Staff Paper

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ABSTRACT

Accelerated prepubertal growth rates can lower heifer raising costs but may put heifers at risk for impaired mammary development and have been found to be detrimental decreased to milk production in the first lactation. The tradeoff between heifer raising costs and milk production loss is examined in a capital budgeting model. Monthly annuity net present value of a heifer investment through the first lactation is assessed for heifers calving at 20, 22, 24, 26 and 28 months of age. A 24 mo AFC base case strategy with 9009.5 kg subsequent first lactation milk yields $7.34 in returns per month. Accelerated growth resulted in higher returns ($12.77/mo for 20 mo AFC; $9.86/mo for 22 mo AFC) when milk production is not affected as total raising costs decline relative to the base case. Slower growth resulted in lower returns ($5.12/mo for 26 mo AFC; $3.15/mo for 28 mo AFC). When milk production declines, revenues decline as do feed and marketing costs which are a function of milk produced. Adjusting for factors, break-even milk production losses were 10.6 % for 20 mo AFC and 5.3 % for 22 mo AFC relative to the 24 mo AFC base. These results were not sensitive to the assumed discount rate, heifer feed costs or discount rate. Other operation-specific heifer management factors including calving season, reproduction, herd size/expansion considerations and, in the longer-term, heifer facilities investments may be more significant economically than the differences found in this analysis.

(**Keywords**: heifer growth, economics, investment)

INTRODUCTION

Raising dairy heifers is an investment where labor, capital, feed, management, facilities and other resources are utilized with the intention of recouping those costs, plus a profit, from either milk and calf revenues or sale of the heifer in the future. It is useful to think of heifer raising as an investment rather than a cost because the potential trade-off between rate of investment (growth rate) and return (milk production) is more appropriately analyzed as an optimal investment rate rather than a production cost.

General agreement exists that heifers should be bred when they achieve sufficient size (measured by height or weight) rather than an age breeding benchmark. A heifer grown at a faster rate before puberty will achieve the breeding size more quickly and therefore calve for the first time at a younger age. Accelerated growth can reduce rearing costs (Hoffman and Funk, 1992). However, several studies have found that accelerated prepubertal growth rates may result in a decline in subsequent milk production (Sejrsen and Purup, 1997). Thus, a potential trade-off between increased raising costs generating an earlier return versus lower raising costs generating a later return exists. In light of this tradeoff, the appropriate economic decision is neither to simply maximize potential future milk production nor to minimize rearing costs. Maximum milk production is not the optimum when costs to achieve that level of milk production, such as increased raising costs, exceed the economic benefits. Similarly, minimizing raising costs might result in a growth rate that excessively compromises milk production potential. Further, the timing of the cash flows is potentially important as the savings from heifer growth occur earlier than the lost income from milk production. Therefore, appropriately discounting heifer investment cash flows to current dollars results in larger cost savings and smaller foregone revenues for heifers grown at accelerated rates.

Past research has largely focused on whether a trade-off between prepubertal growth rate (and thus raising costs) and subsequent milk production exists. Important factors appear to include calving bodyweight and protein to energy ratio of the heifer diet. For example, Radcliff et al. (1997, 2000) found that rearing costs to breeding size were decreased by $77 when heifers were fed diets that produced prepubertal weight gains of 1.2 versus 0.8 kg/d. The accelerated growth rate enabled calving 3 months earlier (21 vs 24 months) but decreased milk yield by 14%. The authors did not attempt to calculate profitability.

Some studies have also attempted to assess the economic consequences of heifer growth management decisions. Van Amburgh (1998) examined heifers raised to calve at 21, 24 and 27 mo. When the heifer was valued at $1,165 with no change in daily raising costs, Van Amburgh estimated that 21 mo AFC was the most profitable with a net return to feeding of $124/heifer compared to $53 for 24 mo AFC and -$74 for 27 mo AFC.   Mourits et al. (2000) used a dynamic programming model with discounting to determine optimum rearing decisions of replacement heifers. They assumed that 0.9 kg/d was a critical threshold beyond which future milk production ability was depressed. For example, a prepubertal growth rate of 1.1 kg/d was expected to depress milk production by 4.9%. Even so, their model indicated that faster growth generated higher returns.

The most appropriate method to assess potential trade-offs between growth rate and milk production is to use a net present value approach converted to monthly annuity equivalent. Rather than impose critical growth rates or assume milk production or health response to growth rate, this analysis looks for thresholds for key economic parameters. The objective was to identify break-even threshold responses to prepubertal growth program rates that result in ages at first calving (AFC) of 20, 22, 26, and 28 months compared to a standard for 24-month standard age at first calving (**AFC**). As with most economic analyses, the outcome for an individual farm depends on the costs, revenues, and production parameters unique to that operation. Break-even milk production losses, feeding costs, and discount rates are used to evaluate the robustness of results. Other considerations, including expected milk price, seasonality, and heifer facilities and investment, are discussed relative to the heifer growth factors.

MATERIALS AND METHODS

This research uses enterprise budgets, capital budgeting investment analysis and evidence of biological parameters from previous studies on heifer growth rate and subsequent milk production to put forth and illustrate a framework for analyzing heifer growth rate decisions. To determine the value of the heifer growth management, the cash flows in lactations of different AFC scenarios are quantified and standardized to their value at birth using present value analysis. Then, monthly annuity equivalent values of each of these AFC growth rates are determined and the values compared.

Net Present Value Calculations

Growing heifers on a dairy farm is a capital investment. Due to the duration of time that capital is committed to heifers prior to them becoming productive assets, the rate and method of investment in heifer growth is an important decision. With cash outflows and inflows taking place at different times and rates depending on the age at first calving, net present value analysis (capital budgeting) is utilized to examine the effects in current dollars. Comparisons of heifer growth investments to produce heifers calving at 20, 22, 24, 26, and 28 months followed through the first 10 mo (305 d) lactation were made by calculating the Net Present Value (**NPV**) of each. The NPV is computed by discounting the cash flows (revenues net of expenses for each month summed over the lifetime of the investment) at the firm's opportunity cost of capital. The NPV of each AFC can be expressed as:

$$NPV = \sum_{t=0}^{T}[(I_t - E_t)/(1+r)^t] + S/(1+r)^T,$$

where

I = monthly revenue (cash inflows),

E = monthly expense (cash outflows),

t = monthly index,

r = the discount rate,

S = the salvage value of the cow after the first lactation, and

T = the length of the investment.

Here r is set at 9 percent and T is the AFC plus the first lactation 305 d (10 mo). The salvage value is what the heifer is worth at the finish of the first lactation.

When comparing investments of difference lengths, it is desirable to compare them in annuity form. The AFC growth rates can be compared on the basis of monthly expected return by converting the net present value of the heifer growth and first lactation to their monthly equivalent value. The monthly annuity equivalent is the constant flow of funds that would make the manager indifferent between it and the existing uneven flow of funds from the heifer investment over the same time period. For this study, the annuity equivalent is the perpetual stream of income that a particular AFC and subsequent first lactation would generate each month in perpetuity at the opportunity cost of capital. The annuity equivalent value is the present value of the AFC adjusted by an annuity factor based upon the investment's length solved for as:

$$M = NPV \times [r/(1-(1+r)^{-T})]$$

where

M = is the fixed annuity payment,

r = discount rate,

T = the number of annuity payments equal to the AFC plus 10 mo for lactation,

and NPV is defined as above.

Assumptions and Parameters in the Base Model

The cash-flows required to calculate NPV were derived from enterprise budgets for heifers and lactating cows. The importance of these values lies in the resulting ranking of NPV across the heifer growth strategy. The robustness of NPV rankings to important assumptions is examined using sensitivity analysis and breakeven values.

Heifer growth rates. Heifer growth was divided into nine periods: milk fed calf (1-28d), milk + grain fed (29-42d), weaned calf (43-90d), three to six months of age, six to nine months of age, pre-bred heifer, bred heifer, bred > 2 mo, and the last three weeks of gestation. Because we are interested in examining the effect of pre-pubertal growth, the growth rate of the unweaned calves (first two age groups) as well as the bred > 2 mo and last three weeks of gestation were held constant across AFC. The other prepubertal age group growth rates (weaned calf, three to six months of age, six to nine months of age, pre-bred heifer, and bred heifer) were set to achieve a 615 kg pre-calving bodyweight (565 kg post-calving) (Table 1).

Heifer raising costs. The costs of raising heifers can be partitioned into those that will likely not vary with faster growth rates (e.g., breeding and vaccines), costs that will change as a function of growth rate (feed), and costs that will change as a constant function of days in the heifer enterprise (e.g., labor, facilities).

The effect of the desired growth rate on feed cost is multifaceted. Faster growth rates require more total feed energy per day and thus a higher daily feed cost. As heifers eat more energy per day and grow faster, however, the relative percent of feed energy converted to growing body tissues increases and the relative percent consumption used for maintenance declines Thus, faster growth rates will decrease the total feed energy consumption to first calving but the impact of this feed savings on total feed costs to first calving is less clear. Diets that are formulated for faster growth rates should contain more protein, minerals, and vitamins per unit of energy. Moreover, diets formulated for faster growth rates can use less poor quality low energy feeds, such as mature forages, pasture, or other feeds that may not be suitable for lactating cows. For our analysis, feed costs were calculated using the ME requirements for maintenance and gain from NRC (2001) and a variable cost per unit of ME as the Mcal requirements for the growth rate from NRC times the cost per Mcal given in (see Table 2). The price of feed was adjusted to reflect the higher quality diets required to achieve earlier AFC with the same bodyweight. The total feed cost, not discounted, was $476 to $479 for all AFC schemes. After adjusting for the time value of money, the longer AFC are lower per day in present dollars.

While feed costs are affected by the growth rate, most other costs such as labor, supplies, and overhead are assumed to be constant per day during heifer growth. Heifer costs, other than feed, used in the base case are described in Table 3. These costs were derived by taking the average expenses from four sources: Dhuyvetter et al. (2005), Harsh et al. (2001), Penn State University (2000), and Radcliff et al. (1997). The costs of labor, veterinary and medical, utilities and fuel, supplies, other variable, and fixed expenses (depreciation, interest, repairs, taxes, and insurance) were spread uniformly across months on an average daily cost basis.

Milk revenue and costs. Milk price used was $0.305/kg ($13.85/cwt) which was the average “All milk” price for the United States from 2000 through 2005 (USDA-NASS, Agricultural Prices). Over that same period, the milk-to-feed price ratio was about 3.0. To be conservative, a feed cost of $0.11/kg milk ($5/cwt) times the milk production level was used. Similarly, milk hauling and milk marketing costs were charged per kg of milk production (Table 3). Thus, when examining break-even milk production levels below, the feed cost, milk hauling and milk marketing costs vary proportionally with the milk production level. Other costs during lactation included labor, breeding, veterinary and medicine, supplies, fuel and oil, equipment repairs, buildings, utilities, miscellaneous, and fixed expenses (interest, insurance and overhead). Since the lactation was assumed to be 10 mo (305 d) regardless of AFC, the costs that did not vary proportionally with milk production were taken from average expenses by Harsh et al. (2001), updated to 2004 dollars values using the US Department of Agriculture milk production price index, and averaged per day across the 305 d lactation (Table 3).

The quantity of milk produced was calculated using a modified Woods equation developed by Oltenacu et al. (1981) with parameter values from Hady et al. (1994). The Woods lactation equation is:

$$MP = A\,(DIM)^{b}e^{cDIM}e^{gDP}$$

where

MP = daily milk production (kg),

A = ([RHA x .01] – 20)/2.96,

RHA = rolling herd average (kg),

DIM = days in milk,

DP = days pregnant,

e = the base of the natural logarithm, and

b,c, g = constants that determine the shape of the lactation curve (Hady et al.).

For lactation 1, b=.08, c=-.002, and g=-.001. To calculate A, RHA was set to 10,000 kg (22,046 lb). The result is that the first lactation was set at a default level of 9,009.5 kg (20,000 lb). The sum of monthly milk production was multiplied by the milk price to derive milk revenues.

Another cash in-flow was the calf produced by the grown heifer. The calf was valued as a weighted average of heifer ($300) and bull ($110) calf value assuming a 5 % mortality rate.

One of the inputs necessary to implement the net present value model is the risk-adjusted discount rate for that investment. Wolf et al. (2002) estimated discount rates appropriately adjusted for risk on dairy farms at 9 percent. We adopt that value in the base case but later examine the importance of this assumption.

Initial heifer calf purchase price was set at $300. Even if the heifer was born on-farm, rather than purchased, this cost reflects the opportunity cost as the heifer calf could be sold as a newborn rather than raised. The salvage value of a healthy heifer sold for dairy purposes after the first lactation was set at $1500/head which was the average replacement heifer price for the US from 2000 through 2005 (USDA-NASS, Agricultural Prices). A cull price was set at $673/head ($1.10/kg times 612 kg). Hadley et al. found that 17.9 % of first lactation cows were culled. Thus, the salvage value in the base case was set at $1,352/hd (0.179X $673 + 0.821 x $1500). Culling is assume to occur only at the end of the lactation.

Not accounted for in the calculations were returns for capital investment and managerial input. Thus, the NPV's calculated here reflect returns to those unpaid factors.

Breakeven values and sensitivity analysis

Using the financial budgets and biological responses a base case comparison across the age at first calving was computed. The importance of key assumptions was evaluated by calculating the breakeven values. Breakeven values simply produce a NPV equal to the base case (here 24 mo AFC) or an NPV of zero. One can then consider the reasonableness of these breakevens relative to past experience and common sense. The variables that were examined included milk production loss and cow salvage value following the first lactation. When the milk production level declines, then revenues decline as well as feed and milk marketing expenses.

Level of milk production is determined by the ability of the mammary gland to produce milk and the ability of the cow to supply the gland with necessary nutrients. The ability of the mammary gland to produce milk is largely dependent on its content of milk-secreting cells, which are found in the mammary "parenchymal" tissue (Tucker, 1987). The number of milk-secreting cells is determined by genetics and heifer environment during mammary development, especially during the rapid mammary growth that occurs before and during the time of puberty, between 3 and 10 months of age (Sinha and Tucker, 1969). The ability of the cow to provide nutrients for milk synthesis depends on size, health, and fitness during lactation.

Three published studies used prepubertal diets that promoted gains >1 kg/d, and each has shown decreased milk yield (decreases ranged from 16 to 52%; Gardner et al., 1977; Little and Kay, 1979; Peri et al., 1993). In addition, there are five other published studies in which gains were 900 g/d or greater, and in each case, milk yield was decreased (decreases ranged from 4 to 38% and were not always significant statistically; Capuco et al., 1995; Gardner et al., 1988; Lammers et al., 1999; Valentine et al., 1987; Van Amburgh et al., 1998). Recent publications suggested that part of the variation in milk responses to prepubertal diets was caused by differences in the dietary protein concentration of heifer diets and in the body weight at which heifers in the control and treated groups calved (Van Amburgh et al., 1998; Radcliff et al., 2000).

Zanton and Heinrichs (2005) performed a meta-analysis using the results from several of these studies (as well as many others) to conclude that the relationship between milk production (and milkfat production) was quadratic. That is, the highest level of milk production was found at 836 g/d above which milk yield declined. In fact, for each 100 g/d increase in daily gain above 900 g/d, milk production decreased 5.5% and fat-corrected milk production decreased 3.5%.

This research examines break-even values and potential implications. It is likely that the precise trade-off between raising costs and foregone milk production varies by herd, manager and even animal. In order for the decision to be in question, it is important, however, that under reasonable assumptions the break-even milk loss fall somewhere in the range of previous research results. Sensitivity analysis is performed by examining the effect of milk price, discount rate, feed cost, and cull rate. The variable in question is changed, e.g., milk price is increased 10%, and then the break-even milk production with the 24 mo AFC is calculated to assess the sensitivity of the results with the assumed variable level (milk price).

RESULTS AND DISCUSSION

Calculated annuity values indicate that, given the base assumption of no decline in milk yield, accelerated prebuteral growth results in higher returns (Table 4). Even though total feed costs at slower growth rates are comparable to raising the heifer at accelerated rates, other costs such as interest, repairs, utilities are less when the heifer enters the milking herd earlier with accelerated growth. The 24 mo AFC yielded $7.34/mo while achieving a 20 mo AFC was worth $12.77/mo. Thus, given these assumptions, slower growth rates result in lower returns.

As was discussed above, the decline in milk production resulting from accelerated growth has been found to encompass a wide potential range in previous research. With a 24 mo AFC resulting in a base milk production level of 9009.5 kg, a break-even milk production level for the accelerated (and slower) growth rates was calculated. The results indicate that the 20 mo AFC would break-even with the base case absorbing an 10.6% decline in first lactation milk production (Table 4). Similarly, the 22 mo AFC break-even first lactation milk decline was 5.3%. Longer AFC required an increase in milk production, all else equal, to break-even with a 24 mo AFC. Thus, the values for break-even milk loss and expected milk loss fall within the range, meaning that the relationship of prepubertal diet and mammary development continues to be important and worthy of investigation.

Sensitivity analysis was performed to assess the importance of key assumptions. Assumed values of milk price, discount rate, heifer feed cost, and cull probability were examined by first calculating the 24 mo AFC monthly annuity at that value and then calculating the milk production change that would result in the same annuity. In this manner one can examine whether the economic results across AFC were sensitive to that assumption. Table 5 displays the results of the sensitivity analysis and it is clear that the pattern is unchanged by these assumptions. That is, the break-even milk production was generally around 10% for the 20 mo AFC compared to the 24 mo AFC irrespective of the changing parameter values. For example, a higher milk price made the break-even milk decline slightly larger but not substantially. Milk production largely drives the economic outcome from heifer raising strategies and the trade-off between future milk production and raising costs is clearly of utmost economic importance.

The analysis thus far has focused on the individual heifer. This is the appropriate level of analysis in the short term when facilities and labor cannot be substantially altered. In a longerrun planning horizon, a shorter AFC results in the need for less heifers to maintain current herd size. The result is that the producer may keep less heifers on-farm cutting total heifer enterprise costs or that heifers may be sold which increases heifer enterprise revenues. This may increase the attractiveness of accelerated heifer growth for producers considering heifer facilities investments.

However, there are other considerations of accelerated heifer growth that may make slower growth potentially more attractive. These may include availability of inexpensive feed sources, as well as timing the calving to correspond to when heifers are needed (e.g., when facilities are completed during an expansion) or to account for milk and feed price seasonality (milk prices tend to be highest during September and October in the US so peak milk production at that time is often desirable). Seasonality of milk production and related calving and reproduction stress may also be key factors so that producers may wish to accelerate or slow heifer growth to avoid summer heat.

Of paramount importance in farm heifer growth on commercial farms is when the heifers are needed or can be effectively incorporated into the dairy herd. This depends on herd expansion plans, facilities and forecasted prices. For example, if an expansion is to be completed in one year, it may be desirable to aim heifers at that date for calving regardless of whether that is accelerating or slowing down growth.

CONCLUSIONS

Accelerated prepubertal growth rates can lower heifer raising costs but may put heifers at risk for impaired mammary development and have been found to be detrimental decreased to milk production in the first lactation. The tradeoff between heifer raising costs and milk production loss was examined in a capital budgeting model. Monthly annuity net present value of a heifer investment through the first lactation was assessed for heifers calving at 20, 22, 24, 26 and 28 months of age. When milk production was identical across AFC, accelerated growth produced higher returns. However, the budgets reveal that the break-even milk production declines were within the range found in previous research. Thus, this question is of economic interest and worthy of consideration. The commercial farm manager will want to consider other operation-specific heifer management factors including calving season, reproduction, herd size/expansion considerations and, in the longer-term, heifer facilities investments which may be more significant economically than the differences found in this analysis.

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Table 1. Heifer growth rates to produce desired age at first calving

			Age at first calving				
Period	Age (d)	Age (d)	20 mo	22 mo	24 mo	26 mo	28 mo
			Rate of gain				
	Start	End	kg/d				
Milk-fed calf	0	28	0.500	0.500	0.500	0.500	0.500
Milk +grain	29	42	0.800	0.800	0.800	0.800	0.800
Weaned calf	43	91	0.978	0.832	0.724	0.641	0.575
3 to 6 months	92	183	0.978	0.832	0.724	0.641	0.575
6 to 9 months	184	274	0.978	0.832	0.724	0.641	0.575
Prebreeding	275	328	0.978	0.832	0.724	0.641	0.575
Bred heifer	238-572[1]	389-632[1]	0.978	0.832	0.724	0.641	0.575
>2 months pregnancy	390-633[1]	588-831[1]	0.950	0.950	0.950	0.950	0.950
Last 3 weeks of pregnancy	589-832[1]	609-852[1]	0.900	0.900	0.900	0.900	0.900
Average overall rate of gain			1.006	0.914	0.838	0.774	0.724
			kg				
Breeding body weight			350	359	364	369	373
Pre-calving body weight			615	615	615	615	615

[1] The start and ending days of “bred heifer” through “last 3 weeks of pregnancy” vary with the age at first calving.

Table 2. Heifer feed costs

Growth period	ME cost				
	20 mo	22 mo	24 mo	26 mo	28 mo
			$/Mcal		
Milk-fed calf	0.250	0.250	0.250	0.250	0.250
Milk +grain	0.200	0.200	0.200	0.200	0.200
Weaned calf	0.080	0.073	0.065	0.058	0.050
3 to 6 months	0.064	0.059	0.054	0.049	0.045
6 to 9 months	0.047	0.045	0.043	0.041	0.039
Prebreeding	0.042	0.040	0.038	0.036	0.034
Bred heifer	0.035	0.034	0.033	0.031	0.030
>2 months pregnant	0.035	0.035	0.035	0.035	0.035
Last 3 weeks	0.060	0.060	0.060	0.060	0.060

Table 3. Base case heifer and lactation expenses and revenue assumptions

Heifer expenses[1]	**Cost**	**Unit**
	$/unit	
Labor	0.30	day[2]
Breeding	32.85	heifer
Veterinary & Medicine	0.03	day
Supplies[3]	0.07	day
Utilities and Fuel	0.04	day
Miscellaneous variable expenses	0.10	day
Fixed expenses[4]	0.27	day
Lactation expenses		
Feed	0.12	kg[5]
Labor	2.08	day
Breeding	49.26	lactation[6]
Vet and Med	120.44	lactation[6]
Supplies	142.34	lactation[6]
Fuel & Oil	21.90	lactation[6]
Equip Repairs	89.78	lactation[6]
Building	58.03	lactation[6]
Utilities	54.75	lactation[6]
Miscellaneous	27.37	lactation[6]
Milk hauling	0.0106	kg
Marketing	0.0033	kg
Fixed	0.60	day

[1] Heifer feed expenses are described in Table 2.

[2] All expenses designated "day" are a set charge per day.

[3] Supplies includes bedding.

[4] Fixed expenses include depreciation, interest, repairs, taxes and insurance.

[5] Expenses designated "kg" are charged per kilogram of milk produced.

[6] These expenses were distributed uniformly over the 305 d lactation.

Table 4. Net present and monthly annuity value of different heifer growth rate investments through one complete 305d lactation with break-even milk production and cull probability values

	Age at First Calving (months)				
	20	22	24	26	28
NPV with 1500 salvage ($)[1]	342.01	279.63	219.48	161.01	103.84
Equivalent monthly annuity	12.77	9.86	7.34	5.12	3.15
Break-even milk production with 24 mo annuity[2]	8058.3	8534.9	9009.5 (base)	9486.8	9967.6
Break-even milk production change from base (9009.5 kg) (%)	-10.6	-5.3	0	+5.3	+10.6

[1]All NPV calculations assume a 9% discount rate.

[2] First lactation milk production that produces a $7.34 monthly annuity value all other factors held constant with the annuity values calculated in row 2.

Table 5. Sensitivity of break-even milk production values to milk price, discount rate, heifer feed cost, and cull rate assumptions

	Age at First Calving (months)				
	24 (base)	20	22	26	28
	Annuity ($)	Break-even milk production change (% decline from 9009.5 kg base)			
High milk price ($0.366/kg)	-14.71	-10.9	-5.5	+5.5	+11.0
Low milk price ($0.244/kg)	-0.04	-10.1	-5.0	+5.0	+10.8
High discount rate (12%)	4.73	-10.8	-5.4	+5.4	+10.9
Low discount rate (6%)	9.99	-10.3	-5.1	+5.2	+10.3
High heifer feed cost (+10%)	5.90	-10.2	-5.1	+5.1	+10.2
Low heifer feed cost (-10%)	8.78	-10.9	-5.5	+5.5	+11.0
High cull probability (36%)	3.46	-9.4	-4.7	+4.7	+9.4
Low cull probability (9%)	9.25	-11.1	-5.5	+5.6	+11.2