SYMPOSIUM: DAIRY FARMS IN TRANSITION

Dairy Cow Culling Strategies: Making Economical Culling Decisions

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ABSTRACT

The purpose of this report was to examine important economic elements of culling decisions, to review progress in development of culling decision support systems, and to discern some of the potentially rewarding areas for future research on culling models. Culling decisions have an important influence on the economic performance of the dairy but are often made in a nonprogrammed fashion and based partly on the intuition of the decision maker. The computer technology that is available for dairy herd management has made feasible the use of economic models to support culling decisions. Financial components—including profit, cash flow, and risk—are major economic factors affecting culling decisions. Culling strategies are further influenced by short-term fluctuations in cow numbers as well as by planned herd expansion. Changes in herd size affect the opportunity cost for postponed replacement and may alter the relevance of optimization strategies that assume a fixed herd size. Improvements in model components related to biological factors affecting future cow performance, including milk production, reproductive status, and mastitis, appear to offer the greatest economic potential for enhancing culling decision support systems. The ultimate value of any culling decision support system for developing economic culling strategies will be determined by its results under field conditions.
(**Key words**: culling, dairy, decision support system)

Abbreviation key: **DSS** = decision support system.

INTRODUCTION

Culling decisions represent a major challenge to dairy owners and managers. For most herds in the US, 30 to 35% of the cows are typically culled each year (2). Culling of dairy cows often necessitates associated costs for replacement heifers that account for approximately 20% of the dairy budget (21). The perceived importance of culling decisions is also demonstrated by the observation that owners of particularly large herds, who otherwise are not involved in making individual cow management decisions, often directly participate in the routine decision-making process for selecting cows to cull.

Although significant advances in dairy herd management have been made in recent years through the development of computerized record systems for cow health and production, little progress has occurred at the farm level in making better culling decisions. These record systems have improved the quality and quantity of data that are available for review in making culling choices, but minimal change has occurred in the way these data are analyzed to determine which cows are to be culled from the herd. Many producers start with a list of cows producing less than some specified daily amount of milk based on the most recent test day information. This minimum level may or may not be related to a calculated minimum value for “break-even” daily milk production of the farm. Usually the stage of lactation, reproductive status, and age of the cow are examined next. Low producing cows that are pregnant and approaching a stage of gestation that would provide a reasonably normal length of the dry period are often retained in the herd. Further consideration is typically given to some measure of genetic worth or contribution to herd value, such as pedigree information, the percentage of herd mature equivalent production (49), or ranking of the particular cow in a listing of estimated relative producing ability (59). Additionally, individual cow attributes are often taken into account, such as the existence of chronic health problems or specific conformational defects. Finally, careful thought is often given by the decision maker to current dairy herd dynamics over both the short term and the long term. Consideration would typically include significant variations that would occur

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during the next several months in the number of dry cows and pregnant heifers expected to calve as well as any long-term goals for herd expansion or contraction. These herd-level factors often determine to some extent the actual number of cows to be culled at any given time. Most importantly, nearly all of this analysis occurs by a rather ad hoc and informal process that usually incorporates heuristic methods by the decision maker for reaching conclusions about which cows to cull. This process has also been described as nonprogrammed, depicting variable or unpredictable results being obtained at different times under similar conditions (14).

Adequate methods are not widely available for thoroughly analyzing existing data about cows in the herd to make objective culling decisions based on economic factors. A significant opportunity exists to improve dairy herd efficiency and profitability through improved culling management with negligible effect on the rate of genetic improvement (1, 64). Current advances in computer technology and the widespread use of commercially available software programs for dairy herd management have provided the prospect of incorporating economic models into the managerial decisions affecting culling.

The purpose of this report was to examine important economic elements of culling decisions, to review progress in development of culling decision support systems (**DSS**), and to discern some of the potentially rewarding areas for future culling model research.

FINANCIAL COMPONENTS OF THE CULLING DECISION

The concern for profit must serve as a foundation for culling decisions. Analysis of termination codes from DHI records for cows leaving the herd serves as a useful guide for identifying current or potential problem areas in herd management or preventive health programs, but this review of records provides limited direction for making profitable decisions about future culling. Herd owners, managers, and consultants must make a paradigm shift, if they have not already done so, from viewing culling management as a retrospective analysis of voluntary and involuntary removal categories to consideration of essentially all culling as an economic decision (21).

When a dairy is analyzed from an economic perspective, the tendency is often to focus solely on profit, ignoring other essential elements of the financial framework for any successful business. This tendency applies to culling situations as well. Although every dairy must be profitable if it is to survive as a business, other components of financial performance must also be considered. Cash flow determines to a large extent the feasibility of the business venture, particularly in the short run, and the ability to service debt. Cash flow considerations figure into culling decisions as the prudent manager contemplates the difference in market values between the prospective cull cow as a nonfed beef animal and the potential replacement heifer. A decision to make an investment today to achieve expected future increases in profit has reduced importance if the dairy cannot afford the anticipated short-term negative cash flows required to obtain that future profit.

The producer's attitude toward risk is another important factor that affects culling decisions. Risk-aversive behavior implies that an individual will exhibit a diminishing marginal utility of wealth (obtaining an extra dollar adds less to enjoyment as total wealth increases) (46). Consideration of risk may alter culling decisions as the decision maker attempts to maximize the utility of asset management and minimize conditions of uncertainty regarding outcome; this strategy may produce results that appear to depart from profit-maximizing behavior (41). Risk reduction may be achieved through the application of portfolio theory by diversifying decision choices (23, 42). Diversification within a culling context, for example, could refer to variation in the response of different cows to extrinsic factors, such as weather and housing constraints. An older cow might have greater projected average returns than a younger cow if typical weather patterns are experienced during the planning period. However, if more severe weather conditions occurred, the younger cow might have an economic advantage related to avoidance or reduced effect of certain health problems associated with severe weather. In this example, including both older and younger cows in the culling strategy would help to reduce the risk associated with variation in normal weather patterns. Inadequate consideration of risk may account for the tendency of economic models to predict more risky behavior than is actually observed (41).

DAIRY FARMS IN TRANSITION AND CULLING STRATEGIES

Individual dairy producers, as well as producers of most other agricultural commodities, participate mostly as price takers in a competitive market and have limited opportunities to manage the selling price of milk. As a result, producers look primarily toward expansion of the herd and improved production efficiency as the principal means to increase profit of the dairy enterprise.

Only rarely does an individual producer reduce herd size as a long-term management change. The predominant trend in the dairy industry has been toward decreased total numbers of cows placed among fewer herds. During recent years, the number of herds has steadily declined about 5%/yr, following a steeper decline in herd numbers during the 1980s (28). Pressures to maintain and increase farm profits have resulted in increased milk production per cow and larger mean herd size as dairy producers have attempted to achieve economies of size and scale. Dairy farms in transition appear to be more the rule than the exception throughout the industry, although any given herd may maintain a relatively static herd size over a period of years. In addition to these long-term trends, the dairy manager is continually faced with short-term decisions to manage herd size, such as monthly fluctuations in heifer and dry cow inventories, and, consequently, in cull cow numbers. Herd size can be a dynamic, changing number on both a long- and short-term basis. As a result, there are significant interactions between culling strategies and herd size.

FORMULATION OF THE CULLING PROBLEM

If culling decisions are to be economical, then it is imperative that the culling problem be properly formulated to include all of the major factors affecting profit, defined as the difference between total revenues and total costs. The fundamental principle is to recognize that a dairy cow is a business asset that is owned and operated for profit. A significant challenge is to evaluate objectively the projected cash flows related to the production traits of dairy cattle and to the lactation cycle. Information from these cash flows provides a means of evaluating the potential for profit.

Classic asset replacement theory, derived originally from forest economics (11, 25, 48) and readily applied to certain other agricultural and industrial situations, falls short of meeting the complex needs encountered when modeling economic decisions regarding dairy cattle (30). A major contribution of replacement theory toward developing proper culling strategies has been derivation of the principles of discounted cash flow. This technique provides a method for the equitable comparison of values of current and future production and potential profits. Generic replacement models, however, such as those adapted to model the optimal replacement of farm machines, assume, in their simplest form, that each older unit will be replaced with an identical new unit that has the same performance and life expectancy characteristics (8). Those models can be appropriately modified to adjust for technological changes based on predictable performance improvements of newer machines (8). A model for the dairy cow replacements, however, must cope with variable cash flows of different lengths (i.e., varying lactation lengths) and nonidentical replacement, which makes it difficult to predict expected performance accurately.

Profit equations or functions using field data that include revenues and costs over a fixed period or the total herd life of a cow have been used to assess the importance of different factors such as herd life and milk production (3, 27, 47, 58). All of these studies have omitted the opportunity cost of postponed replacement of the cow in the herd (65). These models have presumed that keeping a cow in the herd does not prevent the acquisition of a new cow or heifer and benefit of the associated profits. In other words, herd growth was not constrained, and herd size was not required to be fixed, in these models. Van Arendonk (65) determined that the relative value of herd life compared with milk production was overestimated by 260% when opportunity costs of postponed replacement existed.

A proper statement of the culling decision assuming a fixed herd size has been formulated by Dijkhuizen et al. (18). Based on profit criteria, the cow in question is not culled because she is no longer able to produce profitably, but because a replacement cow is expected to be more profitable. According to the marginal principle, a cow of a particular age should be kept in the herd as long as her marginal profit is higher than the expected average profit per year of herd life of a young replacement cow. The assumption of a fixed herd size for purposes of economic optimization becomes tenuous, however, as the degree of facility utilization varies as cow numbers in the lactating herd change.

The implications that facility utilization have for culling decisions are related to the changes in the opportunity cost for postponed replacement. When facilities are underutilized, a decision to keep a cow in the herd does not preclude or cause the producer to forego the opportunity of increasing profits by adding additional heifers or cows until full capacity is reached. Otherwise, the theory related to a dairy at full capacity implies that a replacement animal can only be added if a decision is made to cull an existing animal from the herd. This decision would be made if evidence indicated that, over the long run, the replacement would be more profitable than keeping the existing cow. Under the assumption of a fixed herd size, the producer must forego the potential profits of keeping the current cow in order to gain possibly greater profits by culling the cow and substituting the replacement.

One of the challenges of economic replacement decisions, therefore, is to recognize the appropriate opportunity cost of space in the dairy facility (9). Burt (9) described in detail the economic considerations for determining opportunity costs for replacements in intensive livestock operations relative to the availability of space in the facility. Whenever the herd policy of immediate replacement of the culled animal is being followed, the opportunity cost of that space on the dairy is commensurate with the present value of net returns above relevant variable costs over the appropriate planning horizon (9). However, if existing space on the dairy will remain empty for more than a minimal period, this condition would imply that no opportunity costs currently exist for that space (9). Therefore, whenever circumstances of the dairy allow heifers to be added without requiring existing cows to be culled, whether this situation is due to planned long-term expansion or short-term fluctuations in cattle numbers, then opportunity costs for postponed replacement do not exist. For situations in which the herd size is static (i.e., immediate replacement policy), the correct objective function is to maximize total discounted net revenue per cow unit over a reasonably long-term planning horizon for the dairy. However, when expansion in herd size is planned or allowed, the manager should consider keeping any cow as long as the projected average revenues exceed average relevant variable costs for that cow because the opportunity costs for postponed replacement become insignificant.

PROGRESS IN DEVELOPMENT OF IMPROVED CULLING STRATEGIES

To gain economic efficiency, better analytical tools are needed for objective decision making about which cows should be culled. Dairy production, as described within the context of agriculture, is based on knowledge, tradition, and conjecture. According to France and Thornley (22), the purpose of agricultural research, including dairy research, is to increase knowledge at the expense of tradition and conjecture, thereby increasing the efficiency of agricultural production. Economic DSS for management are being developed and will be widely available in the future within the dairy industry (15). These systems integrate historical production records with economic information and analyses to provide producers with improved prescriptive information in the form of economic decision-making tools.

Dynamic programming was first used for analyzing cow replacement in 1963 (33), and even later models were so limited by the capability of available computer equipment at that time that no effort was made to use the models in an operational dairy setting (53, 54). In more recent times, dynamic programming has been widely adapted to solve the Markov decision process problem of optimal replacement for dairy cattle based on single parameters or combinations of milk production, reproductive status, and clinical mastitis (6, 16, 29, 31, 37, 38, 56, 63, 66); reports of the results of their application under field conditions are limited (15). An optimal result, however, implies that no other decision or set of decisions would provide an improved outcome over the choice identified as being optimal. By definition, a manager must follow exactly the results of an optimization program to achieve the anticipated outcome of profit maximization. According to the underlying theory, any other action would be expected to reduce profits.

Whenever the optimal situation is the goal, however, the condition of fixed herd size must be invoked in most dynamic programming applications to solve this replacement problem under the required economic parameters, including opportunity costs of postponed replacement. For herds that do adhere to a fixed size constraint this methodology has advantages over other approaches that do not guarantee an optimal solution. However, practical situations of dairy management may not fit realistically with an assumption of fixed herd size. Fluctuations in cow numbers occur in many herds as management evaluates profit potentials, cash flow projections, and risk profiles of investment opportunities. Whenever the size of the milking herd changes, the economic relationships based on assumptions of a fixed herd size and associated opportunity costs to obtain optimal solutions are no longer valid. Also, changes in tax laws can have additional influence on optimal culling and replacement decisions and can effect the values of future cash flows (13, 34). None of the current optimizing DSS models consider tax implications that would likely have a significant influence on culling strategies, herd expansion plans, and related asset management.

As progress is made in dynamic and other mathematical programming techniques, the potential exists to develop optimizing models that have more flexible constraints. Developments in replacement models using advanced techniques such as classification and regression tree analysis (60) or multilevel hierarchic Markov processes (39), for example, provide the prospect of analyzing complex models and minimizing the dimensionality issue associated with these large problems. Another alternative, recursive stochastic programming, has been used to model individual cows in a herd over time to help establish improved culling decisions (30) rather than requiring strict and, perhaps, unrealistic assumptions to ensure optimal results. This technique simulates expected future economic contributions of cows presently in the herd so that a preferred ranking of cows for culling purposes can be made. Because this approach only provides rankings of cows, no specific recommendation is made regarding the exact number of cows to cull or replace.

CULLING MODEL DESIGN ELEMENTS

The most sophisticated model design for improved decision making cannot compensate for inadequate or faulty design of the model components representing the biological aspects of cow performance and milk production (36). Similarly, overly complex models incur the risk of limited breadth of application because of intensive resource requirements (55). With recent gains in affordable computer capacity, some of the constraints of model design have been relaxed so that development of DSS for culling management of dairy cows is feasible for individual animals (31).

After culling for low milk production, which is traditionally considered as voluntary removal from the herd, culling for reproductive failure and mastitis are the most frequent reasons given for involuntary culling (50). Therefore, the performance traits related to milk production, reproduction, and mastitis appear to offer the greatest economic potential for analysis and incorporation into a culling DSS. Evaluation of these factors must occur over a sufficiently long planning horizon so that both older and younger cows can be evaluated fairly.

Milk Production

Improved or optimal culling decisions rely heavily upon accurate predictions of milk production for individual cows in current and future lactations (35, 67). The sale of fluid milk accounts for more than 90% of the total dairy income for dairies in various regions of the US, emphasizing the important contribution milk production makes toward determining the economic value of a cow to the producer (26).

Various methods for predicting milk production for current and future lactations have been used in culling DSS models. Ben-Ari et al. (6) used annualized values for milk production for each cow that were standardized for comparison among cows using maturity adjustment factors as the cow progressed from one lactation to the next at each stage of the model. The model by DeLorenzo et al. (16) estimated milk production using a linear fifth-order polynomial mathematical model, which was in contrast to the nonlinear least squares estimation used by Van Arendonk (62), Van Arendonk and Dijkhuizen (66), and Rogers et al. (51, 52). The nonlinear model was based on work by Van Arendonk (61) and included effects of season and number of days open on estimated milk production. Milk fat production was estimated by Harris (29) using an intraherd best linear unbiased prediction model that computed future production as a sum of additive genetic and permanent environmental effects for each cow. To predict milk production, Kristensen (37, 38) developed and used a model that incorporated effects of herd level, genetic class, and calving interval (36). Those components were included in an extended model that was estimated by ordinary multiple linear regression. A Bayesian prediction model for milk production has also been proposed as a method to make better use of herd information for improving the accuracy of individual cow milk yield estimates (68).

In an earlier study, improved information for predicting cow performance had more of an effect on the economic gain from culling decisions than more accurate prediction of milk prices (12). Improvements in the accuracy of prediction of future milk production for individual cows should have a significant impact on the evaluation of the cow for culling decisions.

Reproduction

Compared with most other kinds of disease or illness, reproductive inefficiency deserves special attention because of its prevalence and distinct role in determining lactation length for cows that are not culled because of other health problems or low production. Adjustment for reproductive status provides the opportunity to improve prediction of net returns during future periods (50).

Survival analysis techniques may be used to model the reproductive performance of dairy cows. These techniques have the advantage of providing results as time-specific probabilities of conception that can be readily adopted for use in economic and decision analyses (40). More importantly, when reproductive efficiency is measured by parameters based on conception as an outcome, performance may be overestimated if information is excluded from analysis for cows that otherwise would be eligible for breeding but that were culled or left the herd prior to

TABLE 1. Example of lactation, reproductive, udder health, and economic information for culling evaluation of cows and potential replacements.

Chain number	Lactation	LTD[1] Milk	DIM	DCC	Mean SCS	Extended 305-d FCM	Relative value[2]	Culling DSS annuity value[3]
	(no.)					(kg)	(%)	($)
3187	1	55	326	134	1.6	8941	100	538
Replacement	1	NA[4]	NA	NA	NA	8618	NA	515
1278	2	82	73	0	0.3	9886	100	510
3236	1	71	171	102	1.7	8920	100	508
702	6	118	52	0	0.9	10,801	100	476
Replacement	1	NA	NA	NA	NA	8165	NA	471
3044	4	69	147	0	5.6	11,215	100	460
625	5	18	362	185	1.3	11,187	100	453
38	3	90	50	0	2.2	10,149	100	447
1406	1	49	361	0	1.0	8841	100	390

[1]LTD = Last test day, DCC = days carrying calf, and DSS = decision support system.

[2]Percentage of herd average mature equivalent fat-corrected milk.

[3]Annuity values derived from simulation over a 10-lactation planning horizon based on discounted income over feed costs and cow costs associated with risks for death and severe disease, reproductive failure, and chronic mastitis.

[4]Not applicable.

conception (20, 40, 57). By including data from censored cows, survival analysis has been shown to produce improved estimates of reproductive performance with less bias than conventional methods (20).

Mastitis

Although reduced milk production accounts for up to 70% of the economic losses of mastitis (7), other significant losses are related to culling costs, increased replacement costs, and disease treatment costs (5, 7, 19, 32, 43). Mastitis has been associated with an increased risk of culling (17). In a review by Fetrow (21) of several previous reports analyzing reasons for culling, mastitis was second only to reproduction as the largest involuntary culling category.

Although culling strategies that have increased emphasis on mastitis control provide reduced incidence and prevalence of mastitis, these policies do not achieve maximum financial gain and do not appear to be justified economically compared with policies emphasizing production (10, 31, 45). However, culling policies based on objective criteria that include increased risks and costs associated with mastitis in addition to milk production potential may be economically viable (56). Morse et al. (44) have proposed that the ability to predict recurrence of clinical mastitis and associated costs may play a key role in future dairy culling models and that such methods should be incorporated into dairy farm management practices. The present lack of consistent and accurate records of clinical mastitis for cows in many herds, however, would likely limit general implementation of culling DSS requiring this type of information. As an alternative, information provided by monthly somatic cell count measurements, especially persistently elevated counts, could be used to provide guidance on the increased risk of reduced productive life because of mastitis (4). This increased risk of culling reduces the likelihood that a cow with elevated somatic cell counts would provide the same return or payback over time as a cow with similar production but without mastitis (24).

Application

Various culling criteria based on DHI values and hypothetical calculations implementing discounted cash flows associated with milk production, reproductive performance, and udder health simulated over a 10-lactation planning horizon, are presented in Table 1 to compare culling DSS results with traditional cow evaluations. Annuity values derived from the culling DSS ranged from $390 to $538 for income over feed and cow costs, although relative values were equal to 100% of herd average mature equivalent production on a fat-corrected milk basis. These results (Table 1) emphasize the potential economic difference that can occur in cow values even though criteria, such as relative value, may be equivalent. Such differences are likely to occur because of the evaluation of factors in addition to milk production, such as seasonal reproductive performance or pregnancy status, which affect the potential economic merit of the cow being considered.

CONCLUSIONS

Traditional methods of analyzing culling decisions are often inadequate to provide guidance for future culling decisions. To improve financial performance of the dairy, all culling should consider the economic impacts of the decision. Because of the dynamic nature of the dairy industry, many dairy farms experience transition periods that are characterized by increases or fluctuations in herd size. Such changes can alter the relevance of optimization strategies that assume a fixed herd size because of the significant change in opportunity costs for postponed replacement when facility space is available. The DSS designed to assist culling decisions should include critical components for adequately describing biological traits related to milk production, reproduction, and mastitis. Estimates of these parameters must be incorporated into an appropriate economic framework with a suitable planning horizon for comparison of expected cash flows generated by cows presently in the herd. This information should assist the manager in making economical culling decisions. The ultimate value of any DSS for developing economic culling strategies will be determined by its results under field conditions (21).

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