Ranking Dairy Cows for Future Profitability and Culling Decisions

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Summary

This paper describes a Microsoft Excel based computer program that calculates the future value, or retention pay off (RPO$), for cows in a herd to support culling decisions. The RPO$ is the extra profit expected from keeping the cow until the optimal time of her replacement compared to immediately replacing her with a replacement heifer. Cows with an RPO$ less than $0 should be culled and replaced. The program currently functions as an add-on to PCDART. The RPO$ are illustrated for the cows at the University of Florida Dairy Research Unit.

Introduction

Maintaining dairy cows in the herd is costly. The price of heifers is 3 to 6 times as much as the price of cull cows. Cows stay in a herd on average about 3 years. If a heifer costs $1900 and the cull revenue is $400, then the loss in value is ($1900 – $400) / 3 = $500 per year. Assuming such a cow produces 20,000 lbs of milk per year, then the loss in value is $500 / 20,000 = $2.50 per cwt milk. In other words, the cost to maintain cows in the herd, aside from costs for feeding, housing, milking, care etc, is $2.50 per cwt. Data collected for the Dairy Business Analysis Project (DBAP) in 2004 showed that the average cost to maintain the herd was $1.40 per cwt milk sold. Although a few dairy farms reported lower costs to maintain the herd, many dairy farms reported costs between $2 and $3 per cwt. The cost to maintain the herd is the second or third greatest cost on many dairy farms (after feed and labor).

The significant cost to maintain the herd, and the large variation between dairy farms, suggest that the culling policy deserves attention. On the one hand, it is important to note at what stage of lactation and why cows are being culled. Cows culled early in lactation almost never made it well through the transition period. When there are many such culls, the transition program needs attention. A count of major causes may point to weaknesses in an area. On the other hand, every cull is ultimately an economic decision. A dairy producer expects to better reach his goals (profitability, easy milking cows) when the cow is culled (and replaced with a heifer). Some culling decisions may be obvious (severe health problems), but some are not (for example, open cow late in lactation with average milk production). The dairy producer often has some flexibility in determining the timing of the cull. Profit is lost when the wrong time is chosen (too early or too late).

Studies have shown that dairy producers would not cull equal cows in equal situations at the same time. The optimal time of culling is frequently not obvious. Most replacement decisions are made in a non-programmed fashion and based mostly on intuition. Money is left on the table by not making optimal culling and replacement decisions. Historical average culling rates are not useful guides for culling decisions. The ideal guide ranks all cows currently in the herd based on their future cash flows and suggests whether each cow should be kept or culled (and replaced with a heifer). This paper further explains this principle, and describes a practical computer program that dairy producers may use to guide their culling decisions.

Principles

Researchers haves studied optimal culling principles since as early as the 1960s and in Florida since 1971. They agree that the dairy cow replacement theory is really a special case of the general asset replacement theory (the cow being the asset). The general question to be answered is this: does the dairy farm make more money by keeping the current cow in the herd (until at least the next time culling decisions are made), or is more money made by culling the cow now and replacing her with a heifer? The current cow is said to occupy a slot (position) on a dairy farm. The question is thus how to optimize the replacement decisions for each slot on the farm.

Some major assumptions made by people who study optimal culling decisions are these:

First, a sufficient number of replacement heifers are available. Extra heifers can be purchased if more heifers are needed than are raised. Excess raised heifers can be sold. In other words, there is no pressure from calving heifers to push cows out of the herd, nor is the supply of heifers limited. Heifers are usually animals with an average performance.

Second, the optimal replacement decision for a cow currently in the herd is independent of optimal decisions for other cows in the herd. The decision only depends on her future cash flow and the future cash flow of a challenging heifer. Both are assessed independently from what happens with the other cows in the herd. For example, in practice a limited parlor capacity might affect the decision that a cow is kept or culled, but such a constraint is not considered.

Third, if a cow is culled she is immediately replaced by an average heifer. In other words, slots are never left open. The opportunity cost of an open slot is typically quite large because all revenues are variable but many costs are fixed. In other words, open slots generate no revenues but fixed costs (most of the depreciation, some labor, utilities etc.) still remain. Recent work done in Florida confirms that even in our hot, humid summers it typically does not pay to leave a slot open after a cow has been culled in the summer and wait until the fall to replace her with a heifer (although the loss may be minimal).

Fourth, it is typically assumed the dairy producer would keep making optimal replacement decisions in the future for the cow that is occupying the slot. At any time the future cash flow for the cow in the slot is constantly compared with that of the challenging replacement heifer.

The optimal culling decision is made by comparing the present value of the future cash flows of the current cow in the herd with the present value of the future cash flows of the challenging replacement heifer. The animal with the highest present value should occupy the slot.

Future cash flows for the cow currently in the slot are determined from all revenues and costs in the remainder of the lactation, as well as revenues and costs in the following lactations (if any), and revenues and costs of her future replacement heifers. Over time, every cow will be culled and replaced with a replacement heifer. Even when it is decided not to cull a cow today, there is a chance she needs to be culled and replaced tomorrow (because of death or severe health problems) or any other time in the future. Similarly, if open cows are bred they may or may not get pregnant which affects their future risk of culling. The future cash flow is therefore an average of all possible future cash flows of the current cow and her potential replacement heifers, weighted by the probability that an event happens. Replacement heifers will be replaced by other heifers as well. Probability calculations show that after several years in the future the expected cash flows are independent of the culling decision for a slot made today. Consequently, to make the optimal culling decision of the cow currently in the slot, we need to project future cash flows several years into the future, but not indefinitely.

Because cash flows are unequal over time, discounting needs to be applied to make the value of the sums of the cash flows today, i.e. their present values, comparable. Discounting also makes accurate estimates of revenues and costs farther in the future less important.

Once the present values of the future cash flows of both the current cow in the slot and the challenging replacement heifer are calculated, the optimal decision is simply to keep the animal with the highest present value. The difference in the present values of both animals has been called future profitability or retention-pay off (RPO$). The RPO$ is the extra profit from keeping the current cow until her optimal time of replacement, considering the risk of premature culling, compared to immediate replacement. When the RPO$ > $0, the cow currently in the slot should be kept, at least until the next decision moment. If she were culled today, the opportunity cost equals her RPO$.

When the RPO$ < $0, the cow should be culled and replaced with the heifer. A negative RPO$ equals the opportunity cost from keeping the current cow in the herd until the next decision moment when in fact she should be culled now. The RPO$ can potentially be calculate for every cow in the herd on every day. Cows may be ranked by RPO$ for future profitability. The cow with the highest RPO$ is the most valuable cow.

Implementation

Accurate estimation of future cash flows is a challenging task. It involves prediction of the milk yield in the remainder of the lactation, risk of pregnancy and abortion, risk of death and other risks that cause premature culling, as well as future prices. Another challenge is how to optimize all future breeding and culling decisions, based on predicted performance, risk and prices, so that future cash flows are truly as maximal as possible. The computer program described in this paper can do both: 1) it predicts future performance; 2) it optimizes breeding and replacement decisions (based on dynamic programming).

Calculation of the RPO$ for each cow in the herd is done by a novel 2-step process. The program first optimizes future cash flows for calving heifers. It also optimizes future cash flows for animals that calve into their second or later lactations, for 15 different levels of milk production each (herd module). Secondly, the program predicts future cash flows for cows currently in the herd (cow module). To do this, it makes use of the future cash flows already calculated for the next lactation and for replacement heifers. This 2-step process allows for very cow-specific predictions of future cash flows because the performance in the current lactation can be predicted with a lot of detail. Table 1 lists the types of input data and their sources.

Table 1. Herd and cow inputs for the computer program to calculate the RPO$.

Herd inputs:[1]	Cow inputs:[2]
• Lactation curves	• Lactation number
• Days dry	• Days in milk
• Risk of premature culling	• Testday milk yields
• Voluntary waiting period	• Estimated relative producing ability
• Risk of service, conception, abortion	• Reproductive status (open, bred, pregnant)
• Body weights	
• Prices (milk, feed, heifers, cows, calves)	• Days since last breeding or estrus
• Discount rate	

[1] User-defined: data entered into spreadsheet.
[2] From a report created by PCDART or other dairy management program.

The computer program predicts future cash flows with weekly steps. Lactation length for the replacement heifer and next lactations is at most 2 years (104 weeks). Gestation length is 40 weeks. Therefore, breeding does not take place after 64 weeks in milk in the herd module. Future cash flows for cows currently in the herd are predicted for another 104 weeks in the remainder of the lactation, however (cow module). That means that an open cow has potentially another 64 weeks to get pregnant, regardless of her days in milk today, if it was economically optimal to keep her in the slot. Of course, the computer program may determine that it is more optimal to replace her much earlier than that.

Example herd

To illustrate the computer program, the RPO$ were calculated for the 596 cows at the UF/IFAS Dairy Research Unit (DRU) located in Hague, Florida, on February 14, 2006. Future cash flow calculations were based on the following (actual data for the DRU may be slightly different).

Reproduction

The minimum voluntary waiting period is user-defined (DRU: 42 days). Cows are eligible for breeding once per every 3 weeks. The risk of pregnancy per eligible breeding opportunity is calculated as service rate x conception rate (DRU: 50% x 25% = 12.5%). There is a user-defined risk of abortion after pregnancy diagnosis (DRU: 8%). All cows currently in the herd have the same risk of pregnancy. The risk of pregnancy is independent from lactation to lactation. That means that problem breeders have average risks of pregnancy in the next lactation (if they get there). Cows that abort continue in the same lactation if they are still milking. Dry cows that abort continue in the next lactation. Breeding decisions are optimal. That means that the program may decide not to breed a cow if that improves her expected future cash flows. In practice, this means that high producing first lactation cows may have greater voluntary waiting periods.

Milk sales

Lactation curves for first, second and greater lactations in the herd module are calculated by the method of Best Prediction based on user-defined pounds of herd average ME milk, fat, and protein (DRU: 22,800; 853; 661 lbs, respectively). Figure 1 shows the lactation curves for first, second, third lactations without test day observations. Best Prediction is also used to predict milk yield in the remainder of the current lactation for cows currently in the herd based on known testday yields in their lactation in progress. This method is used by USDA-Animal Improvement Programs Laboratory (AIPL) for the quarterly genetic evaluation of cows and bulls. Because Best Prediction predicts daily milk yields for the first 365 days of the lactation, the average decline in milk yield in the last month is used to predict milk yields past 365 days. The daily milk yield predictions include a reduction caused by pregnancy. The user enters the number of weeks dry. Level of milk production in the next lactation for cows currently in the herd is based on their Estimated Relative Producing Abilities (ERPA). The ERPA is an estimate of the extra milk produced in the next lactation compared to herd mates. The milk price is user-defined (DRU: $18 / cwt).

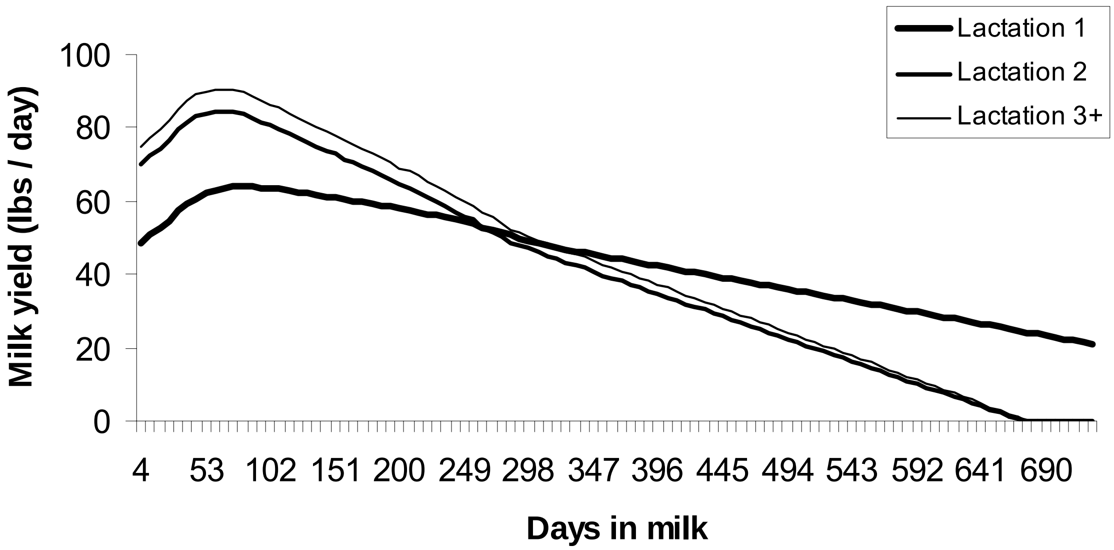

Figure 1. Lactation curves calculated by Best Prediction based on 22,800 lbs herd average ME milk for Holsteins.

Body weight

Body weights for first and greater lactation cows are based on the NRC (2001). An adjustment for pregnancy is included. The predicted body weights are used to calculate the cull revenue (together with a user-defined price per lbs body weight) and dry matter feed intake for lactating animals.

Feed costs

Dry matter intake (DMI) is calculated using the equation in the NRC (2001). This equation is based on body weight, days in milk, and fat-corrected milk. The user enters the price for the lactating ration (DRU: $11 / lbs DMI) and the dry ration (DRU: $7 / lbs DMI).

Risk of premature culling

The risk that cows leave the herd as a result of death or severe health problems is greater early in lactation. The default inputs are a linear decline from 0.62% in the first week after calving to 0.22% at day 100 and later after calving. Older cows have greater risk of premature culling. For the DRU, the default input risks were multiplied by 1.20, 1.65, 2.63, and 3.77 for first, second, third, and fourth and greater lactations. Culling later in lactation is typically a result of failure to conceive combined with low milk production. The computer program makes the optimal culling decisions for these cows.

Other prices

All prices are user-defined. For the DRU: $1800 heifer price (assuming heifers are purchased), $200 calf price, and $46 per cwt body weight cull price. The program assumes that culled cows are never sold for "dairy" purposes. The cost of interest is set at 8% per year. Discounting occurs weekly. Fixed costs do not need to be included because they are independent of the type of cow that occupies the slot.

Results for the Example Herd

RPO$ in the example herd

Given the inputs and calculations described above, the computer program calculates the RPO$ for each cow currently in the herd. Of the 596 cows at the DRU, 38 have negative RPO$. These cows should be replaced with heifers (in reality, the DRU raises its own heifers and replacement heifers are not routinely purchased). Figure 2 shows the RPO$ for the first 17 cows (sorted by index) at the DRU together with some of their characteristics.

University of Florida Dairy Research Herd

RPO$ on February 14, 2006

Index	DIM	Lact#	LastCalv	DIM_Tst	LastBredMDY	Milk	STATUS	RPO$
690	71	2	12/05/05	55		85	OPEN	798
714	114	1	10/23/05	98	01/20/06	86	BRED	1386
832	68	1	12/08/05	52		80	OPEN	1284
877	123	1	10/14/05	107	12/30/05	89	OPEN	1549
905	120	1	10/17/05	104	01/25/06	72	BRED	1093
2664	25	8	01/20/06	9		34	OPEN	524
2678	135	8	10/02/05	119	12/23/05	68	OPEN	345
2823	369	7	02/10/05	353	01/02/06	39	OPEN	28
2824	371	8	02/08/05	355	11/21/05	46	OPEN	36
2853	234	8	06/25/05	218	12/15/05	43	PREG	231
2854	413	6	12/28/04	397	12/16/05	59	PREG	289
2973	333	7	03/18/05	317	12/30/05	67	OPEN	104
3034	189	8	08/09/05	173	01/27/06	23	BRED	22
3156	500	5	10/02/04	484	01/06/06	33	BRED	7
3165	464	5	11/07/04	448	01/13/06	17	BRED	-9
3213	582	5	07/12/04	417	05/06/05	Dry	PREG	946
3235	12	7	02/02/06	273		0	OPEN	1023

Figure 2. RPO$ and other characteristics of the first 17 cows at the University of Florida Dairy Research Unit. The herd was sorted by index.

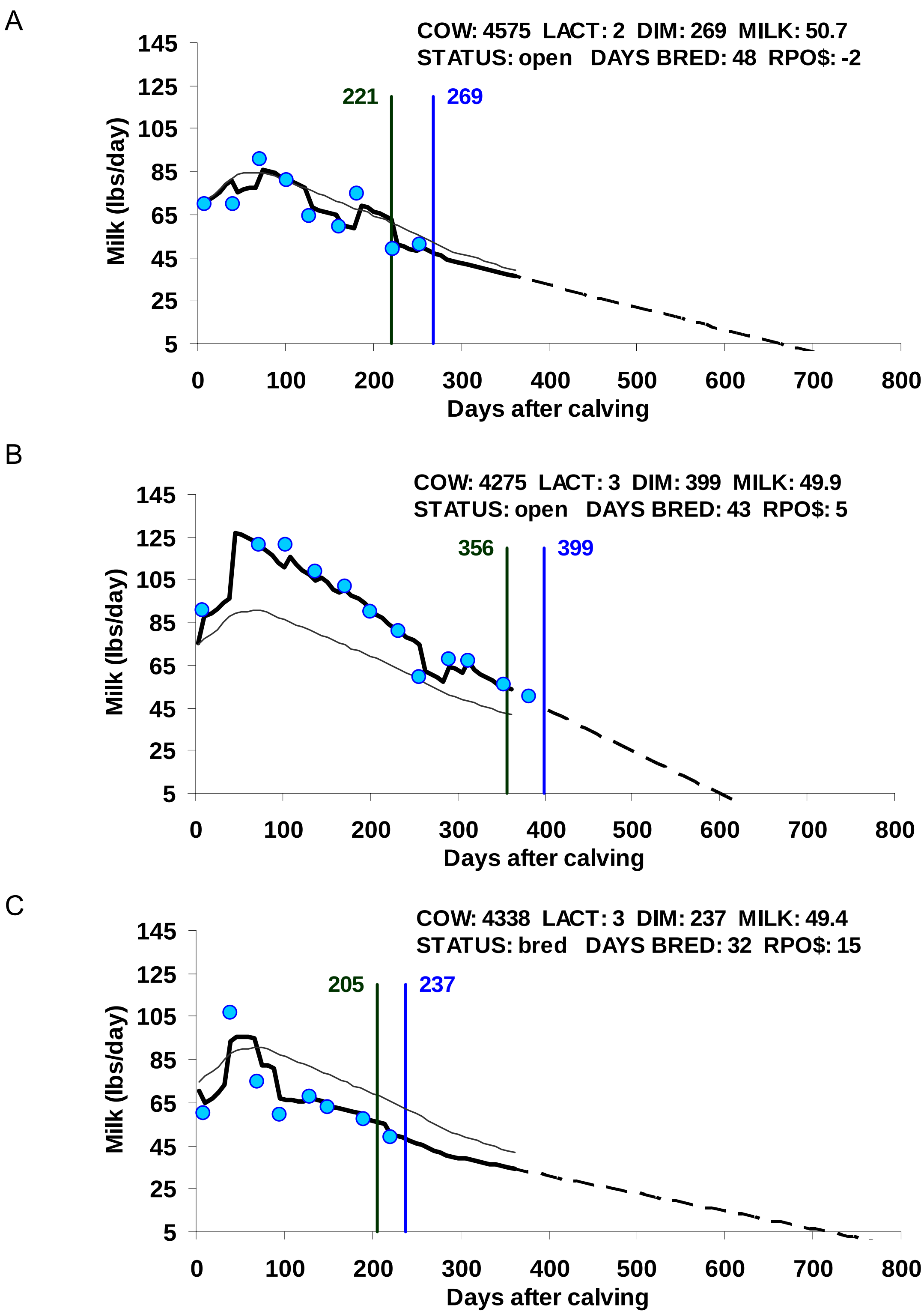

Figure 3. Test day history for three cows with low RPO$. The left vertical bar indicates last day of breeding. The thin lactation curve is for the average herd mate. The right vertical bar indicates current days after calving.

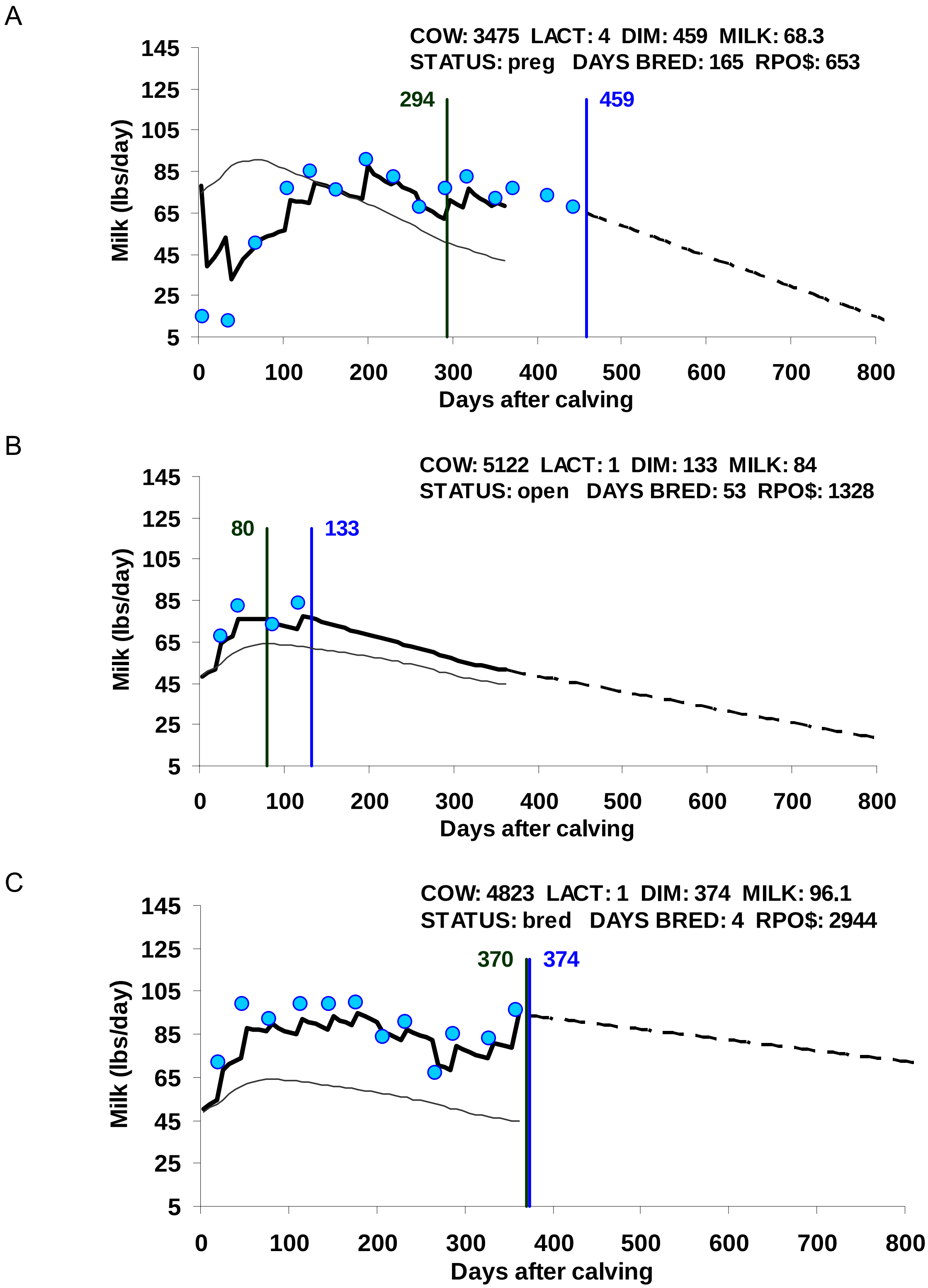

Figure 4. Test day history for three cows with average or high RPO$. The left vertical bar indicates last day of breeding. The thin lactation curve is for the average herd mate. The right vertical bar indicates current days after calving.

The lowest RPO$ is $-41. This means that $41 is lost if the cow is kept another week instead of immediately being replaced. RPO$ cannot be very negative because the computer program applies optimal replacement decisions now and at any point in the future. Therefore if the cow is kept despite the recommendation to cull her now, the computer program calculates that she will be culled next week. The loss is therefore the result of keeping her only one week too long.

Low RPO$ typically are the result of low expected milk production in the remainder of the lactation, or in the next lactation. Pregnant cows with low milk production and very low ERPA therefore also may have negative RPO$. Older cows and those not pregnant late in lactation typically have lower RPO$. The last test day milk yield for the 38 cows with negative RPO ranged from 0 lbs (dry cows) to 52 lbs. Figure 3 shows the testday history of three cows with low RPO$. Most dairy producers would agree that these cows should be considered for culling.

The highest RPO$ in the herd is $2944 for a very persistent, possibly pregnant, high producing cow. Cows with high RPO$ are typically young and have high, persistent milk yields. Open cows early in lactation and pregnant cows that get close to calving also typically have high RPO$. Figure 4 shows the testday history for three cows with average or high RPO$. Dairy producers would agree that these cows should be kept.

The RPO$ of an average heifer that just calved is $1049. The value of the calf in the current lactation is not included because only future cash flows need to be considered in the RPO$ calculation (her calf is assumed to have been sold at birth). The value of a calf in future lactations is included, however. The RPO$ of an average heifer that just calved is essentially the difference between the purchase price ($1800), her beef cull price, and the calf price. The average RPO$ for all cows in the herd is $904.

Association between RPO$ and other measures

Figure 5 shows the distribution of RPO$ by days after calving for open, bred, and diagnosed pregnant cows on February 14, 2006. There is not a clear association with days after calving. Some open and bred cows later in lactation still have high RPO$ because their milk production is very persistent. The RPO$ for diagnosed pregnant cows includes pregnant cows at all stages of gestation: from cows that were just diagnosed pregnant (approximately 40 days after last breeding) to cows almost ready to calve again.

In Figure 6 the RPO$ is plotted against the ERPA (difference in expected milk yield in the next lactation compared to herd mates). The trend is that cows with a greater ERPA also have a greater RPO$. Of course, there is no guarantee that the cow has a next lactation. Unlike the ERPA, the RPO$ includes the risk that a cow does not become pregnant in time and therefore is culled and replaced.

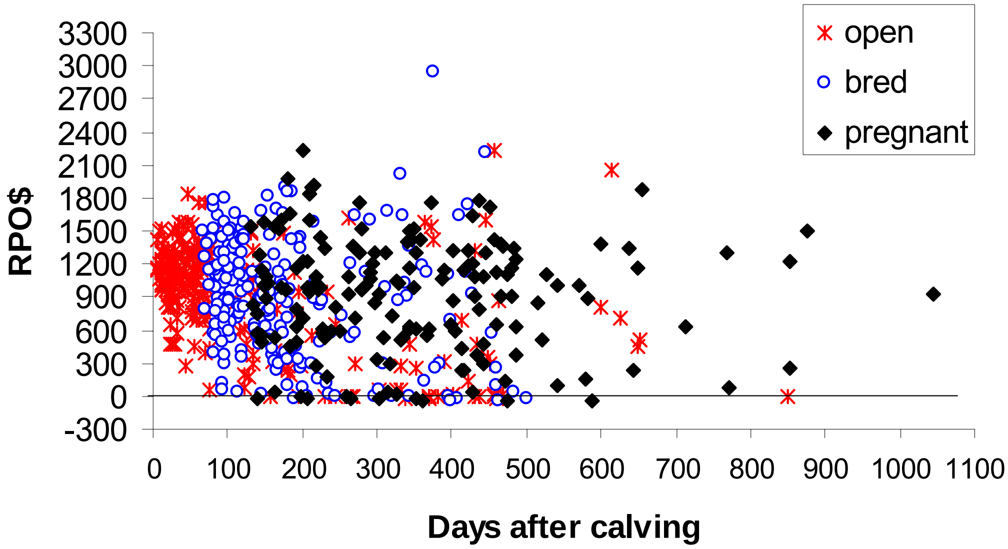

Figure 5. RPO$ by days after calving for open, bred, and diagnosed pregnant cows on 2/14/2006.

The DHI-150 culling guide lists potentially low profit cows which may be candidates for culling. Projected Relative Profit (PRP) predicts each cow's income over feed cost for the remainder of the current 305-d lactation, a feed cost for the estimated days dry, and income over feed cost for the next lactation. Cows that are open or bred are assumed to immediately get pregnant. The PRR was estimated for all cows by the computer program. Figure 7 shows the distribution of RPO$ by PRP.

The plot in Figure 7 shows that there is a trend that RPO$ increases when PRP increases. The difference is primarily explained by the risk that open and bred cows do not become pregnant. Such cows late in lactation have low RPO$ whereas the PRP calculation assumes they immediately get pregnant and have a next lactation, although with a longer dry period. Therefore the RPO$ penalizes non-pregnant cows more than the PRP.

Together, Figures 5, 6, and 7 show that the RPO$ is not well correlated with other measures that may be associated the future profitability of a cow. The combination of reproductive status and future milk production into the RPO$ calculation makes the RPO$ a useful new measure to rank cows for culling decisions.

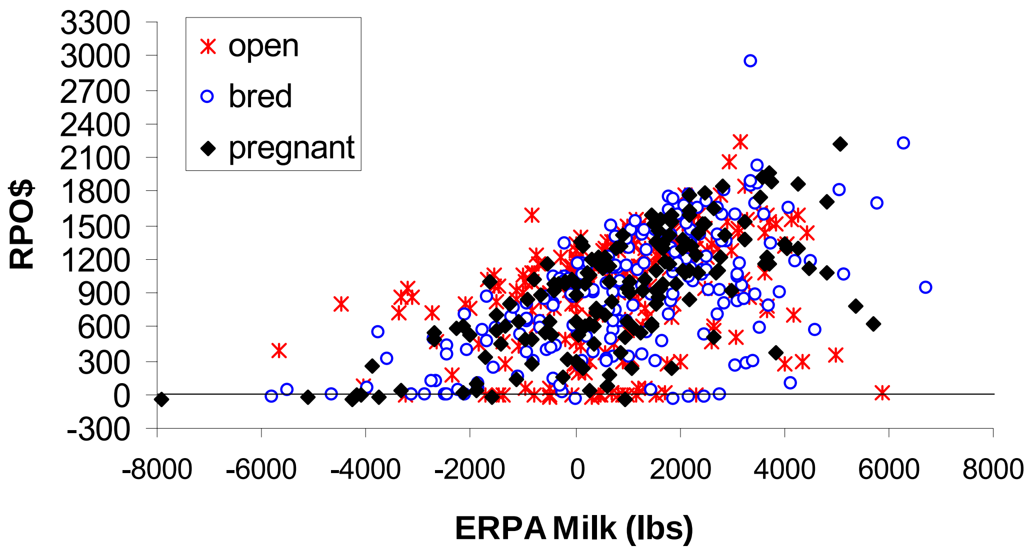

Figure 6. RPO$ by Estimated Relative Producing Ability (ERPA) for milk on 2/14/2006. Estimated Relative Producing Ability is an estimate of the extra milk produced in the next lactation compared to herd mates.

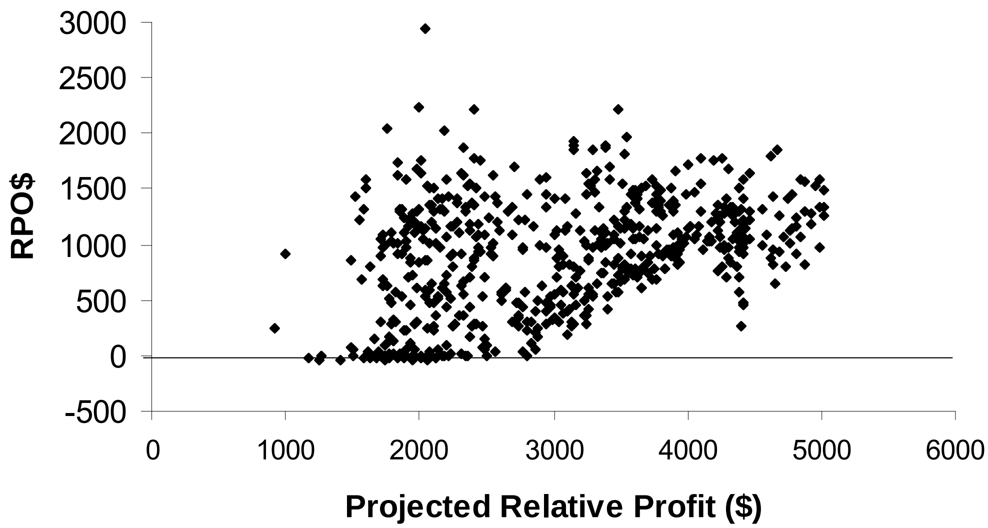

Figure 7. RPO$ by Projected Relative Profit (PRP) on 2/14/2006. Projected Relative Profit is an estimate of the total income over feed cost in the remainder of the current lactation and the next lactation.

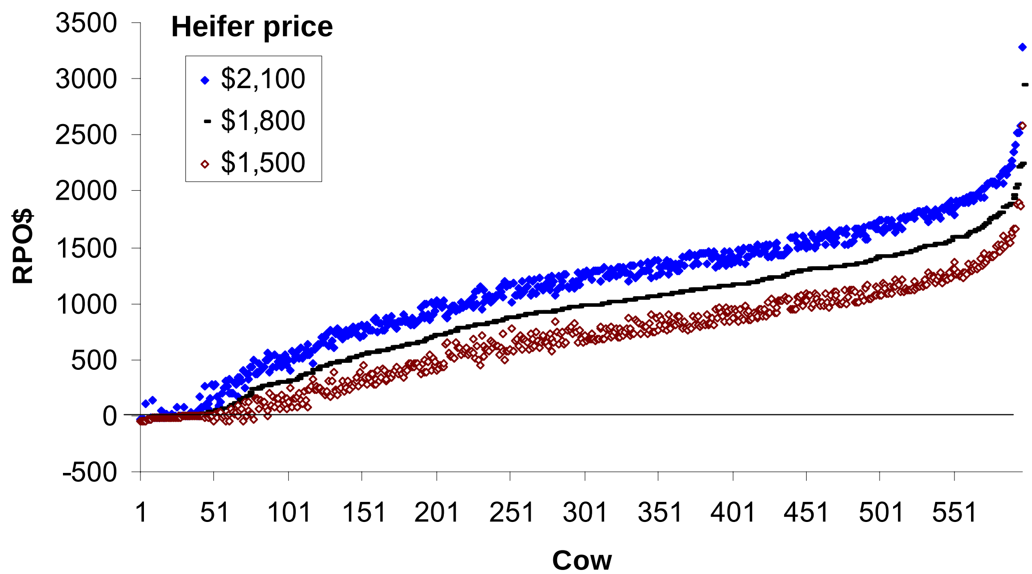

Figure 8. RPO$ when heifer prices are $2100, $1800, or $1500 per head. Cows are ranked by RPO$. Higher heifer prices increase the RPO$ because it is more valuable to keep the current cow in the slot.

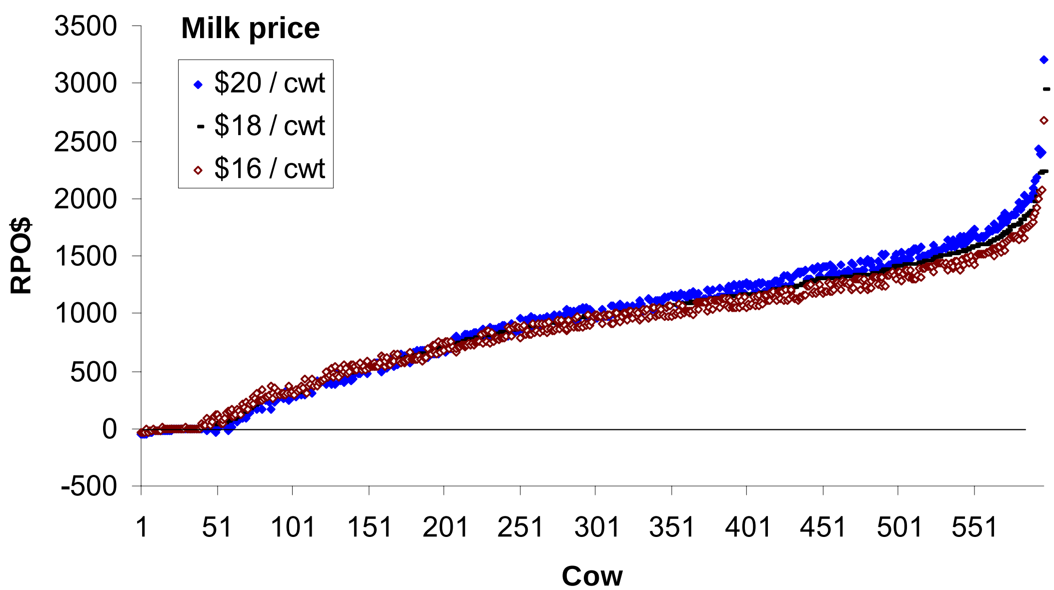

Figure 9. RPO$ when milk prices are $20, $18, or $16 per cwt milk sold. Cows are ranked by RPO$. For some cows the RPO$ increases, for others the RPO$ decreases.

Effects of changes in heifer price and milk price on RPO$

Higher heifer prices increase the RPO$ of the cows currently in the slot (Figure 8) as might be expected. It is more valuable to keep the current cow in the slot when replacements are expensive. An increase in heifer price to $2100 from the default of $1800 increases the average RPO$ in the herd from $904 to $1135. The RPO$ of every cows increases (on average $231), but the increase ranges from only $2 (typically cows with low RPO$) to $359. Only 25 cows have RPO$ less than $0. Lower heifer prices have the opposite effects. A decrease in heifer price to $1500 reduces the average RPO$ in the herd to $676. The RPO$ of all cows decrease (on average by $228). Minimum decrease is $2 and maximum decrease is $385. Fifty-seven cows have RPO$ less than $0 when heifer price is $1500.

Increases in milk prices change the RPO$ in both ways. When the RPO$ is low (open cows at in lactation), the increase in milk price lowers the RPO$ but when the RPO$ is high (pregnant cows or high producing persistent cows), the increase in milk price typically increases the RPO$. Decreases in milk price have the opposite effects (Figure 9). The average decrease in milk price by $2 / cwt (from $20 to $18 or from $18 to $16) lowers the RPO$ by $35 but the change ranges from a decrease of $266 to an increase of $103.

RPO$ when no replacement heifers are available

When no heifer is available to replace culled cows for one week, the RPO$ of each cow is creased by the average revenues minus variable costs per cow per week. At the DRU this is $28 per week. Only 7 cows have RPO$ less than $0. Their variable costs are greater than their revenues.

Other Considerations

The RPO$ is a solid measure to rank cows based on their future profitability. The key to a useful RPO$ is an accurate prediction of a cow's discounted future cash flows. Strategies to improve the future cash flows of the current cows and replacement heifers through improvements in cow performance are valuable and should be strived for. Use of the RPO$ should maximize these cash flows by optimizing breeding and culling decisions and reduce the arbitrariness of culling.

The RPO$ calculation considers many important factors. Several potentially valuable factors are not included in the current version of the RPO$ calculation, however.

Seasonality in performance (milk production, reproduction) or prices is not included in the RPO$ for the DRU as shown above. The computer program can account for seasonality in performance and prices, but the challenge will be to estimate this seasonality accurately on any dairy farm. Seasonality does affect the RPO$, but the effect on the ranking of cows is minimal.

Health problems such as metabolic diseases, mastitis or lameness are not directly considered. Problems that affect the risk of pregnancy or abortion are currently not accounted for. For example, the effect of a difficult calving on the risk of pregnancy is not yet included. Problems that reduce milk production are automatically accounted for through lower testday milk yields. The inclusion of health problems is therefore thought to have a limited effect on RPO$ or the ranking of dairy cows.

Genetic progress in heifers is also not directly accounted for. In theory, when heifers are genetically superior, cows should be culled sooner. But research has shown that the effect of genetic improvement on day to day optimal culling decisions is minimal.

The RPO$ calculation assumes that there are no limiting constraints. A limiting constraint is for example a limited supply of heifers, parlor capacity, or milk quota. Overcrowding that affects cow performance is also an example of a limiting constraint. A breeding or culling decisions for one cow may affects the decisions for other cows. The effect of such limiting constraints on RPO$ and ranking of cows is not well studied but probably small.

The RPO$ is the result of comparing 2 discounted future cash flows that result from the decision to keep or cull the cow. This principle can also be used to support other decisions. For example, the value of a pregnancy can be calculated by comparing the discounted future cash flows of a pregnant cow and an open cow; their only difference is the pregnancy status, everything else is equal. Similarly, the value of an insemination is the difference between the discounted future cash flows expected when breeding a cow and when not breeding a cow. The decision when to dry off a cow, or whether or not to treat a cow (for example for mastitis), could also be supported this way. The value of a pregnancy and the value of an insemination are currently calculated with the computer program.

Practical Implementation

The computer program that manages the RPO$ calculations has been developed in Microsoft Excel. The procedure starts with running a predetermined user report in PCDART that saves the necessary cow data such as index, test day data, and reproductive data into a CSV-type file. CSV files can be read into Excel.

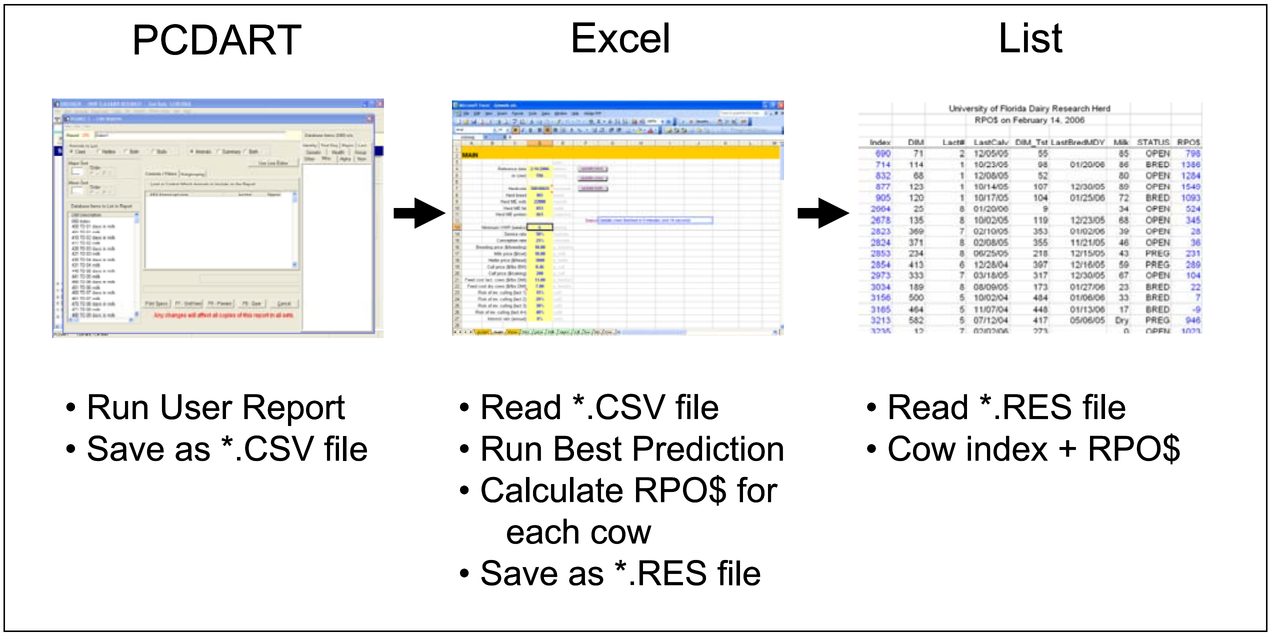

Figure 10. Procedure to obtain the RPO$ for cows in the herd. The procedure starts with running a report in PCDART and ends with the presentation of a list of cows with their RPO$. The steps in Excel are automated by macros.

Macros in Excel automate the calculations. The macros read the CSV file, run the Best Prediction program to obtain predicted milk yields in the remainder of the lactation, run the program that calculates the RPO$ for each cow, and finally presents the results in Excel and saves the list with the RPO$ (Figure 10). The whole procedure takes about 6 minutes for the 596 cows at the DRU. Most of that time is used by the Best Prediction program to predict milk yields for the remainder of the lactation for each cow. The procedure could be shortened if the RPO$ was only calculated for marginal cows that may be candidates for culling. Check the UF/IFAS Dairy Extension website at http://dairy.ifas.ufl.edu for more news about the availability of this computer program.

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