RESEARCH PAPER

The Economics of Longevity in Dairy Cattle – Ontario, Canada

ABSTRACT

An accurate value appraisal of dairy cattle longevity is fundamental in ensuring an economically correct culling strategy is made. The opposing pressures of spreading depreciation over a longer time period and the known yield improvements up to the fourth lactation versus genetic gains at each new generation were measured within a field model to estimate a practical longevity strategy. Production data from cows on seven dairy farms in Eastern Ontario, Canada, was evaluated using a model that ranked cows and heifers based on a simple economic and production index. The results indicated that age was a poor criterion for determining an individual cow's value, but, on a whole-herd basis, cows were at their maximum value during their fourth lactation. Incoming heifers were superior to low-ranking cows. The minimal cull rate was 6%, and the practical cull rate was 40%. In effect, this was the maximum number of heifers that could be expected to be home-raised in one year. This culling strategy resulted in a $677 per cow savings, suggesting a practical management strategy for operators: keep all heifers and target survival to four lactations. Culling pressures should remain on inferior cows, minimizing involuntary culling, and giving serious consideration to purchasing replacement heifers.

(dairy cattle, culling, optimal cow age, longevity)

Abbreviation key: BSE=bovine spongiform encephalopathy, **CM=**contribution margin, **NPV**=net present value, **DHI**=dairy herd improvement, **OMAFRA**=Ontario Ministry of Agriculture, Food and Rural Affairs, **MNI**=mature net income, **ANI=**actual net income. **SPSS** is a registered trade mark.

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May 5, 2006¶

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Dear Editors,¶
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Please accept this electronic manuscript as submission for publication of my report entitled "The Economics of Longevity in Dairy Cattle – Ontario, Canada" in the Canadian Journal of Animal Science.¶
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The attached paper is an investigation into the economics of longevity in dairy cattle. This topic confronts dairy farmers each time they make decisions to cull cattle and is thus of great importance and interest to participants in the dairy industry and to economists striving to understand it. The report rewards readers from the industry by recommending practical management strategies to take advantage of a new perspective on longevity.¶
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The Economics of Longevity in Dairy Cattle – Ontario, Canada¶
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INTRODUCTION

Dairy cows in Ontario are being replaced at an unprecedented rate. The cost of keeping up to this pace is placing enormous pressure on the industry. Not only is it difficult to meet the demand for heifers, but the pre-bovine spongiform encephalopathy (BSE) value of cow ownership (depreciation and interest) was the second largest cost of production next to feed. The problem simply stated is, “Will keeping cows longer result in added profits?”

Amid the labour-intensive routines of dairy farming, producers are regularly faced with the critical decision of cow replacement. The economic value of a dairy cow is its milk-producing ability, which changes predictably throughout the cow’s lifespan. At some point, the producer must cull the cow and replace her with a heifer. Ideally, this event would occur when the producer receives maximum economic advantage.

The primary economic consideration of the replacement is the cow’s immediate milk production, but other factors complicate the issue. Genetic progression, milk quota, health costs, age-yield improvements and cow replacement costs are all factors that cannot be ignored in a proper identification of the economics of longevity. Involuntary culls, such as culls due to chronic mastitis, type defects or reproductive failure, also have a profound effect on the economics of the replacement process.

The Ontario replacement rate for dairy cows in 2003 and 2004 was reported at 33% and the average productive life was 4.4 lactations[1] (CanWest DHI 2003; CanWest DHI, 2004). With expensive heifer values, culling a cow early in life will add hundreds of dollars to annual cow ownership costs. Studies have repeatedly shown that cows do not

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[1] Cow longevity is generally considered to be the inverse of cull rate. Lactation numbering starts from one and therefore using lactation number as a proxy for longevity will start from one, not zero. Therefore, a culling rate of 33% infers a longevity of three lactations, meaning a cow has just finished her third lactation or is starting her fourth.

reach maximum production until the fourth lactation and maintain near-maximum production for the next several lactations (Bauer et al. 1993). Farmers cull many animals before they have reached their maximum yield potential, resulting in reduced profits. A field study to valuate longevity in Ontario dairy cattle would contribute clarity to the evaluation of the replacement choice: keep the cow or keep the replacement heifer.

Many published works have contributed to present notions of an optimal culling age and rates for dairy cattle. Faust (1993) found that, considering cash and non-cash costs, the optimum level of culling was between 25% and 30% on an annual basis. In their work, Steinwidder and Greimel (1999) found that profit per farm increased remarkably by increasing longevity up to six lactations. Bauer et al. (1993) showed that cows have significant gains in annuity value (net present value of revenue) up to the fourth lactation, after which there are marginal annual gains up to the tenth lactation.

When cull rates increase, fewer revenues are available because heifers yield less milk in general than older cows and fewer heifers are sold off the farm. In one study, farmers practicing a small cull rate group spent 11% of annual revenues on culling, while a large cull rate group spent 25% of its annual revenue on culling (Hoekema 2000). Also, not only do heifers yield less, but replacement rearing accounts for 9 to 20% of the total expenses on dairy farms (Bailey et al. 1999).

The economics of longevity has been studied from the viewpoint of genetic trait selection affecting longevity and estimating their impact on the dairy industry (Jairath et al. 1998; Weigel et al. 1995; Vollema and Groen 1996). These studies found that milk volume was the primary trait affecting profits, followed by traits affecting survivability (the ability of a cow to avoid being culled). Kulak et al. (1997) found that productive life was second only to average milk revenue as a profit-producing trait. Although not quantified, longevity was found to improve profits.

Another viewpoint is to investigate culling behaviour amongst dairy producers. Simply stated, if farmers don't cull their cows, they will live longer. So, why are cows being culled and is this optimal business behaviour? Dynamic programming, an optimising procedure that allows for stochastic events, is the preferred tool of many researchers for making computerized replacement decisions. Since 1962, when Bellman first developed dynamic programming, many studies have worked to refine the process (Smith 1973; Allaire 1981; van Arendonk 1984; Kristenson 1987; Taylor 1993). The consensus among studies is that the replacement decision process is an economic comparison of the cow and the average replacement heifer. This comparison is made using the net present value (NPV) of earnings over an extended or infinite length of time.

A number of studies have used dynamic programming to evaluate the optimal age of culling for dairy cattle. Redman and Kuo (1969) described a dynamic programming model that resulted in an optimal replacement rate of 17%. Bauer et al. (1993) used Markov equations and determined that the economically optimal replacement age of a dairy cow was at the end of the sixth lactation. Stott (1994) used dynamic programming to show that an additional lactation added $45 to the investment potential of the replacement dairy heifer. Vargas et al. (2001) found that optimal replacement policies varied according to feeding strategies for dairy herds. A change in feeding strategy resulted in changes of up to 6.8 months in optimal herd age.

Dynamic programming is not without its challenges when applied to dairy herds. Some of the procedure's assumptions, such as uniformity of heifers, availability of heifers and uniformity of cow reproductive cycle, are questionable (Ben-Ari et al. 1983).

The aforementioned studies do not describe the Ontario dairy industry where producers are bound by production quota and respond to stimuli that this imposes when making culling decisions.

An empirical field study of longevity is proposed and should account for genetic progress, replacement rates, and theoretical optimal[2] age for a dairy cow. Researchers have not addressed this issue with a practical approach over the last 40 years. In fact, Kennedy and Stott (1993) is the only reference found that addressed the issue of individual heifers as opposed to an average heifer, although they too have used dynamic programming with the complexities of estimating future occurrences across all decision stages to a limitless planning horizon.

Eicker and Fetrow (2003) have described a more practical view of culling. They have developed a management program called "Cow Value" that looks for the optimal profit of a slot within the dairy by answering the question: "Will the worst cow produce more profit in this slot than the average heifer?" The program is understandable and easy to use. Profit is defined as revenues less marginal feed costs and maintenance costs for an infinite time period, and all amounts are discounted to present value. Cow Value is a farm decision tool that considers age, stage of lactation, reproductive status and production level. This current study also uses cow rankings to evaluate culling decisions, but the objective is to estimate the value of longevity and identify on-farm benchmarks for longevity.

The overall objective of this study is to describe an approach to making profitable culling decisions using individual cow information and to demonstrate this approach using seven dairy farms in Ontario. Using information from these seven farms,

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[2] This study addresses a practical measure of cow age and replacement rates as opposed to optimal, because heifers are assumed to be home-grown. Replacement heifers can, of course, be purchased.

longevity benchmarks are estimated including minimum, practical and voluntary culling rates, average optimum cow age in the herd, value of involuntary culling, and the economic value of an optimal strategy for longevity.

MATERIALS AND METHODS

Data was collected from seven Eastern Ontario dairy farms: six Holstein and one Ayrshire. At the beginning of 2003, each farm was visited to develop a specific dairy enterprise budget reflecting their 2002 financial data (Canadian dollars). The Ontario Ministry of Agriculture, Food and Rural Affairs' (OMAFRA) budgeting template for dairy was used for the budget format within the model. Dairy Herd Improvement (DHI) field tests, taken at five-week intervals from March 2003 through April 2005, were used in conjunction with the financial data to rank cows from worst to best at each test.

THE MODEL:

A spreadsheet model[3] was developed to identify the worst cow and compare this cow with the heifer at hand. The heifer's economic value was estimated using the Canadian indices for milk, fat and protein or, when indices were not available, retroactively using her first DHI test. The cow's value was estimated using OMAFRA's dairy budgeting tool, modified for use in this model (Table 1). It is acknowledged that full budgeting information was not necessary to rank cows because recorded variable costs are usually averaged, not individualized, and recorded fixed costs are surely averaged, not individualized. Therefore, the use of actual or mature milk value, or milk yield (milk is formula priced under the Canadian production quota system) would give

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[3] Microsoft Excel

similar rankings to net income or contribution margin[4] (CM) rankings. However, in this model, CM was used to rank for two reasons. Firstly, an attempt was made to individualize variable costs by assigning a health value to each animal based on her linear score. Feed costs were adjusted based on actual 305 day yield. Each was pro-rated based on the herd average. Secondly, production costs were desired to garner the economic value of benchmark calculations such as the value of minimal, practical and voluntary culling, the cost of non-optimal culling, and to evaluate optimal cow age.

A data sheet (Table 2) within the model served to input field results at each DHI test. The parameters used for this model included cow identification number, lactation number, days in milk, age at first calving, actual 305 day yield, actual 305 day milk value, mature equivalent milk value, reproductive status, linear score and calving interval. Holstein Canada and Ayrshire Canada provided indexing scores for each animal including Canadian milk/fat/protein scores and Canadian Lifetime Profit Index (www.cdn.ca).

The model then ranked cows at each test based on their individual performance in the herd and their economics (Table 3). This was accomplished by developing a ranking procedure for all cows in the herd based on a combination of economic and production indices. The economic index for each animal was measured using CM based on mature equivalent milk value[5]. Mature value was used to adjust the bias of age, allowing heifers

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[4] Contribution margin is defined here as revenues less variable costs.

[5] To calculate Mature Equivalent Milk Value, DHI uses the 305 day Projected Yields for Milk, Fat, and Protein to look up on the BCA tables, for an animal at 60 months of age, and the month of freshening is January. This number is then applied against her actual 305 day yields, and a factor is determined. This factor is then multiplied against her 305 day projected yields, and multiplied by DHI $ amounts for milk components shown on the bottom of the Cow Income Monitor Report to determine the Mature Equivalent Milk Value. The ME Holstein standards then are: 5292 kg for milk, 195 kg for fat and 165 kg for protein. Other breeds will have differing targets.

to compete on an even basis with older cows. The production index involved three effects on mature milk value: calving interval at minus 7% per month after 13 months (Pryce et al. 2000), age at first calving at minus 8.4% per year after 2 years (Arora et al. 1996), and Canadian Linear Score at minus 25% on each score above 3.0 (Hortet and Seegers 1998). Economic and production indices were combined on an even basis and resulted in a cow ranking within each herd. Cows were ranked in this fashion and immediately thereafter each farm was informed.

Heifers were ranked into the herd (i.e. into Table 3) by using their Canadian milk/fat/protein indices. The mature milk value for a new heifer was estimated thus:

Equation 1:

> Herd average Mature Equivalent Milk Value + (Heifer Canadian Milk Index- herd average Canadian Milk Index)*herd average Other Solids%/100 * price/kg OS + (heifer Canadian Fat Index - herd average Canadian Fat Index)*price/kg Fat + (heifer Canadian Protein Index – herd average Canadian Protein Index)*price/kg Protein

This equation provided a mature equivalent milk value for new heifers and, when used with animal costs, provided an estimate of mature CM and net income for these animals. This was adequate to rank the new animals into the herd. During the study, when Canadian indices were not available for heifers, values were identified at the first recorded DHI test soon after she started milking. In this fashion, heifers were retroactively ranked into the herd for evaluation.

THE ANALYSIS:

Farmers were informed about their worst set of cows and then at the next test, data was recorded as to which cows were actually culled vis-à-vis which ones should have been culled. It is important to remember that for a 100-cow herd, with normal culling rates of 33%, only 3 or 4 cows need be culled at each test. As a general observation, the worst cows were easy to identify, being severely deficient in milk yield, usually in the magnitude of half that of the best cows.

A retrospective matching procedure was executed to evaluate the discrepancies between optimal and actual culling decisions. Before each cull event, the data for each cow in the herd was entered into the culling model and the ranking algorithm was applied. The cows that ranked worst in the herd had the lowest value and therefore should have been culled. After the cull had been completed, each culled cow was retroactively labeled as an “Actual Cull”. Next, a group of cows, the number of which was equivalent to the number of Actual Cull cows, was selected from the bottom of the pre-cull herd; those cows were labeled “Optimal Cull” cows. If the Actual Cull group matched the Optimal Cull group exactly, the farmer had culled optimally. Any Actual Cull cow which was not in the Optimal Cull group represented a non-optimal culling decision; thus, the cull was, at least to some extent, considered involuntary. The difference between the NPV of future earnings of optimal and non-optimal culls created a ‘cost’ of non-optimal culling and thus was one proxy for the value of longevity.

Each of the Actual Cull cows was paired with an Optimal Cull cow. If an Actual Cull cow was included in the Optimal Cull group, it was paired with itself. The remaining culls were paired as follows: The lowest-ranked Actual Cull cow was paired with the lowest-ranked Optimal Cull cow, the next-lowest Actual Cull with the next-lowest Optimal Cull, and so forth until all cows were paired. Economic variables were then evaluated across all cow-pairs to determine the effects of culling and the relationship with age. Matching enhanced the analysis by allowing non-optimal culling to be quantified by dollars and rank by measuring the differences in these variables between pairs.

NPV of future CMs were calculated for each Optimal and Actual Cull animal (Table 4a), and each new heifer (Table 4b). Based on CMs, the lactation yield curve has been imbedded in the calculations evenly between lactations, and then discounted at a rate of 7% per lactation (or year). The value of the useful life of an animal was for the duration of ten lactations from the oldest animal in the paired group.

Two datasets were created and analyzed. The first data set contained all records from all DHI reports for all farms, some 18,000 cow records over 25 months on 7 farms. The second set contained only data from animals involved in the culling decision: the Optimal Cull cows, the Actual Cull cows, and potential replacement heifers. These datasets were analyzed separately.

The complete data set was used to determine a relationship between value (NPV of lifetime CM) and age (lactation number). The data set with only animals involved in the culling decisions was used to estimate the value of involuntary culling, and the ranking of heifers versus older cows.

Optimal age was determined by using the model to rank cows at each lactation number. The model used ten cows, one per lactation, each adjusted for milk yield by lactation, variable costs and genetic improvements. Fixed costs included cow depreciation using the straight line method, varying in the amount of $2,000, $1,000 or $0 of depreciation over the life of the cow, itself varying from one to ten lactations. The model then was used to rank cows based on their lactation number.

Finally, to determine minimal and practical culling rates, each cow on each farm in March 2005 was tested for negative CMs and for failure to cover its share of fixed costs. This was simply a listing of data, which was sorted and counted.

SPSS (version 12.0) was used as an analytical tool. Data analysis included averages, standard deviations, t-tests, correlations of age on NPV, and regression analysis. For the whole herd, age was correlated with rank (‘normalized’ using a percentile and sample size of 400 records), 305-day actual net income (ANI), and DHI adjusted mature net income (MNI). Regression analysis was also done for each of these by farm and then for the group as a whole, with the purpose of identifying a relationship between value and age.

RESULTS AND DISCUSSION

ANALYIS OF ANIMALS INVOLVED WITHIN THE CULLING DECISION:

A total of 636 cows were culled in the 25 months of this study from the seven farms. Cull rates paralleled Ontario average cull rates published by DHI (CanWest DHI 2003-4). In our study, 29.8% of cows were culled between April 2003 and March 2004; Ontario’s 2003 average was slightly higher at 31.7% (CanWest DHI 2003). In the second year of our study, cull rates increased to 36.4%, similar to Ontario’s 2004 average of 36.1% (CanWest DHI 2004). The increase in cull rates was likely a result of farmers reacting to the BSE crisis. The devaluation of cull stock resulted in farmers ‘stockpiling’ cull cows. After a full year of the BSE crisis and with no relief in sight, farmers finally yielded and sold off excess cull stock, raising the cull rate from 31.7% to 36.1%.

At each cull event, Actual Cull cows were matched with Optimal Cull cows. Only 21.6% of Actual Cull cows were included in the Optimal Cull group. Therefore, 78.4% of culls were considered non-optimal or involuntary, at least to some extent. The NPV of lifetime CM was used as a measure of an animal’s value (again, this NPV number was for the remainder of the oldest of the pairs' life). The NPV of the Optimal Cull cow group was $4,596[6] per cow, while that for the Actual Cull cow group was much more at $9,687 per cow (Table 5). Thus the cows that were actually being culled were much better cows and the difference in value between them represents the cost of non-optimal culling. Each involuntary cull resulted in an average loss of $5,091 NPV in potential future milk CM.

The rank of Actual Cull cows averaged at the 31st percentile in the herd, with one being the worst (Table 5). Although significantly smaller than the herd average ($p<0.01$), the average rank of Actual Cull cows was significantly greater than the mean rank of Optimal Cull cows (3.6%), indicating that producers were not culling optimally ($p<0.01$). Furthermore, the average rank of culled cows was better approximated by the herd average than the optimal average, indicating that chance (involuntary culling) had a greater effect on cull selection than farmer choice. This again indicates a large amount of involuntary culling, which had a profound effect on profit and longevity. The problem that exists on-farm is seen when a superior cow is involuntarily culled, requiring two inferior cows to maintain production quota. Over time, inferior cows seem to be 'collecting' at the farm by remaining in the herd as long as they are healthy and contributing even a little bit of milk. Involuntary culling will therefore exacerbate the problem of too many inferior cows. If involuntary culling could be eliminated, a much smaller culling rate could be maintained, saving significant amounts of money and extending longevity. Methods to reduce involuntary culling are worthwhile investigating.

Actual Cull cows had a lesser number of lactations, higher days-in-milk in their current cycle, and higher NPV of future CMs than Optimal Cull cows (Table 5). This

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[6] All in Canadian Dollars

indicates that producers were culling young cows, choosing cows that were towards the end of their lactation curve and culling problem cows that otherwise should have been milking at a profitable level ($P < 0.01$).

A total of 651 replacement heifers were added to the seven herds over the 25 months, which was roughly equivalent to the number of culls. Heifers ranked well up into the herd on average, upon entry into the herd. Averaging at the 57th percentile upon herd entry (Table 5), heifers ranked significantly greater than the herd mean of 50% ($p<0.01$). The NPV of new heifers' CM was \$17,678 on average, well above that of both Optimal Cull cows (\$4,596, $p<0.01$) and Actual Cull cows (\$9,687, $p<0.01$).

Culling of heifers was extremely rare. In fact, of the 651 heifers, only 22 (3.4%) were ranked for cull upon entry into a herd in the 25 months of the trial. It is clear that the strategy of keeping all heifers for herd replacement is optimal. The results show that at most test dates there were very poor-doing cows in each herd. Heifers were seldom at risk of not competing with the worst set of cows in a herd. Again, it helps to remember that within a 100-cow herd, only three or four cows are being culled at each DHI test date.

Correlating cow lactation number with NPV of future CM identified a relationship between age and value. There was a small but statistically significant relationship between this value for Optimal Cull cows and their age, with a negative correlation of -0.29 and a regression coefficient of -\$1,058 per lactation ($R^2 = 0.084$, $p<0.01$) on a lifetime earning of only \$7,737 NPV (Table 5). For poorly ranked cows, producers would lose only \$1,058 in lost future NPV CM per lactation if the animal were culled. Age alone explained only 8.4% of this loss. In a similar fashion, the correlation of age on NPV of future CM of Actual Cull cows was -0.37 and the regression coefficient was -$1,817 ($R^2$ = 0.137, p<0.01) on a lifetime earnings of $14,782 (Table 5). For this group of cows, producers will lose a lesser amount of $1,817 in future NPV CM per lactation if these animals were culled, and from a greater potential lifetime earning of $14,782. The relationship found here between age and value within the Actual Cull group is again significant but very weak.

ANALYSIS OF THE WHOLE HERD DATA:

Data for all cattle in the seven herds was summarized for the 25 months of the project (about 20 DHI tests each). This method of data collection resulted in data being collected for the same set of cows as time went on, except for some cows that left the herds while other heifers entered the herds. Lactation number (age) was correlated and regressed on rank (normalized for herd size), 305 day ANI and MNI. Out of 18,416 cow records, 7,272 were first lactation and 5,019 were second lactation records. Only 19 records exist for lactations 10 and 11, and represent only three cows (Table 6). Analysis after lactation six became unreliable because of insufficient data.

To help correct for the data bias (number of records at each lactation number), 400 records from cows in each of the first to fifth lactations and all 283 records from the sixth lactation cows were randomly selected for further analysis.

The correlation of age on rank was –0.23 and the regression coefficient was –6.04 ranking points percentile (Table 6). With each new lactation, a cow dropped 6.04 percentile on average in rank in the herd, i.e. each generation of cows was better than the previous one (P<.01). The ranking process used here was the production and economic index inherent within the model, where the economic index used mature milk income and so the ranking was adjusted for the effect of age on milk yield. The reduction in rank with age is therefore mostly attributable to genetic improvements. Considering lactations separately, cows constantly descended in rank throughout the first six lactations, with the largest drop occurring between the second and third lactations.

The correlation of lactation number on ANI was positive at 0.07 and the average regression coefficient was $44.28 ($R^2$= .469, p<.01) (Table 6). ANI increased by $44.28 per lactation on average for the first 6 lactations, agreeing with Stott (1994). The second lactation improved by $425, the third decreased by $31, the fourth increased by $65, the fifth improved by only $20 and the sixth went down by $293. Because of the method used to collect data, animals at each lactation number were different animals for the most part, and so there were at least two opposing economic forces at play here. Improvements in milk yields are known to occur up to and including the third lactation, and genetic improvements accrue at each generation.

The correlation of age on MNI was –0.34 and the average regression coefficient was -$254 per lactation ($R^2$=0.642, P<0.01) (Table 6). Because DHI's Mature-Equivalent Milk Value adjusts 305 day actual milk value for cow age, differences here between lactations are attributable to genetic improvement. Each new generation of heifers was $254 genetically better than the previous one, on average.

In Table 6 the changes of MNI for the first four lactation totals were -$971. Due to the nature of MNI, this value has been adjusted for lactation yield and so the change must be attributed to genetic improvements. In a similar fashion, the changes for ANI for the first four lactations total $459. This change must be due to both lactation yield and genetic improvements. Since these forces work against one another, the lactation yield must be $1,430: the difference of the two. Since milk yield improvements and genetic gains cannot accrue in the same animal, the tradeoff can be stated that 68% of the benefits of having mature cows can be replaced by improved genetics. The R^2 was fairly high for this model, indicating the model has a good fit with the data, particularly for MNI on age where lactation number accounted for 64.2% of variance.

AN ESTIMATION OF OPTIMAL COW AGE AND OPTIMAL LONGEVITY:

The opposing forces of cow depreciation and lactation yield improvements (each favouring older cows) versus genetic improvement (favouring new heifers) must be considered when evaluating longevity. At the beginning of 2003, depreciation on a dairy cow in Ontario was about $2,000 over a longevity of about 4.4 lactations. During the project, cow depreciation plummeted to about $400 due to the Canadian BSE crisis. This high or low amount of depreciation can be allocated up to 10 lactations for the purposes of this study.

Genetic improvements happen at each generation and are assumed to be cumulative since most genetic progress of Canadian dairy cows is accountable to the bull's side. Genetic improvement was measured at $254 per generation on average.

Lactation curve improvements for the whole herd data were measured from our data and results showed improvements in yield of 30.7% between first and fourth lactations, 13.7% between second and fourth, and 5% between third and fourth lactations. As cows get older, they milk more up to the fourth lactation.

Our model was modified and used to rank cows given the opposing economic factors of depreciation (straight line method) and lactation yield improvements versus genetic improvement. The culling model was modified to include only ten cows, one at each lactation number. The budgets were adjusted for milk value and yield, cow costs and genetic improvements, all for lactation number and then the model was used to rank them. Total depreciation was assumed and accounted into the costs at each lactation number. For example, a cow in her 6th lactation was assumed to be culled here, and so all her depreciation was accounted for over longevity of 6 lactations. This time the ranking was based only on the economic ranking and used 305 day ANI, i.e. not adjusted for age. The results showed the ANI a cow would earn at each lactation number. The economic scenarios included high and low depreciation levels to observe the robust nature of the relationship of cow earning value on age. These scenarios were again reverse-ranked, with one being the worst.

Keeping cows for one or ten lactations were ranked the worst options with large depreciation (Table 7). When depreciation levels were small, a shorter longevity could be somewhat justified. Fourth lactation cows were consistently ranked the best no matter what the level of depreciation. Rankings rapidly improved to the fourth lactation and then diminished to the tenth. Therefore, a replacement strategy that replaces cows at the first or the tenth lactations were the worst. It was optimal to manage cows to reach the fourth lactation and then remove inferior cows thereafter. The average longevity for our seven herds was 4.37 lactations, which is just about optimal. The interesting observation here is that managing for longevity after the fourth lactation was not optimal.

AN ESTIMATION OF MINIMUM AND OPTIMUM CULLING RATES:

Production quota and non-optimal culling both interfere with the culling process. The implication of producing milk to meet quota can be seen within our data, as inferior cows were kept sometimes for as many as five tests (six months) before being culled. As long as a cow was healthy and producing some milk, she remained in the herd if needed to meet quota. In addition, involuntary culling interfered with voluntary culling by replacing it, and thus exacerbated the need to keep inferior cows to meet quota. An optimal culling rate will assume zero involuntary culling and therefore, becomes somewhat of a hypothetical benchmark. This analysis of replacement heifers has strongly shown that almost all home-grown replacement heifers should be given an opportunity to perform within the herd. So, given the cows and their rankings during this study and assuming no involuntary culling while retaining all home-grown heifers, then how many cows should have been culled? The model was used to estimate minimal, practical and voluntary benchmarks for culling rate for our seven farms.

Minimal culling rate is defined as those cows that had a negative CM based on mature milk value. Unless there were quickly fixable reasons why these cows had tests that were so low, these cows should not remain in the herds. A practical cull rate is defined as those cows that earn their full cost-of-production, i.e. mature adjusted milk revenues less variable and fixed costs are greater than zero. A voluntary cull rate is proposed here as the post-cleanout rate. Because heifers rank into the herd on average at the 57th percentile, then the difference between the practical cull rate and where heifers rank is what remains to be replaced, called here a voluntary rate. This assumes that all the cows not making their cost-of-production are culled, leaving a group of cows ranking between a point of breaking even and one where heifers rank into the herd. None of this is defined as optimal, because the option of purchasing replacement heifers is not considered.

To accomplish an estimation of a minimal culling rate, the data was amalgamated for the seven farms. One DHI test (March 2005) was used from each farm, where all cows were grouped together so as to make up one herd. In total 913 cows were included, 822 cows ranked and 91 cows were not ranked (dry cows with no test data were not ranked, however these cows were expected to soon calve and would normally not be considered for immediate culling). During March, 55 cows had negative CMs based on mature milk value. These negative contribution cows contribute nothing to pay for fixed costs. The data showed that these 55 cows collectively had a CM of negative $18,060 per year, which would be added to profits if they were removed from the herds, even if no cows were to replace them ($19.78 per average cow). The heifers however, ranking at the 57th percentile, were found to contribute $2,000 per year on average in CM. Only 42 heifers were needed to replace these 55 inferior cows. The result of replacing 55 inferior cows with 42 average heifers would be $84,000 per year in additional CMs. And the 13 cows reduced from the herd had variable cost of $51,740 per year which is now a savings ($92.00 and $56.67 per year respectively over a total of 913 cows).   The minimal cull rate is then 6% with a net savings of $168.45 per year for each cow in the herd.

The practical culling rate can be defined when total costs of production are earned. Again, MNI was used. In our case, 314 replacement heifers would be needed to replace 366 substandard cows based on MNI, or a cull rate of 40% which was slightly higher than the Ontario provincial average during 2004 of 36%. The savings of variable costs on 52 cows was $197,362 per year and the difference in additional CM between these 366 inferior cows and an average heifer was $267,474 per year ($216 and $293 per year respectively over a total of 913 cows). This is about as many heifers as can be home-raised in one year. So again, retaining all heifers for replacement seems to be the correct replacement strategy at the farm level.

This farm level analysis depended on the ranking system of cows. Rankings were based on a combination of a production and economic index. Estimates for the robust nature of this index were tested, and it was found that a pure production index provided much the same result as a pure economic index. A test of correlations was used to test ranking schemes amongst each other. It was concluded that any reasonable measurement of cow performance, including yield, actual gross milk value, mature gross milk value, net actual or net mature milk value, will identify the inferior cows within a herd. This is the group really necessary to exercise a successful culling strategy, and so regardless of the ranking process, similar results would accrue.

CONCLUSIONS

It became apparent early on in this study that it was practical to keep all home-grown heifers for replacements. Very few heifers did not rank well up into the herd, and on average they ranked 57th percentile. With so few inferior heifers, it would not be worthwhile sorting them out before they were to enter the herd.

Concerted efforts are warranted to minimize involuntary culling through new research and management practices. Too many animals are lost to reproductive failure and injury, particularly during their first lactation. A potential area of concern is identified with young cows, as it seems they are not able to compete in modern dairy barns with older cows and therefore management practices need to reflect this.

This research found very little relationship between longevity and value. Younger cows were found to be better, largely due to genetic progress at each new generation.

Two opposing factors at play are genetic improvements and lactation curve improvements. From this analysis, the total improvement for the whole herd on average was estimated at $1,430 from first to fourth lactation. Of this, 68% of the benefit of having mature cows was replaced by improved genetics.

The optimal replacement strategy ‘to plan on four lactations and then remove inferior cows thereafter’ predicts what farmers were doing. The average longevity for our seven herds was 4.37 lactations while the average for the Ontario industry was 4.4 during this time. Many first lactation cows were being culled, which was the worst scenario for culling. The industry could do much better in this area, which would greatly improve herd longevity. Conversely, industry goals that reward longevity towards the tenth lactation need to be reconsidered as this is the second worst longevity scenario.

The minimum-culling rate was estimated at 6% and had a net benefit of $168 for every cow in the herd. A practical culling rate of 40% would save an additional amount of $509 for every cow in the herd. If inferior cows were disposed of, and only voluntary culling pressures were maintained, an estimated 17% annual culling rate (57% minus 40%) would prevail, which agrees with Redman and Kuo (1969).

This farm level assessment of dairy cow longevity has successfully accounted for producer decisions for replacing cows. In Ontario, quota demands and involuntary culling are two factors that are contributing to high cull rates and shorter longevity. Post-BSE with low heifer values, an opportunity exists to replace a large portion of inferior cows at a reasonable cost by purchasing replacement heifers. This will reap significant profits, lower future cull rates and improve herd longevity. The need to reduce involuntary culling in the meanwhile is essential because herds will refill themselves with inferior cows if culling pressure is not maintained on this optimal cull group of cows.

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REFERENCES

Allaire, F. R. 1981. Economic consequences of replacing cows with genetically improved heifers. *Journal of Dairy Science* 64: 1985-95.

Arora, C. L., R. A. Singhal, R. C. Garg and N. B. Subramanian. 1996. Age at first calving in Frieswal cows and its influence on first lactation milk traits. *Indian Journal of Animal Sciences* 66 (10): 1067-9.

Richard Bellman. 1962. Dynamic Programming Treatment of the Traveling Salesman Problem. *Journal of the ACM* 9(1): 61-63.

Bailey, T. 1999. Heifer inventory and the economics of replacement rearing. Virginia: Virginia Cooperative Extension, Retrieved August 12, 2005 from http://www.ext.vt.edu/pubs/dairy/404-287/404-287.html

Bauer, L., G. Mumey and W. Lohr. 1993. Longevity and genetic improvement issues in replacing dairy cows. *Canadian Journal of Agricultural Economics* 41 (1): 71-80.

Ben-Ari, Y., I. Amir and S. Sharar. 1983. Operational replacement decision model for dairy herds. *Journal of Dairy Science* 66: 1747-59.

CanWest DHI. 2004. 2004 Management Centre Benchmarks. Retrieved August 12, 2005 from http://www.canwestdhi.com/pdf_files/2004%20ontario%20benchmarks.pdf

CanWest DHI. 2003. 2003 Management Centre Benchmarks. Retrieved August 12, 2005 from http://www.canwestdhi.com/pdf_files/final%20benchmark%20for%202003.pdf

Eicker, S. and J. Fetrow. 2003. A Prospective View of Culling. Proceedings from 2003 Midwest Dairy Herd Health Conference. Madison: University of Wisconsin – Madison.

Faust, M. 1993. Capitalizing on dairy cow head life. Iowa: Iowa State University.

Hoekema, M. J. 2000. Guess what may be eating your lunch: the hidden costs of cull rate. Retrieved June 25, 2005 from http://www.animal.ufl.edu/dbap. Florida: Florida Georgia Dairy Business Analysis Project.

Hortet, P. and H. Seegers. 1998. Calculated milk production losses associated with elevated somatic cell counts in dairy cows: review and critical discussion. *Veterinary Research* 29 (6): 497-510.

Jairath, L., J. C. M. Dekkers, L. R. Shaeffer, Z. Liu, E. B. Burnside and B. Kolstad. 1998. Genetic evaluation for herd life in Canada. *Journal of Dairy Science* 81 (2): 550-62.

Kennedy, J. O. S. and A. W. Stott. 1993. An adaptive decision-making aid for dairy cow replacement. *Agricultural Systems* 42: 25-39.

Kristensen, A.R. 1987. Optimal replacement and ranking of dairy cows determined by a hierarchic Markov Process. *Livestock Production Science* 16: 131-44.

Kulak, K. K., J. C. M. Dekkers, A. J. McAllister and A. J. Lee. 1997. Lifetime profitability measures for dairy cows and their relationships to lifetime performance traits. *Canadian Journal of Animal Science* 77 (4): 609-16.

Pryce, J. E., M. P. Coffey and S. Brotherstone. 2000. The genetic relationship between calving interval, body condition score and linear type and management traits in registered Holsteins. *Journal of Dairy Science* 83 (11): 2664-71.

Redman, J. C. and L. P. H. Kuo. 1969. Replacement of dairy cows: A multistage decision-making problem. Research Report 1. Lexington: University of Kentucky, December.

Smith, B. J. 1973. Dynamic Programming of the Dairy Cow Replacement Program. *American Journal of Agricultural Economics* 55 (1): 100-04.

Steinwidder, A. and M. Greimel. 1999. Economic valuation of longevity of dairy cows. *Austrian Journal of Agricultural Research* 4: 50-56.

Stott, A. W. 1994. The economic advantage of longevity in the dairy cow. *Journal of Agricultural Economics* 45 (1): 113-22.

Taylor, C. R. 1993. Dynamic programming and curses of dimensionality. In *Applications of Dynamic Programming to Agricultural Decision Problems*, edited by C. Robert Taylor. Boulder, Colorado: Westview Press.

Weigel, D. J., B. G. Cassell, I. Hoeschele and R. E. Pearson. 1995. Multiple-trait prediction of transmitting abilities for herd life and estimation of economic weights using relative net income adjusted for opportunity cost. *Journal of Dairy Science* 78 (3): 639-47.

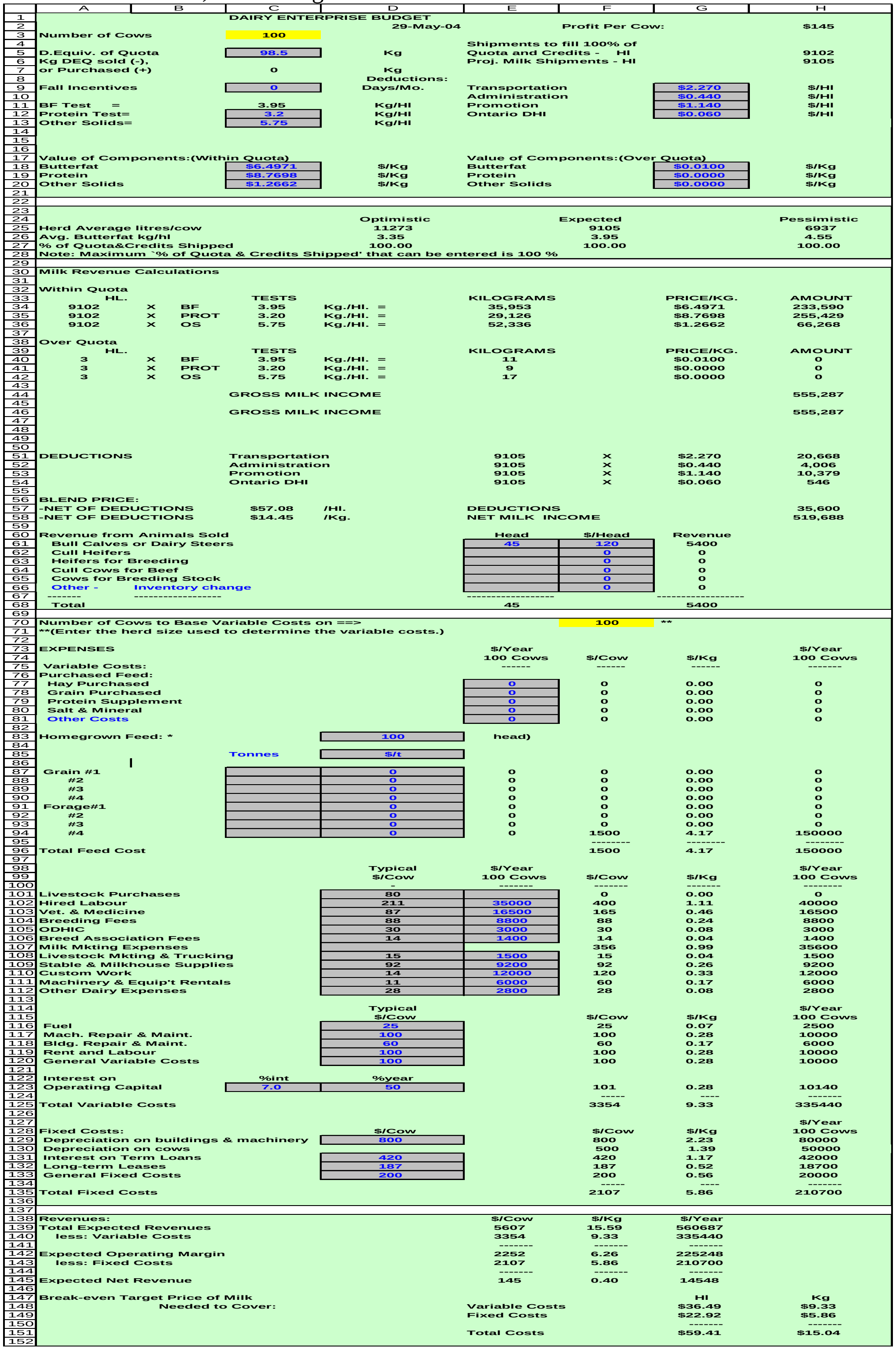
van Arendonk, J.A.M. 1984. A model to estimate the performance, revenues and costs of dairy cows under different production and price situations. *Agricultural Systems* 16: 157-89.

Vargas, B., M. Herrero and J. A. M. van Arendonk. 2001. Interactions between optimal replacement policies and feeding strategies in dairy herds. *Livestock Production Science* 69 (1): 17-31.

Vollema, A. R. and A. F. Groen. 1996. Genetic parameters of longevity traits of an upgrading population of dairy cattle. *Journal of Dairy Science.* 79 (12): 2261-7

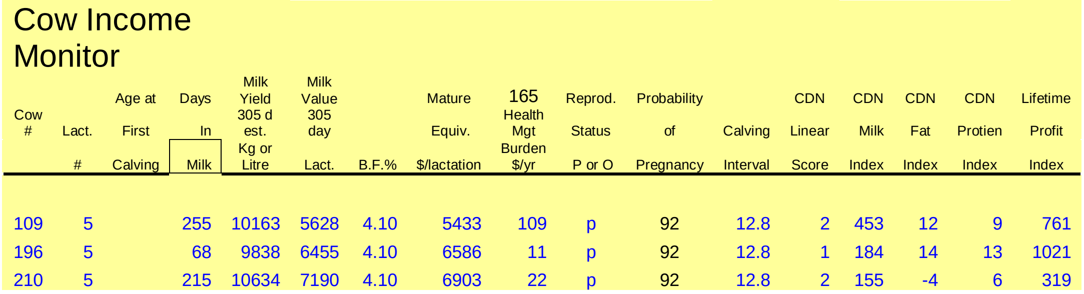
www.cdn.ca, Lifetime Profit Index. Canadian Dairy Network.

Table 1: The Model, Farm Budget



	A	B	C	D	E	F	G	H
1			DAIRY ENTERPRISE BUDGET					
2				29-May-04		Profit Per Cow:		$145
3	Number of Cows		100					
4					Shipments to fill 100% of			
5	D.Equiv. of Quota		98.5	Kg	Quota and Credits - Hl			9102
6	Kg DEQ sold (-),				Proj. Milk Shipments - Hl			9105
7	or Purchased (+)		0	Kg				
8				Deductions:				
9	Fall Incentives		0	Days/Mo.	Transportation		$2.270	$/Hl
10					Administration		$0.440	$/Hl
11	BF Test =		3.95	Kg/Hl	Promotion		$1.140	$/Hl
12	Protein Test=		3.2	Kg/Hl	Ontario DHI		$0.060	$/Hl
13	Other Solids=		5.75	Kg/Hl				
14								
15								
16								
17	Value of Components:(Within Quota)				Value of Components:(Over Quota)			
18	Butterfat		$6.4971	$/Kg	Butterfat		$0.0100	$/Kg
19	Protein		$8.7698	$/Kg	Protein		$0.0000	$/Kg
20	Other Solids		$1.2662	$/Kg	Other Solids		$0.0000	$/Kg
21								
22								
23								
24				Optimistic		Expected		Pessimistic
25	Herd Average litres/cow			11273		9105		6937
26	Avg. Butterfat kg/hl			3.35		3.95		4.55
27	% of Quota&Credits Shipped			100.00		100.00		100.00
28	Note: Maximum `% of Quota & Credits Shipped' that can be entered is 100 %							
29								
30	Milk Revenue Calculations							
31								
32	Within Quota							
33	HL.		TESTS		KILOGRAMS		PRICE/KG.	AMOUNT
34	9102	X BF	3.95	Kg./Hl. =	35,953		$6.4971	233,590
35	9102	X PROT	3.20	Kg./Hl. =	29,126		$8.7698	255,429
36	9102	X OS	5.75	Kg./Hl. =	52,336		$1.2662	66,268
37								
38	Over Quota							
39	HL.		TESTS		KILOGRAMS		PRICE/KG.	AMOUNT
40	3	X BF	3.95	Kg./Hl. =	11		$0.0100	0
41	3	X PROT	3.20	Kg./Hl. =	9		$0.0000	0
42	3	X OS	5.75	Kg./Hl. =	17		$0.0000	0
43								
44			GROSS MILK INCOME					555,287
45								
46			GROSS MILK INCOME					555,287
47								
48								
49								
50								
51	DEDUCTIONS		Transportation		9105	X	$2.270	20,668
52			Administration		9105	X	$0.440	4,006
53			Promotion		9105	X	$1.140	10,379
54			Ontario DHI		9105	X	$0.060	546
55								
56	BLEND PRICE:							
57	-NET OF DEDUCTIONS		$57.08	/Hl.	DEDUCTIONS			35,600
58	-NET OF DEDUCTIONS		$14.45	/Kg.	NET MILK INCOME			519,688
59								
60	Revenue from Animals Sold				Head	$/Head	Revenue	
61	Bull Calves or Dairy Steers				45	120	5400	
62	Cull Heifers					0	0	
63	Heifers for Breeding					0	0	
64	Cull Cows for Beef					0	0	
65	Cows for Breeding Stock					0	0	
66	Other -	Inventory change				0	0	
67	-------	------------------			------------------		------------------	
68	Total				45		5400	
69								
70	Number of Cows to Base Variable Costs on ==>					100	**	
71	**(Enter the herd size used to determine the variable costs.)							
72								
73	EXPENSES				$/Year			$/Year
74					100 Cows	$/Cow	$/Kg	100 Cows
75	Variable Costs:				------	------	------	-------
76	Purchased Feed:							
77	Hay Purchased				0	0	0.00	0
78	Grain Purchased				0	0	0.00	0
79	Protein Supplement				0	0	0.00	0
80	Salt & Mineral				0	0	0.00	0
81	Other Costs				0	0	0.00	0
82								
83	Homegrown Feed: *			100	head)			
84								
85			Tonnes	$/t				
86		I						
87	Grain #1			0	0	0	0.00	0
88	#2			0	0	0	0.00	0
89	#3			0	0	0	0.00	0
90	#4			0	0	0	0.00	0
91	Forage#1			0	0	0	0.00	0
92	#2			0	0	0	0.00	0
93	#3			0	0	0	0.00	0
94	#4			0	0	1500	4.17	150000
95						--------	--------	--------
96	Total Feed Cost					1500	4.17	150000
97								
98				Typical	$/Year			$/Year
99				$/Cow	100 Cows	$/Cow	$/Kg	100 Cows
100				-	-------	-------	-------	--------
101	Livestock Purchases			80		0	0.00	0
102	Hired Labour			211	35000	400	1.11	40000
103	Vet. & Medicine			87	16500	165	0.46	16500
104	Breeding Fees			88	8800	88	0.24	8800
105	ODHIC			30	3000	30	0.08	3000
106	Breed Association Fees			14	1400	14	0.04	1400
107	Milk Mkting Expenses					356	0.99	35600
108	Livestock Mkting & Trucking			15	1500	15	0.04	1500
109	Stable & Milkhouse Supplies			92	9200	92	0.26	9200
110	Custom Work			14	12000	120	0.33	12000
111	Machinery & Equip't Rentals			11	6000	60	0.17	6000
112	Other Dairy Expenses			28	2800	28	0.08	2800
113								
114				Typical				$/Year
115				$/Cow		$/Cow	$/Kg	100 Cows
116	Fuel			25		25	0.07	2500
117	Mach. Repair & Maint.			100		100	0.28	10000
118	Bldg. Repair & Maint.			60		60	0.17	6000
119	Rent and Labour			100		100	0.28	10000
120	General Variable Costs			100		100	0.28	10000
121								
122	Interest on		%int	%year				
123	Operating Capital		7.0	50		101	0.28	10140
124						-----	----	-------
125	Total Variable Costs					3354	9.33	335440
126								
127								$/Year
128	Fixed Costs:			$/Cow		$/Cow	$/Kg	100 Cows
129	Depreciation on buildings & machinery			800		800	2.23	80000
130	Depreciation on cows					500	1.39	50000
131	Interest on Term Loans			420		420	1.17	42000
132	Long-term Leases			187		187	0.52	18700
133	General Fixed Costs			200		200	0.56	20000
134						-----	----	-------
135	Total Fixed Costs					2107	5.86	210700
136								
137								
138	Revenues:				$/Cow	$/Kg	$/Year	
139	Total Expected Revenues				5607	15.59	560687	
140	less: Variable Costs				3354	9.33	335440	
141					-------	-------	-------	
142	Expected Operating Margin				2252	6.26	225248	
143	less: Fixed Costs				2107	5.86	210700	
144					-------	-------	-------	
145	Expected Net Revenue				145	0.40	14548	
146								
147	Break-even Target Price of Milk						Hl	Kg
148		Needed to Cover:			Variable Costs		$36.49	$9.33
149					Fixed Costs		$22.92	$5.86
150							-------	-------
151					Total Costs		$59.41	$15.04
152								

Table 2: The Model, Cow Data



Cow Income Monitor

Cow #	Lact. #	Age at First Calving	Days In Milk	Milk Yield 305 d est. Kg or Litre	Milk Value 305 day Lact.	B.F.%	Mature Equiv. $/lactation	165 Health Mgt Burden $/yr	Reprod. Status P or O	Probability of Pregnancy	Calving Interval	CDN Linear Score	CDN Milk Index	CDN Fat Index	CDN Protien Index	Lifetime Profit Index
109	5		255	10163	5628	4.10	5433	109	p	92	12.8	2	453	12	9	761
196	5		68	9838	6455	4.10	6586	11	p	92	12.8	1	184	14	13	1021
210	5		215	10634	7190	4.10	6903	22	p	92	12.8	2	155	-4	6	319

Table 3: The Model, Cow Ranking

Economic Ranking

19-Mar-05

174 Cows

			Mature Equivalent Annual								-------- Reverse ----------		
Cow #	Marginal Over Quota Milk Value	Milk Value for 305 day Lact.	Milk Value	Var. Costs	Fixed Costs	Cont. Margin	Net Income	Actual Net Income	Fisher's Production Score	LPI Ranking	Economic Ranking	Production Ranking	Worst Cow
482	0	3983	4217	2578	1918	1639	-279	-513	3391	123	5	3	3
436	0	7112	7934	2875	1918	5059	3141	2319	6610	126	143	120	131
437	0	7157	7378	3030	1918	4348	2430	2209	6109	119	112	92	106

8 Table 4a: Net Present Value of Worst Cow

9

10

Lactation #	NPV	Actual CM
the cow		
=IF(B6=1,SUM(U$41:U$50),0)	=V41	=IF(B6=1,'WORST COW VS REPLACEMENT'!D14,0)
=IF(B6=2,SUM(U42:U50),0)	=PV('WHOLE HERD'!C123/100,2,,-V42,0)	=IF(B6<=2,'WORST COW VS REPLACEMENT'!D14+(ANALYSIS!G13-'WORST COW VS REPLACEMENT'!D14)/3,0)
=IF(B6=3,SUM(U43:U50),0)	=PV('WHOLE HERD'!C123/100,3,,-V43,0)	=IF(B6<=3,'WORST COW VS REPLACEMENT'!D14+(ANALYSIS!G13-'WORST COW VS REPLACEMENT'!D14)*2/3,0)
=IF(B6=4,SUM(U44:U50),0)	=PV('WHOLE HERD'!C123/100,4,,-V44,0)	=G13
=IF(B6=5,SUM(U45:U50),0)	=PV('WHOLE HERD'!C123/100,5,,-V44,0)	=G13
=IF(B6=6,SUM(U46:U50),0)	=PV('WHOLE HERD'!C123/100,6,,-V44,0)	=G13
=IF(B6=7,SUM(U47:U50),0)	=PV('WHOLE HERD'!C123/100,7,,-V44,0)	=G13
=IF(B6=8,SUM(U48:U50),0)	=PV('WHOLE HERD'!C123/100,8,,-V44,0)	=G13
=IF(B6=9,SUM(U49:U50),0)	=PV('WHOLE HERD'!C123/100,9,,-V44,0)	=G13
=IF(B6=10,U50,0)	=PV('WHOLE HERD'!C123/100,10,,-V44,0)	=G13

11

12 Table 4b: Net Present Value of Replacement Heifers

13

Lactation #	NPV	Actual CM
the heifer		
=IF(B6=1,SUM(X$41:X$50),0)	=Y41	='WORST COW VS REPLACEMENT'!F$14*'$ RANKING'!C$181/'$ RANKING'!D$181
=IF(B6=2,SUM(X$42:X$50),0)	=PV('WHOLE HERD'!C123/100,2,,-Y42,0)	='WORST COW VS REPLACEMENT'!F$14*'$ RANKING'!C$181/'$ RANKING'!D$181
=IF(B6=3,SUM(X$43:X$50),0)	=PV('WHOLE HERD'!C123/100,3,,-Y43,0)	='WORST COW VS REPLACEMENT'!F$14*'$ RANKING'!C$181/'$ RANKING'!D$181
=IF(B6=4,SUM(X$44:X$50),0)	=PV('WHOLE HERD'!C123/100,4,,-Y44,0)	='WORST COW VS REPLACEMENT'!F$14
=IF(B6=5,SUM(X$45:X$50),0)	=PV('WHOLE HERD'!C123/100,5,,-Y45,0)	='WORST COW VS REPLACEMENT'!F$14
=IF(B6=6,SUM(X$46:X$50),0)	=PV('WHOLE HERD'!C123/100,6,,-Y46,0)	='WORST COW VS REPLACEMENT'!F$14
=IF(B6=7,SUM(X$47:X$50),0)	=PV('WHOLE HERD'!C123/100,7,,-Y47,0)	='WORST COW VS REPLACEMENT'!F$14
=IF(B6=8,SUM(X$48:X$50),0)	=PV('WHOLE HERD'!C123/100,8,,-Y48,0)	='WORST COW VS REPLACEMENT'!F$14
=IF(B6=9,SUM(X$49:X$50),0)	=PV('WHOLE HERD'!C123/100,9,,-Y49,0)	='WORST COW VS REPLACEMENT'!F$14
=IF(B6=10,43,0)	=PV('WHOLE HERD'!C123/100,10,,-Y50,0)	='WORST COW VS REPLACEMENT'!F$14

Table 5: Comparison of Optimal-Cull Cows, Actual-Cull Cows and Heifers

	Optimal Cull	Actual Cull	Heifers
Future Contribution Margin (NPV)	$4,596	$9,687	$17,678
Rank Percentile	3.6%	31.8%	57.1%
Days in Milk	143	187	-
Lactation Number	2.9	1.6	-
Correlation Coefficient Age vs. NPV	-.290	-.370	-

Table 6. Economic Variables and Rank by Lactation Number – Total Herd

	Counts		Rank		Actual Net Income		Mature Net Income	
Age	Original	Sample	Mean	Change	Mean	Change	Mean	Change
1	7272	400	73.7	--	-659	--	835	--
2	5019	400	69.9	*-3.8*	-234	*425*	500	*-335*
3	3159	400	59.7	*-10.1*	-265	*-31*	-39	*-539*
4	1687	400	55.6	*-4.2*	-200	*65*	-136	*-97*
5	789	400	49.5	*-6.1*	-180	*20*	-225	*-88*
6	283	283	44.8	*-4.6*	-474	*-293*	-457	*-232*

Table 7. Effects of Depreciation Amounts on Actual Net Income and Rank - Average

Age	Milk Value	Variable Costs	Fixed Costs Depreciation at			Actual Net Income Depreciation at			Rank Depreciation at		
			0	1000	2000	0	1000	2000	0	1000	2000
1	5972	3352	0	1000	2000	2620	1620	620	4	1	1
2	6642	3549	0	500	1000	3093	2593	2093	7	5	4
3	6951	3622	0	333	667	3329	2996	2663	9	9	8
4	7046	3612	0	250	500	3434	3184	2934	10	10	10
5	6793	3615	0	200	400	3178	2978	2778	8	8	9
6	6540	3733	0	167	333	2807	2640	2474	6	7	6
7	6287	3522	0	143	286	2765	2622	2479	5	6	7
8	6034	3550	0	125	250	2484	2359	2234	3	4	5
9	5781	3587	0	111	222	2194	2083	1372	2	3	3
10	5528	3552	0	100	200	1976	1876	1776	1	2	2