Milking Them for All They Are Worth

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Introduction

The modern dairy cow is a marvel of genetic selection and intense management. Her environment has been remodeled to allow for a multitude of nutritional tweaks, vaccines, milking systems, mastitis precautions, foot trimming equipment, stall types, etc. Sophisticated genetic evaluation programs from BLUP to selection indexes have been developed. Breeding technology goes from natural service to cloning. And with all of this, reproduction statistics report increasingly disappointing results.

Is the modern cow getting a bad rap? She has been placed in a situation designed for great milk output and managed in such a way that she is exposed to two potentially fatal experiences each year. First, she must become pregnant each year to initiate or renew her lactation curve for greatest average milk per day of lactation. Second, she must give birth to a calf which means she is exposed to a dry period and a calving each year. These two experiences are very dangerous for her. If she fails to have a pregnancy, she is culled. If she has a dry period, her exposure to new mammary infections increases substantially. When she gives birth to a calf, numerous dangers are possible ranging from serious dystocia to metabolic aftermath diseases. Then, she advances to a high risk of displaced abomasum. And all the while, with each pregnancy, her eventual udder edema and failures of her feet and legs cause misery as she ages.

Wait! This magnificent cow is endowed with tremendous milk production ability. Yet, her manager continues to manage her for high production on a given day, not for her lifetime. She is consistently forced through the lurking dangers of annual calving. This must stop if she is ever going to have the chance to give her best lifetime performance.

Cows have been documented to produce profitably for four years and even longer. Dairy farmers have testimonies of their great cows that were too good to cull even though they did not become pregnant after repeated inseminations. Mostly, such cows are discarded after a while, to make room for a heifer replacement. Isn't it common knowledge that a cow just pays for herself in the first lactation and doesn't start to add profit to the business until the second or even the third lactation? With culling rates of 35% or more in many herds, the average cow experiences less than three

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complete lactations. Is the problem coming into focus now? We must give these wonderful cows a chance to produce for a long lifetime to see the profit they can earn.

These great, high-producing cows that were thrown away because of reproductive problems should have been exploited, not discarded. They are a resource of unique ability that should be explored, developed for their special ability to milk well for years. Pregnancy reduces the lactation curve of a typical cow past her mid-term as she partitions nutrients to fetal growth and experiences hormonal changes contrary to great milk production. If she remains open, she will produce more milk. BST can be thrown into the mix for cows with long calving intervals to push them for another 15% of milk as they wait to get to the dry-off date. Without pregnancy, as in the case of hard-breeding cows, there is actually an advantage to extending the expression of great milk production. Furthermore, a cow's youthfulness and strength are sustained longer without the rigors and bodily insults of further pregnancies beyond the first one.

This report tells the story of a research project designed to assess the feasibility of managing dairy cows for very long lactations in the order of four years duration.

Methodology

Dr. Al Rotz of the USDA, ARS is a designer of an extraordinary modeling program for farm systems, including dairy operations. It is known as "The Integrated Farm System Model" (Rotz et al., 1999; Rotz and Coiner, 2003). This model is published and available on the Internet (Rotz and Coiner, 2003). When approached by myself, Dr. Rotz accepted the challenge to model a dairy farm with the cows managed for four-year lactations, where no inseminations or dry dates were imposed on the cows once they initiated lactation the first time.   Establishment of the assumptions for the model required our scanning of the literature and recruitment of Ken Crandall of the DHI Computing Service, Inc., Provo, UT to produce data on real cows with unusually long lactations.

The three of us proceeded to conduct the experiment which was published last August (Rotz et al., 2005). For the sake of comparison, the model was applied to five different management scenarios, that were imposed upon a common land base and cropping system. This was selected to represent a typical Pennsylvania dairy farm of 247 acres. The key unifying factor was that all five models were required to stay within a phosphate management standard for the farm. Nitrogen management was a given as it is less stringent than phosphorus budgeting. Logical bases of comparison engaged common management choices of rearing replacements on a standard farm, purchasing all replacements for that farm, or perennial lactation (namely four years) with all replacements purchased for that farm. Expansion designs were also tested. The typical farms were assumed to have annual 35% culling rates, while the perennial farm had a 25% culling rate.

Scenario 1. The standard farm, 100 total cows, replacements reared on site.
Scenario 2. Same as 1, but all calves are sold and replacements are bought.

Scenario 3. Same as 2, but all cows have perennial four-year lactations and only 25% culling rate.
Scenario 4. Same as 2 but with the herd size expanded to 120 cows to fill the available space without heifers.
Scenario 5. Same as 3, but with the herd size expanded to 128 cows to fill the available space without dry cows or heifers.

The feed utilization, manure nutrient and management factors characteristics of the scenarios are shown in Table 1. Also shown are the effects of the variables on annual net return to management. This table is from Rotz et al. (2005).

A DHI data base of 852,000 real cows was tapped to reveal all cows on record at DHI Computing Service, Inc. in the summer of 2003 that had been in continuous production 700 days or longer. There were 4259 valid records produced. They were partitioned into half-year intervals of lactation +/- 60 days for analysis. Table 2 (Rotz et al., 2005) exhibits the number of cows in each increment (units converted from kg to lb). Production data, pregnancy data and SSC data are included.

The 26 cows at four years of lactation were of particular interest as they represented the presumed target of the perennial lactation model. All were Holsteins except for one Jersey. They are portrayed in Table 3.

The model parameters are reported in Table 4 from Rotz et al, (2005). The sensitivity analysis was conducted to ascertain the effects of changing key assumptions used in the model. As a result, the factors that most affected the profitability of a perennial dairy at stocking capacity were tested when certain conditions were changed.

Results

With the number of cows held constant, it isn't surprising to learn that scenarios 2 and 3 were not superior to scenario 1 regarding profitability even though they were more environmentally beneficial. Replacement heifers are very expensive in current markets, and the dairy facilities were not being used at capacity when no heifers were present plus the omission of dry cows with criterion 3. This explains why many farms with a substantial land base usually rear their own heifers, not to mention the advantages of knowing the genetic values and herd health control coincidental to home reared heifers.

But, when the facilities were filled to capacity by expansion in either alternative management system, profitability changed importantly. The perennial herd at 128 cows vs. 100 cows in standard management yielded a 38% reduction in purchased protein and mineral supplements, increased annual milk sales by 21% and reduced nitrogen losses by 17%. The annual net return to management was increased $3200.

Comparing the perennial herd of 128 cows to the herd of 120 with purchased replacements reveals reduced protein and mineral feed purchases by 36%, increased manure production by 7%, 10% less nitrogen lost and $12,700 greater annual net return to management.

Sensitivity analyses illustrated the large effect of milk production per year on the profitability estimates. While the standard dairy of 100 cows was estimated to have 22,667 lb milk per year per cow, the perennial dairy was estimated to have 5% less milk per cow per year because of the greatly extended lactations. On the other hand, the perennial cows did not have dry periods each year and did not experience the diminishing production of milk associated with pregnancy. If the production was dropped another 5% in the sensitivity analysis, the comparative advantage of the perennial herd was lost. It is important to have a high persistence in the perennial cows. Along this line of thought, reflect back on Table 1 where the average production per day of lactation was essentially the same for all the categories of long production, at least until year four.

Another analysis was conducted to test the effect of having perennial cows in a herd of mixed lengths of lactation. See Figure 1 from Rotz et al., 2005. This is meant to handle the situation of cows that do not have high persistence of lactation. Should they be culled at two years or should they be rebred and maintained in the herd? Amazingly, the worst case was to have all cows with shorter lactations of 2 years duration. Table 1 supports the conclusion that it is best to have 3 to 4 years of lactation length because the average production per day of lactation was about the same across all durations. The sensitivity analysis proved that the more cows there were in the herd with long lactations, the better was the annual net return to management. The increase in annual net return per cow ranged from about $540 to nearly $700.

The culling rate differential from 35% for the standard herds to 25% for the perennial herd suggests that standard herds have about 1/3 of the cows as first lactation 2-yr-olds at any one time. The perennial herd would have only ¼ of the herd as 2-yr-olds at any one time. Still, the perennial herd would have only first lactation cows, albeit very long lactations. Of course, recycling of the perennial cows would change the mix of ages and parities.

Mammary health does not seem to be an issue with these long lactations. Table 2 reveals about the same SCC for each category of lactation length. As the numbers of cows per category diminished, the affect of a few high SCC cows would have an exaggerated impact on the average SCC data. A trend of notable increase in SCC was not seen.

Can lactation persistence of cows be increased by management? Yes! Avoiding pregnancy is the first such step to take. Of the 26 cows with four-year lactations, only one was pregnant at that point. BST is a generally understood tool that would stimulate persistence. It is not known if the data set analyzed contained BST effects. There are genetic factors such as IGF_1 (Hadsell et al., 2002) that affect milk secretion and can respond to genetic selection. Jerry et al. (2002) report genetic functions which can lead to identifying cows with superior persistence of lactation. Grossman and Koops (2003) described a multi-phasic milk production model for extended lactations. Capuco et al. (2003) found that proliferating epithelial cells in the mammary gland stain lightly. They speculated that characterization of these cells could lead to methods for enhancing cell proliferation leading to greater lactation persistence. Coincidentally, there would be reduced dependence upon a dry period to capture great lifetime production.

These notions lead to the key question of genetic discovery of cows that are best suited to very long lactations. Are the best cows of today, who are products of the current sire proving system, the right ones for perennial lactation? Since cows with very long lactations are relatively rare and have never been analyzed for their genetic differences, there is little knowledge about this matter. Of the 26 cows analyzed, all but 3 were in different herds and the sires involved were numerous with no readily seen common sire relationships any greater than the population as a whole. How did these 26 cows get to four years of lactation? They were profitable producers that did not get pregnant and drop out at earlier stages of lactation. They had multiple inseminations during the current lactation. Most were in their first lactation. What proportion of today's cows could do the perennial deal if they were never bred? Why did the long-lactation cows not conceive a pregnancy during the current lactation? Could that factor, whatever it is, contribute to persistency? Can we find effective methods to keep these perennial cows from coming into heat? It would seem to be a good idea.

Another intriguing question asks, "Should these cows be recycled after their long lactation?" Because they are bound to have better body condition and stronger mammary attachments than other 6-yr-old cows, they may serve well for another four years. Yet, it may be difficult to get cows pregnant after four years. It does not seem to be unusually difficult for other mammals to get pregnant with long intervals between pregnancies until they are aged, so it is reasonable to be positive about this.

Discovery of the best age to initiate a perennial lactation is fundamental to the optimization of perennial lactation management. In the data set analyzed, the cows with one or even two previous ordinary lactations did the best in the long lactation. But, is that the most profitable angle to take? If the heifer has a little more growth before she starts her first lactation, will she be more efficient? But, that means another six months of feed and care costs before she starts generating milk sales.

Are there important breed differences in the possibility for perennial lactation management...who knows! And, of course, the major research question centers around nutrition, since that typically accounts for about half the cost of milk production. What nutritional program is needed to support the cow with perennial lactation? She will not be nearly as challenged as a standard cow who is either transitional, in negative energy balance, or tailing off in latter pregnancy. Will these perennial cows have a tendency to get fat? Should they get a constant ration every day, as compared to stage or challenge feeding. Would alternative feeds give them an advantage as the seasons and years pass?

Conclusion

The concept of perennial lactation has been identified as possibly more profitable and more conservative of manure nutrient production on a typical Pennsylvania dairy farm. Can this concept work equally well in other locations? How would it prove out in a confinement system with a limited land base and major feed purchases? I find the perennial lactation idea to be challenging and exciting. It does not require any new technology right away and can be accomplished by anyone. Perhaps, new genetic measures will be needed to improve the selection of bulls and cows for this management choice. With sex selection of pregnancies on the horizon, and the need for fewer replacements in the perennial system, generating replacements for the program should not be difficult. The most elite cows could even be super-ovulated, be flushed and become mothers of many embryos borne by the replacement heifers already on hand. Fascinating research questions emerge that are begging for resolution. I hope other scientists will be captivated by the chance to improve profitability of dairy farms, cow welfare, and environmental stewardship.

References

Capuco, A.V., S.E. Ellis, S.A. Hale, E. Long, R.A. Erdman, X. Zhao and M.J. Paape. 2003. Lactation persistency: Insights from mammary cell proliferation studies. J. Anim. Sci. 81:18–31.

Grossman, M. and W.J. Koops. 2003. Modeling extended lactation curves of dairy cattle: A biological basis for the multiphasic approach. J. Dairy Sci. 86:988–998.

Hadsell, D.L., S.G. Bonnette and A.V. Lee. 2002. Genetic manipulation of the IGF-I axis to regulate mammary gland development and function. J. Dairy Sci. 84:365–377.

Jerry, D.J., E.S. Dickinson, A.L. Roberts and T.K. Said. 2002. Regulation of apoptosis during mammary involution by the p53 tumor suppressor gene. J. Dairy Sci. 85:1103–1110.

Rotz, C.A. and C.U. Coiner. 2003. The Integrated Farm System Model, Reference Manual. http://pswmru.arsup.psu.edu. Accessed March 29, 2004.

Rotz, C.A., D.R. Mertens, D.R. Buckmaster, M.S. Allen and J.H. Harrison. 1999. A dairy herd model for use in whole farm simulations. J. Dairy Sci. 82:2826–2840.

Rotz, C.A., D.L. Zartman and K.L. Crandall. 2005. Economic and environmental feasibility of a perennial cow dairy farm. J. Dairy Sci. 88:3009-3019.

Table 1. Effect of purchased replacement animals and a perennial cow herd on annual feed production, feed use, nutrient balance, costs, and net return of a dairy farm in central Pennsylvania.

		Set farm size		Expanded with Similar feed purchase[4]	
Production or cost parameter	Standard farm[1] 100 cows	No heifers[2] 100 cows	Perennial cows[3] 100 cows	No heifers[2] 120 cows	Perennial cows[3] 128 cows
Alfalfa hay and silage production, metric tons DM	273	273	273	273	273
Corn silage production, metric tons DM	433	219	251	321	407
Grain production, metric tons DM	100	197	180	152	112
Grain purchased, metric tons DM	157	67	61	155	177
Protein and mineral supplement, metric tons DM	40	31	15	39	25
Average milk production, lb/cow/yr	22,667	22,667	21,510	22,667	21,510
Manure produced, metric ton	6200	4700	4800	5600	6000
Nitrogen lost by volatilization, kg/ha	61	50	43	53	46
Nitrogen lost by leaching, kg/ha	29	27	25	29	28
Nitrogen lost by denitrification, kg/ha	9	8	7	9	8
Phosphorus accumulation (shortage), kg/ha	0	(3)	(4)	0	0

Potassium accumulation (shortage), kg/ha	(12)	(21)	(21)	(17)	(16)
Feed production cost, $	69,800	67,300	67,600	68,700	69,500
Manure handling cost, $	15,400	12,800	13,000	14,200	15,100
Labor cost, $	38,500	34,400	34,600	40,500	43,300
Purchased feed and bedding cost, $	35,500	21,300	16,100	34,300	33,800
Animal and milking facilities cost, $	43,800	39,000	39,000	41,100	41,900
Animal purchase and livestock expenses, $	23,800	75,800	55,000	91,000	70,400
Property tax, $	5200	4800	4800	5000	5100
Total production cost, $	232,000	255,400	230,100	294,800	279,100
Milk sale income, $	269,000	269,000	255,200	322,800	326,700
Feed and animal sale income, $	29,600	26,300	19,500	29,100	22,200
Net return to management, $	66,600	39,900	44,600	57,100	69,800
SD of net return across years, $	8600	8200	7700	7600	6700

[1]100 mature cows and 80 replacement heifers on 100 ha of cropland simulated over 25 yr of State College, PA, weather.

[2]Same as standard farm except that replacement animals were purchased ($1600/head), heifer housing was eliminated, other facilities were adjusted, and annual livestock expenses were reduced by $40/cow.

[3]Perennial cows were used, all replacement animals were purchased ($1600/head), heifer housing was eliminated, other facilities were adjusted, and annual livestock expenses were reduced by $88/cow. Perennial cows had a peak milk production a few weeks after calving with a slow decline through the remainder of their productive life of 4 yr.

[4]Cow numbers were increased to obtain a similar amount of purchased feed as that used in the standard farm where replacement heifers were raised on the farm.

Table 2. Milk production and pregnancy records for cows with lactation lengths of 700 days or greater.[1]

Yrs. in production ± 60 d	Days in production	Number of cows	Cows pregnant (%)	Avg. time in milk (d)	Total production (lb)	Average production (lb/d)	Last test production (lb/d)	Last test SCC[2] (x1000 cells/mL)
2.0	700 to 790	2110	33	738	47,011	63.7	44.5	398
2.5	853 to 973	848	24	908	56,005	61.7	45.6	421
3.0	1035 to 1155	129	18	1075	67,195	62.4	45.2	399
3.5	1218 to 1338	74	8	1277	78,871	61.7	49.4	422
4.0	1400 to 1520	26	4	1449	86,066	59.3	47.6	465

[1]Obtained from a national database of DHI Computing Service, Inc. for 852,000 cows in production in the midsummer of 2003. Animals within these periods include 75% of the 4259 cows found with lactation lengths of 700 d or more.
[2]Somatic cell count at last test date; SCC data are from an expanded database of DHI Computing Service, Inc. (Provo, UT) collected from March 2003 through April 2005.

Table 3. Characteristics of the 26 cows with four-year lactations.

HOLSTEINS				
Lactation No.	No. Head	Ave. Total Milk lb.	Ave Milk / Yr lb.	Last Test Day lb.
1	18	86,317	21,580	47.8
2	1	105,059	26,265	52.9
3	3	96,872	24,218	62.2
4	2	70,860	17,715	35.3
5	1	97,909	24,478	47.2
Average	25	87,561	21,890	48.7
Std.Dev. Lactation 1		19,922	4,981	20.5
JERSEY				
1	1	48,728	12,182	20.1

Table 4. Important economic parameters and prices assumed for various system inputs and outputs for the analysis of the representative dairy farms. Prices were set to represent long-term relative prices in current value, which were not necessarily current prices.

Parameter	Value	Parameter	Value
Labor wage rate	$10.00/h	Selling prices	
Diesel fuel price	$1.21/gal	Cull cow	$0.41/lb
Property tax rate	2.3%/yr	Calf	$20/animal
Total livestock expenses	$238/cow/yr	Milk (mailbox)	$11.88/cwt
Cow free-stall barn	$1000/cow	Buying prices	
Heifer free-stall barn	$625/animal	Corn grain	$125/t DM
Feed commodity shed	$70/cow	Alfalfa hay	$135/t DM
Fertilizer prices		Soybean meal	$300/t DM
Nitrogen	$0.25/lb	Protein mix	$330/t DM
Phosphorus	$0.30/lb	Mineral/vitamin mix	$350/t DM
Potassium	$0.13/lb	Straw bedding	$85/t DM
Annual cost of seed and chemicals		Replacement animals	$1600/head
New alfalfa	$80.94/ac	Economic life	
Established alfalfa	$6.07/ac	Storage structures	20 yr
Corn following other crops	$54.63/ac	Machinery	10 yr
Corn following corn	$66.77/ac	Salvage value	
Oats	$22.26/ac	Structures	0%
Real interest rate	6.0%/yr	Machinery	30%

Figure 1. Annual net return for a simulated dairy farm with a varying portion of the herd being perennial cows having 4-yr-long lactations.