values are then multiplied by the probability values to calculate the expected utility value, as opposed to the expected monetary value.

The same approach can be used without the consideration of economic values. In this approach the decision maker assigns a subjective assessment to the value of each possible outcome—for example, death (0), spontaneous resolution (100), and various other outcomes (e.g., surgery with serious complications, scaled appropriately between these extremes).

9.5 Benefit-Cost Analysis

If a control program involves substantial initial investment and the benefits gradually accumulate subsequently, it is necessary to weight annual costs and benefits by a factor making immediate costs and benefits more valuable than those occurring in the future. Benefit-cost analysis is a technique directly applicable to long-term investment in disease control and finds its principal application in the assessment of public disease-control programs, where a government or other agency will contribute to a large-scale program. In deciding whether to initiate a large scale animal disease-control program, governments or leaders must consider whether society as a whole will benefit from the action, whether transfers of financial or nonfinancial benefit between sections of the community may result, whether the project should receive priority over other projects, and how heavily economic and social achievements of the project should be weighted. An analysis of this type is termed benefit-cost analysis when measurable economic costs and benefits are considered and may include a tabulation of nonfinancial consequences as well. A related technique, cost-effectiveness analysis (9.5.4), is appropriate when only costs are being considered.

Once the alternative control strategies have been identified, there is a natural sequence to be followed so a decision can be made. For each alternative the steps include: the enumeration, measurement, and valuation of the benefits and costs for each time period; adjustment of these values to account for the effect of different cash flow patterns over time; and evaluation and strategy comparison.

9.5.1 Assessing Benefits and Costs

Benefit-cost analysis rests on the premise that a policy should only be implemented if the discounted benefits outweigh the discounted costs. To assess this, the benefits and costs over time must be identified and expressed in monetary terms.

In essence, benefit-cost analysis is a form of forward budgeting that includes methods of adjusting cash flow. Most of the benefits and costs of a program are received or incurred within its own budgets, whereas some benefits that may affect others are known as externalities. The former need to be included in all analyses, whereas the inclusion of externalities will depend to a great extent on the scope of the project (James and Ellis 1980).

In general, the costs of a particular program are related to the resources consumed. Once these physical resources have been determined, it is usually not difficult to assign a monetary value to them. Such costs generally include manpower and operating costs plus resources used by the program (such as vaccines).

To assess the benefits of a control program, it is necessary to know the effect of the disease in the absence of control, and to estimate the likely consequences of the program on these. In this way, many of the benefits are the result of the avoidance of losses; that is, the difference between the losses experienced under "no control" or under the current program and each of the alternatives being investigated. For example, many of the benefits of a foot-and-mouth disease (FMD) control program accrued from the avoidance of production losses such as mortality, the indirect and direct effects of FMD on meat and milk production, the losses associated with lameness in draught animals, and from restrictions on international trade (James and Ellis 1978). An alternative approach to estimating benefits is to determine how much less of each of the various production input resources would be used, as a result of implementing a program, to produce the existing volume of animal product.

In practice, the benefits of animal disease-control programs fall into three categories, the relative significance of each depending on the disease under consideration.

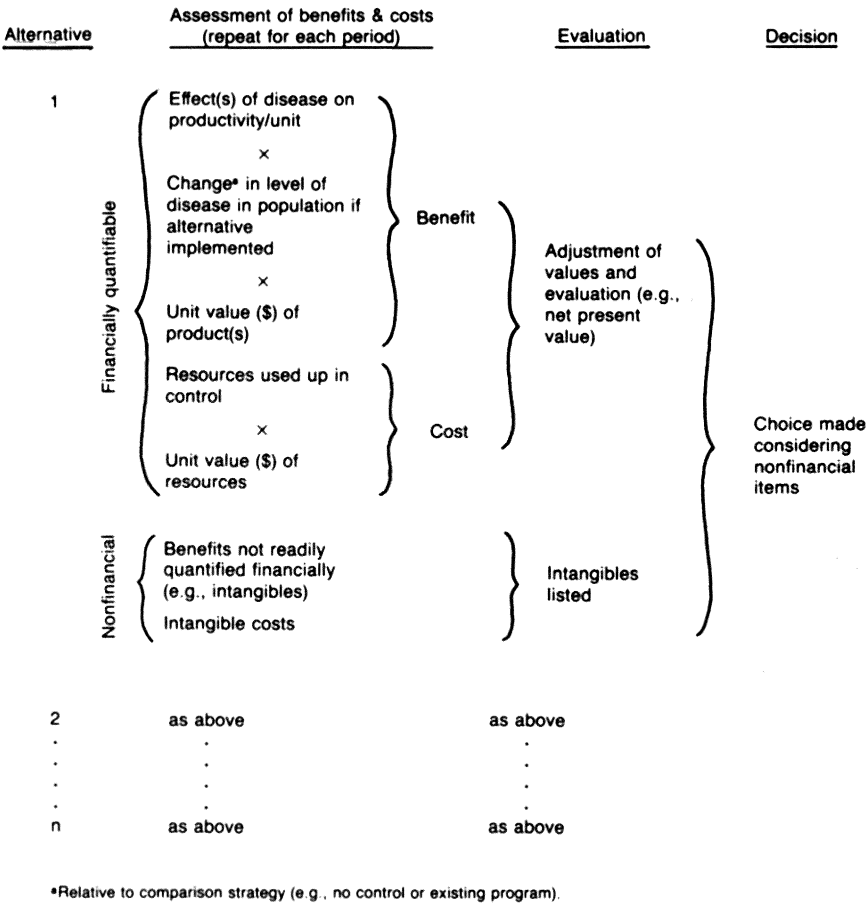
1. Readily quantifiable economic benefits (e.g., increased live births and milk production resulting from bovine brucellosis control).

2. Economic benefits that exist but are not so readily quantifiable in financial terms, either because market values are not clear or are not susceptible to accurate calculation, or because the biological consequences of a control program are uncertain (e.g., the effects of brucellosis eradication on the export price of beef).

3. Benefits not suitable for any form of economic evaluation, such as the psychological benefit to farmers and others that results from the removal of the fear of contracting brucellosis. Benefits of this sort would be included under intangibles.

A scheme depicting the conceptual approach used to calculate the estimated benefits and costs in each year of a planned project is presented in Figure 9.5. The benefits are the difference between the losses under the proposed new control strategy versus "no control" or the current program, where losses within each control option are a function of the level of disease in the population, the effect of disease on each productive unit (e.g., kg of milk production lost/cow affected), and the value of the product (e.g., the price of milk/kg).

While Figure 9.5 presents the basic approach, it is an oversimplification in that it implies that the economic benefits might be calculated based on current market prices (i.e., the existing price prior to implementation of the control program). This situation may suffice at the individual farm



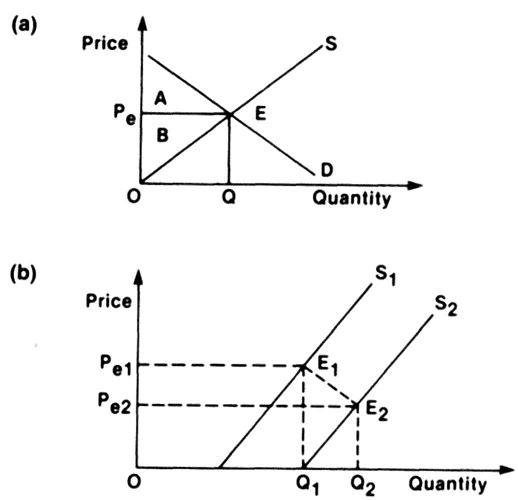
9.5. Schematic representation of conceptual approach to benefit/cost analysis.

level, but at the aggregate social level a number of complexities are introduced.

One of these complexities relates to the fact that the consumer is not likely to buy more product at current market prices simply because it is available unless demand is perfectly elastic. (Elasticity of demand is the slope of the demand curve and is defined as the percent change in quantity divided by the percent change in price. In the case of perfect elasticity the slope will be zero.) Usually, given that the demand curve is inelastic, consumers will demand a drop in price if they are to purchase the increased quantity available. If the elasticity of demand for swine was −0.5 at the farm level, a 1% increase in the quantity of swine produced would result in a 2% decline in prices.

The above discussion raises the concept of consumer and producer surplus. Consumer surplus represents the area of benefits under the demand curve that consumers receive in addition to what they pay through the market. Producer surplus represents the value that producers receive over and above their costs of supply. At the equilibrium price P_e (Fig. 9.6a) consumers and producers exchange the quantity Q for the total cost represented by the area OP_eEQ. However, consumers gain all the benefits under the demand curve up to E, thereby receiving the surplus represented by A. Producer costs are represented by the area under the supply curve up to E and therefore they receive a surplus of area B.

The consumer/producer surplus approach measures benefits as gains (or losses) in the sum of these two economic surpluses created by shifts in the supply curve under the assumption that society is indifferent to any resulting redistribution of income. Such shifts are generally the result of technological advances resulting from research and improved supporting services (e.g., veterinary care). For present purposes and by way of example, assume that the supply curve has been shifted due to a technological advance that allows the implementation of a new disease control program. By shifting the supply curve to the right, consumer surpluses are usually



9.6. Consumer and producer surpluses. A = consumer surplus; B = producer surplus; S = supply; D = demand; P = price; Q = quantity; E = equilibrium.

increased whereas producer surpluses may or may not be depending on the elasticity of supply and demand. Figure 9.6b illustrates the impact of a shift in supply from S_1 to S_2 on consumer surplus and, for the sake of simplicity, assumes no change in producer surplus. In this example and as a result of the disease control program, the quantity of product available to be sold has increased from Q_1 to Q_2, and a new equilibrium between supply and demand is achieved at price P_{e2}. The change in consumer surplus is represented by the area $P_{e2}\,E_2E_1P_{e1}$, and in this case would represent a benefit to the consumer because of a lowering of the price. Two points arise from this. First, the slope (elasticity) of the demand curve should be considered when computing the benefits of a disease control program. Second, if as the result of a control program producers simply produce more, the benefits in the long term may accrue to the consumer, not the producer. Producers might collectively benefit by producing the same amount but using the improvement in technology to produce it more efficiently.

An in-depth discussion of these and other complexities (e.g., international markets) goes beyond the scope of this book. Many important judgments have to be made by professionals when valuing future benefits and costs. These have been briefly mentioned here in an attempt to establish the basic concepts and to bring out a number of important points. Interested readers may wish to refer to more advanced books such as those by Drummond (1980) and Sugden and Williams (1978).

9.5.2 Adjustment of Values

The time that a cost or benefit occurs has an effect on its value. Even in the absence of inflation, an individual places a higher value on one dollar received now than on one dollar received a year from now. There are at least two reasons for this. First, the goods and services the dollar will purchase may be desired now, and hence one is willing to pay a premium. Second, the dollar could be invested and earn interest, either in the bank or in some other alternative, and hence be worth more at the end of the year. The economic value of the estimated costs and benefits must therefore be adjusted to take account of the time they occur. The adjusted value of a benefit or cost is called its present value. The procedure used for the adjustment is called discounting and is the reverse of compound interest calculation (see below). Before applying these techniques it is necessary to establish several formulas. The following symbols will be used: i—the relevant annual interest rate expressed as a decimal; r—the relevant annual discount rate expressed as a decimal; n—the number of years; PV—the present value; FV_n—the future sum accruing at the end of n years; and A_1, A_2, A_3, . . . , A_n—a series of n annual payments made at the end of each respective year. Note that the quantities PV, FV, and A may be either costs or revenues.

Compounding. In compounding, the time movement is from the present to the future. If the sum P is invested now at an annual interest rate of i, it will be worth $P(1 + i)$ 1 year from now. Two years from now it will have grown to $P(1 + i)^2$, assuming i does not change. In n years it will have grown to $P(1 + i)^n$. Hence the general compounding formula is:

$$FV_n = P(1 + i)^n$$

where FV_n is the terminal value after n years of the sum P invested now.

Discounting. In discounting, the time movement is from the future back to the present. The present value of the future sum FV_n is that sum P that if invested now would grow to FV_n by the end of the nth year. This can be calculated from the compounding equation:

$$PV = FV_n/(1 + r)^n$$

Present Value of a Series of Unequal Payments. If the sums A_1, A_2, $A_3 \ldots A_n$ arise at the end of years 1, 2, 3 . . ., n respectively, the basic discounting formula can be applied to each payment, and the present value of the payment series is:

$$\begin{aligned} PV &= A_1/(1 + r) + A_2/(1 + r)^2 + \ldots + A_n/(1 + r)^n \\ &= \sum_{t=1}^{n} A_t/(1 + r)^t \end{aligned}$$

The general formulas are presented in the form of a benefit-cost analysis in Table 9.5.

Table 9.5. General formulas for the calculation of project present values for benefits and costs

Year (1)	Present value of $1 (2)	Benefits: Actual (3)	Benefits: Present value (4) = (2) × (3)	Costs: Actual (5)	Costs: Present value (6) = (2) × (5)
1	$\frac{1}{(1+r)}$	X_1	$X_1 \frac{1}{(1+r)}$	Y_1	$Y_1 \frac{1}{(1+r)}$
2	$\frac{1}{(1+r)}^2$	X_2	$X_2 \frac{1}{(1+r)}^2$	Y_2	$Y_2 \frac{1}{(1+r)}^2$
3	$\frac{1}{(1+r)}^3$	X_3	$X_3 \frac{1}{(1+r)}^3$	Y_3	$Y_3 \frac{1}{(1+r)}^3$
n	$\frac{1}{(1+r)}^n$	X_n	$X_n \frac{1}{(1+r)}^n$	Y_n	$Y_n \frac{1}{(1+r)}^n$
Total		$\sum_{t=1}^{n} X_t$	$\sum_{t=1}^{n} \frac{X_t}{(1+r)}^t$	$\sum_{t=1}^{n} Y_t$	$\sum_{t=1}^{n} \frac{Y_t}{(1+r)}^t$

Present Value of a Series of Equal Payments. If the payments A_1, A_2, $A_3 \ldots$, A_n are equal, this is called an annuity. The present value of an annuity is given by:

$$PV = A\,[(1 + r)^n - 1]/[r(1 + r)^n]$$

When n tends toward infinity, this equation reduces to $PV = A/r$, the capitalization formula.

For purposes of demonstration and using the above discounting formulas, the present value of $1 at the end of various periods of time and at several discount rates is presented in Table 9.6. Just as the interest rate received affects the size of the dividend paid at the end of a period, so the discount rate affects present values. This raises the question of which rate should be used. In general, the discount rate should represent the opportunity cost of capital; and this will vary depending on the scope and nature of the given situation. For government sponsored projects, the rate should reflect the social value of capital, while for a wealthy producer it might represent the rate received on other investments, such as money in the bank (James and Ellis 1980). In general, one should choose a rate that reflects the environment in which the decision is being made, work through the calculation, and then rework the calculation using rates that represent the likely range of possible rates (i.e., one should assess the sensitivity of the decision over the likely range of discounting values).

Another frequent question is how to deal with the effects of inflation. In general, inflation can be ignored since all benefits and costs are being standardized to present values; interest is in the real value of a good or service, not its artificially inflated value. However, if the relative value of different items is expected to change with time, the values can be adjusted to reflect this prior to the discounting procedure (Ellis and James 1979a).

Table 9.6. Present value of one dollar at the end of various future periods of time and at various discount rates

	Discount rate (%)		
Year	8	10	12
1	.9259	.9091	.8929
2	.8573	.8264	.7972
3	.7938	.7513	.7118
5	.6806	.6209	.5674
10	.4632	.3855	.3220
15	.3152	.2394	.1827
20	.2145	.1486	.1037

9.5.3 Evaluation and Strategy Comparison

Having determined the benefits and costs, and having adjusted them to account for timing, they can now be compared. The decision criterion used for this is usually one or a combination of the following three measures of economic efficiency or investment worth: net present value, benefit-cost ratio, or internal rate of return.

Net Present Value. The net present value (NPV) criterion is defined as the present value of benefits (B) less the present value of the costs (C) incurred. The formula to calculate NPV is:

$$NPV = \sum_{t=1}^{n} [(B_t - C_t)/(1 + r)^t]$$

A positive NPV indicates that the control strategy is economically feasible and an alternative with a higher positive NPV is preferred. This measure is often affected by the scale of the project, and while it gives some idea of the value of implementing the project, it does not indicate how much the benefits may outweigh the costs in percentage terms.

Benefit-cost Ratio. The benefit-cost ratio (B/C) is defined as the present value of benefits divided by the present value of costs. The formula for its calculation is:

$$B/C = \sum_{t=1}^{n} [B_t/(1 + r)^t] / \sum_{t=1}^{n} [C_t/(1 + r)^t]$$

The costs incurred and the benefits received during each period of the project are stated as present values and totaled; the present value benefit total is then divided by the cost total. If the ratio is greater than 1, the investment is economically feasible. An alternative with a higher B/C is preferred.

Internal Rate of Return. The internal rate of return (IRR) criterion expresses the return to investment in terms analogous to an interest or discount rate. Specifically, it is defined as that rate of discount that makes the total of the discounted benefits equal to the total of the discounted costs (i.e., the rate of discount such that NPV = 0).

The main advantage of the IRR method is that there is no need to specify a discount rate before the calculation. One of its major drawbacks is that there is no simple formula to determine the rate, and hence it must be determined by an iterative procedure.

The higher the internal rate of return of an alternative, the more likely it is to be preferred. Specifically, the IRRs calculated for all the strategies under consideration are ranked and compared to the opportunity cost of capital, such as the borrowing rate of interest.

Each of the above indices can be deceptive under some circumstances and must be interpreted with care. In general, it is a good idea to calculate and take all three into consideration when making a decision.

Table 9.7 presents a hypothetical example of the use of benefit-cost analysis to choose between two potential investments (A and B). In the example the actual estimated future benefits and costs of each project are equal. However, because of the different cash flow patterns of the two projects, Project A would be the best investment as indicated by all three previously discussed criteria.

A practical example of a benefit-cost analysis to assess alternative programs for bovine brucellosis was conducted by Agriculture Canada (1979). A planning horizon of 20 years was used with the base year being 1977. The spread of brucellosis was estimated by means of a computer simulation model. The benefits of a particular control program were assessed as being the difference between the losses incurred without a control program and the losses incurred under each alternative control strategy. The benefits and costs for each of the four programs investigated are presented in Table 9.8.

Table 9.7. Use of benefit-cost analysis to choose between two potential investments, A and B (discounted at 10%)

		Potential Investment			
	Present value	A		B	
Year	of $1	Benefits	Costs	Benefits	Costs
1	.9091	$ 250	$ 500	$ 0	$ 500
2	.8264	250	1000	100	500
3	.7513	500	500	100	500
4	.6830	500	0	250	500
5	.6209	500	0	500	0
6	.5645	500	0	500	0
7	.5132	500	0	500	0
8	.4665	500	0	500	0
9	.4241	500	0	1025	0
10	.3855	500	0	1025	0
Total		$4500	$2000	$4500	$2000
Total present value		$2638.38	$1656.60	$2240.91	$1584.90
Net present value (NPV)		$981.78		$656.01	
Benefit-cost ratio (B/C)		1.59		1.41	
Internal rate of return (IRR,%)		30.07		18.73	

Table 9.8. Benefit-cost analysis of alternative programs for brucellosis

	Program[a]							
	1		2		3		4	
Year	Benefits[b]	Costs	Benefits	Costs	Benefits	Costs	Benefits	Costs
				(*millions*)				
1	1.79	17.09	2.11	16.06	2.00	15.02	1.99	14.81
2	2.50	17.09	3.01	16.06	3.06	15.02	3.81	13.76
3	3.87	17.09	4.70	16.06	4.66	15.02	5.20	13.76
4	6.38	17.09	7.31	16.06	7.31	15.02	7.64	13.76
5	11.08	17.09	11.93	16.06	12.02	15.02	12.20	13.76
6	19.06	17.09	19.85	16.06	19.98	15.02	20.11	13.76
7	31.54	17.09	32.31	16.06	32.46	15.02	32.55	13.76
8	48.98	17.09	49.75	16.06	49.90	15.02	49.96	13.76
9	69.93	17.09	70.73	16.06	70.88	15.02	70.93	13.76
10	90.87	17.09	91.71	16.06	91.87	15.02	91.91	13.76
11	108.19	17.09	109.12	16.06	109.28	15.02	109.31	13.76
12	120.33	17.09	121.35	16.06	121.53	15.02	121.55	10.59
13	127.83	17.09	128.98	16.06	129.18	15.02	129.19	10.59
14	132.18	17.09	133.46	16.06	133.68	13.54	133.69	10.59
15	134.70	17.09	136.16	16.06	136.39	13.54	136.40	10.59
16	136.30	17.09	137.94	16.06	138.18	13.54	138.19	10.59
17	137.37	17.09	139.21	16.06	139.46	13.54	139.47	10.59
18	138.15	17.09	140.21	16.06	140.47	13.54	140.48	6.50
19	138.73	17.09	141.01	16.06	141.29	13.54	141.30	6.50
20	139.17	17.09	141.71	16.06	142.00	13.54	142.01	6.50
Present value	437.71	145.50	445.60	136.73	446.42	125.78	448.00	109.69
Net present value	292.21		308.87		320.64		338.31	
Benefit-cost ratio 1[b]	3.0		3.3		3.6		4.1	
Benefit-cost ratio 2[c]	3.5		3.8		4.1		4.7	

Source: Agriculture Canada 1979, with permission.
[a]Programs described in text. Dollar values rounded to nearest $100,000.
[b]Includes only benefits to producer.
[c]Includes producer benefits plus benefits due to undulant fever and export trade.

A discount rate of 10% was used. The four programs investigated were: (1) test and slaughter, (2) test and slaughter plus adult vaccination, (3) test and slaughter with some depopulation, and (4) herd depopulation. Benefits to the producer involved milk yield, value of animals, calf crop, and conception rates. Other benefits examined included the effect of undulant fever on the human population and the effect of brucellosis on export trade. Costs included personnel, operation, and capital costs plus compensation payments.

As can be seen from Table 9.8, and as judged by the benefit-cost ratio and net present value, all programs were feasible with herd depopulation providing the greatest economic return on investment. Benefit-cost ratios for producer benefits only and for all benefits considered are presented separately.

In the past few years benefit-cost analyses have been used to investigate control activities for a number of animal diseases including foot-and-mouth disease (James and Ellis 1978; Powers and Harris 1973), swine fever (Ellis 1972), cattle tick (Johnston 1975), bovine trypanosomiasis (Habtemariam et al. 1982/1983), and bovine leukosis (Hūgoson and Wold-Troell 1983).

9.5.4 Cost-effectiveness Analysis

A technique that overcomes some of the difficulties involved in putting a dollar figure on all the benefits of a disease control program is cost-effectiveness analysis. This approach is appropriate where the benefits are difficult to quantify (e.g., the benefits to the human population of rabies control), when production losses under each control strategy are equal, or when the activity has been defined as essential for one reason or another. In such instances the requirement is for a method of analysis that determines how the desired result can be achieved at minimum (discounted) cost. In fact, the procedure is the cost part of a benefit-cost analysis carried out on its own. The question of whether the benefit is sufficiently worthwhile to justify the expenditure may, for example, be strictly a political one.

Thus, the benefit-cost group of techniques available range from benefit-cost analysis at one end of the spectrum, which deals only with financially quantifiable benefits and costs, through to cost-effectiveness analysis at the other end, where all benefits are considered unquantifiable, equal, or are otherwise ignored, and only the costs are calculated. In most cases the actual technique will be a hybrid of the two, in which monetary and non-monetary benefits are quantified and the nature of unquantifiable benefits for each strategy is stated.

References

Agriculture Canada. 1979. Evaluation of alternative brucellosis programs by benefit-cost analysis. Systems and Consulting Division Tech. Report.

Anderson, J. R. 1976. On making decisions. Span. 19:120–22.

Anderson, N., R. S. Morris, and I. K. McTaggart. 1976. An economic analysis of two schemes for the anthelmintic control of helminthiasis in weaned lambs. Aust. Vet. J. 52:174–80.

Davidson, J. N., T. E. Carpenter, and C. A. Hjerpe. 1981. An example of an economic decision analysis approach to the problem of thromboembolic meningoencephalitis (TEME) in feedlot cattle. Cornell Vet. 71:383–90.

Drummond, M. F. 1980. Principles of Economic Appraisal in Health Care. Toronto: Oxford Univ. Press.

Ellis, P. R. 1972. An economic evaluation of the swine fever eradication programme in Great Britain, using cost-benefit analysis techniques. Univ. of Reading, Dept. of Agric. Study No. 77.
Ellis, P. R., and A. D. James. 1979a. The economics of animal health. I. Major disease control programs. Vet. Rec. 105:504–6.
______. 1979b. The economics of animal health. II. Economics in farm practice. Vet. Rec. 105:523–26.
Habtemariam, T., R. E. Howitt, R. Ruppanner, and H. P. Riemann. 1982/1983. The benefit-cost analysis of alternative strategies for the control of bovine trypanosomiasis in Ethiopia. Prev. Vet. Med. 1:157–68.
Hugoson, G., and M. Wold-Troell. 1983. Benefit-cost aspects on voluntary control of bovine leukosis. Nord. Vet. Med. 35:1–17.
James, A. D., and P. R. Ellis. 1978. Benefit-cost analysis in foot-and-mouth disease control programmes. Br. Vet. J. 134:47–52.
______. 1980. The evaluation of production and effects of disease. Proc. 2nd Int. Symp. Vet. Epidemiol. Econ., May 1979, Canberra, Australia.
Johnston, J. H. 1975. Public policy on cattle tick control in New South Wales. Rev. Mark. Agric. Econ. 43:3–39.
Morris, R. S. 1969. Assessing the economic value of veterinary services to primary industries. Aust. Vet. J. 45:295–300.
______. 1975. The economics of animal disease control. Proc. 19th Annu. Conf. Aust. Agric. Econ. Soc.
Morris, R. S., and A. H. Meek. 1980. Measurement and evaluation of the economic effects of parasitic disease. Vet. Parasit. 6:165–84.
Powers, A. P., and S. A. Harris. 1973. A cost-benefit evaluation of alternative control policies for foot-and-mouth disease in Great Britain. J. Agric. Econ. 24:573–79.
Sugden, R., and A. Williams. 1978. The Principles of Practical Cost-Benefit Analysis. Toronto: Oxford Univ. Press.
White, M. E., and H. Erb. 1980. Treatment of ovarian cysts in dairy cattle: A decision analysis. Cornell Vet. 70:247–57.
Williamson, N. B. 1980. The economic efficiency of a veterinary preventive medicine and management program in Victorian dairy herds. Aust. Vet. J. 56:1–9.