Optimal Feed Cost Strategies Associated with Early and Late Calving Seasons

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Abstract

Integer programming models were used to examine optimal monthly feeding strategies and costs for March and May calving alternatives. Body condition scores were allowed to fluctuate throughout the year except for calving and breeding periods. The May calving strategy decreased annual feeding costs by $20 per cow.

Introduction

Delaying calving season from late winter to late spring has been suggested as a way for producers in the high elevation areas of the West to reduce feeding costs (Clark et al.; Adams et al.; Grafel). Late spring calving shifts peak nutrient requirements into the early summer when low-cost nutrients are abundant. In addition, low nutrient availability and high energy requirements imposed during the winter months occur earlier in the pregnancy when cows can better afford to lose body condition. Clark et al. measured forage intake on an experimental March and June calving herd on the Nebraska Sandhills. June calving reduced the amount of hay fed during the winter by 1.5 tons per cow. By valuing hay at $30 per ton, they estimated that late calving reduced winter feeding costs by $45 per cow.

Winter feeding, which typically consists of harvested hay in the Northern Rocky Mountain and Great Plains region, represents a large portion of the cost of maintaining a cow herd. As the increase in nutritional requirements accompanying calving and lactation is delayed, lower quality grazed forages will likely satisfy nutritional requirements during the winter.

A potential advantage of a delayed calving forage system is the cost savings resulting from allowing cows to graze the forage rather than baling, hauling, storing, and feeding hay. However, in spite of lower production costs, total wintering costs could increase if additional supplements are required to offset energy or protein deficiencies introduced by replacing hay with a lower quality feed. Profitability also may be reduced if fetal health, lactation, or breeding performance is impaired as a result of a nutrient deficient winter diet. The objective of this study was to identify the calving month, between February and July, that would minimize feeding costs, and observe how the optimal feeding strategy would change as the calving dated was shifted throughout this period.

Methods

Multi-period mixed integer programming models (MIP) were constructed for each calving system with an objective function of minimizing the cost of providing energy and protein to a 1,000 pound mature cow. The ration was balanced, on an as-fed basis, for each month of the year, with requirements dependent on the calving, lactating, and breeding schedule, along with environmental conditions. Nutrients were available depending on the annual forage production cycle. Objective function values from each model were compared to determine the feed cost savings that would occur under the later calving system.

A disadvantage of the mathematical programming approach compared to biological experiments to estimating relative feed costs is that important biological interactions are based on a synthesis of several prediction equations and are subject to the errors inherent in the estimation process. However, a well designed optimization model, with results verified by experimental research, offers several advantages. Variables that cannot be controlled by researchers, such as weather conditions, can be imposed on the model. Parameters and constraints can easily be adjusted to test the robustness of the results over a variety of scenarios, and the characteristics of a ranch operation that are best suited to late calving can be identified.

It was expected *a priori* that late calving would allow cows to better utilize fat reserves accumulated during the growing season to meet energy requirements during the winter. The model was formulated to incorporate cow body condition as a decision variable and estimate the optimal pattern of seasonal condition score changes for each calving system. Managing cows to lose body condition during the winter presents issues that may not be adequately accounted for simply by measuring feed intake during the winter and valuing the feed at a budgeted cost. As cows lose body condition during the winter, part of the cost of winter feeding is deferred to the period when the condition is replaced. For example, stocking rates during the summer may have to be reduced to accommodate increased forage intake required to recover body condition. Year-round feeding costs, therefore, should be considered when evaluating feeding systems that include utilizing fat reserves. Mathematical programming is well suited to account for these issues and determine a least cost feeding system.

The integer programming model is stated mathematically as:

(1) Minimize Feed Cost = $\Sigma\, w_j b_j$; Objective function.

s.t.

$\Sigma e_{ij} b_j = k_i$; Energy requirement constraint.

$\Sigma c_{ij} b_j >= p_i$; Protein requirement constraint.

$\Sigma t_{ij} b_j <= r_i$; Dry matter intake capacity constraint.

Equation (1) represents the objective function of minimizing the cost of feeding a cow year-round, where w_j represents the cost of the j^{th} feeding activity, and b_j is the level that the j^{th} feeding activity enters the solution. Each forage alternative was valued in the model at its estimated production or procurement cost.

Costs associated with each feeding alternative in the objective function were separated into production or acquisition, and consumption costs; i.e. production and consumption are separate decision variables. A herd size of 400 cows was specified to amortize the fixed costs over a herd representative of the Laramie County area in Southeast Wyoming. The ration was balanced on a per cow basis. However, the model was formulated to acquire enough forage resources to support the entire herd. High and marginal quality irrigated land could be allocated among the following set of production alternatives: spring, summer, fall, or winter pasture; baled and stacked native grass hay; alfalfa hay; grass hay cut and raked into windrows for grazing; and basin wildrye establishment. Hay aftermath was available on acreage used to produce hay. The model could select among these alternatives for consumption in the months they were available. However, certain grazing alternatives within a period were assumed to be mutually exclusive.

High and marginal quality irrigated land was constrained to enter the solution in equal amounts. Ten percent of good irrigated land was assumed to be suitable for alfalfa production. Rangeland could be allocated among native grass and basin wildrye. The rangeland to irrigated land ratio was constrained to be 20 to 1. Purchasing alfalfa and/or native hay at the eight year average Wyoming price, plus a $20/ton deliver charge, was included in the model as an alternative to production. The coefficients on objective function production variables were expressed as production cost per acre. Coefficients on objective function feeding variables were expressed as cost per ton.

The energy constraints are represented by equation (2) where c_{ij} represents the net energy contribution (as-fed basis), measured in megacalories (Mcals) of net energy for maintenance (NE_m), of the j^{th} feedstuff in the i^{th} month since calving. The symbol k_i denotes the monthly energy requirement measured in Mcals of NE_m required in the i^{th} month. Each period included both a slack and surplus variable in the energy constraint to allow either storage or depletion of energy reserves. Each Mcal of NE stored in mobilized tissue will replace 0.8 Mcal of diet NE (NRC, 1996). Condition scores were tracked each month based on NRC estimates of energy (Mcals) mobilized in moving between condition scores.

Morrison and Castle found that cows could lose body condition during the winter and regain it prior to calving without adversely affecting calf production. However, research suggests that allowing condition scores to remain below 5 at calving time can impair lactation and rebreeding performance (Morrison and Castle; Torell and Torell; Wickse et al.; Odde). Condition scores at calving, therefore, were constrained to be 5 or higher. Cows should be gaining or maintaining weight during the period between calving and breeding (Church). Condition loss was not allowed two months prior to calving, or in the months between calving and breeding. Other limitations relating to energy reserves was that body condition could not drop below a score of 3, and that cows could not loose more than one body score in a single month.

Equation (3) represents protein requirement constraints, where c_{ij} represents the crude protein (CP) content of the j^{th} feed alternative in the i^{th} month since calving. The right-hand-side of these constraints, p_i, is the daily crude protein requirement (lbs), in the i^{th} month since calving. Excess protein is excreted rather than stored (Church, 1991), therefore, protein requirements were met each month and surpluses were not stored for later use.

Equation (4) represents the set of dry matter intake (DMI) constraints for each month since calving, were t_i denotes the percent dry matter of the j^{th} feedstuff in the i^{th} month. Cows have a limited capacity to consume dry matter, therefore, the diet should be sufficiently nutrient rich to satisfy requirements. This is the limiting factor for many of the low quality, low cost forage systems from entering the least-cost solution.

Data

The operating cost of each feeding alternative was estimated using enterprise budgets. Production budgets were constructed for round baled native and alfalfa hay, native hay left in windrows, basin wildrye establishment on both irrigated and non-irrigated land. Grazing budgets were developed for rangeland and irrigated pasture based on results from Van Tassell et al.. Rancher/cooperators located throughout Wyoming assisted in identifying relevant activities and machinery used on typical ranches. Labor was valued at $7.00 per hour in all budgets. Formulas developed by the American Society of Agricultural Engineers were used to estimate fuel consumption, repair, and depreciation costs for machinery included in the budgets.

Annual land and machinery ownership costs were included in the objective function coefficient of the land and machinery acquisition variables. Land values were obtained from Bastian and Hewlett. Annual land ownership costs were calculated by capitalizing the land value at a rate of 3.35 percent (Torell and Doll). Fixed costs of owning machinery included capital, taxes, insurance, and housing. A 7 percent interest rate was used to value the opportunity cost of capital invested in machinery.

Nutritional requirements for a 1,000 pound average milking cow (20 lbs of milk per day) were taken for each month from the 1996 edition of the NRC *Nutritional Requirements of Beef Cattle*. The NRC tables assume a seven month lactation period. However, cows in the June and July calving models were weaned by December 1. This assumption reduced the lactation period in these models by one and two months, respectively.

Nutritional requirements developed by the NRC assume thermo-neutral conditions. In Wyoming, the combination of wind and cold temperatures during the winter often impose cold stress on range cattle. To estimate the energy requirement adjustment necessary to account for cold stress, daily wind and temperature data (NOAA) was obtained for the 26 year period from 1972 through 1997 for the Laramie county area. Average daily wind chill adjusted temperatures were computed from a formula developed by Ames and Insley. These results were aggregated to average monthly temperatures. The adjustment factor for each month was estimated using the rule suggested by Ames that for each degree the effective temperature drops below the lower critical temperature, energy requirements increase by one percent. The lower critical temperature used in the model was 18° F (Ames).

Nutritional quality of the feed alternatives were taken from the NRC *Feed Library*. Nutritional quality of feed alternatives included in the model but not in the Feed Library was determined by expert opinion.

Results and Discussion

Table 1 shows the solution of each model assuming average weather conditions. Factors affecting the relative costs of each calving system were weather conditions and forage availability. Feeding costs declined each month calving was delayed. July was the lowest cost calving month, with costs 13.3 percent lower than March calving.

Feeding costs in the late calving herds were less affected by winter weather than the early calving herd. March and May calving models were solved for mild, average, and severe winter conditions. Thermo-neutral requirements were used for the mild winter while the maximum adjustment factor that occurred each month in the 26 year period from 1972 through 1997 was used for the harsh winter. The difference in costs resulting from a mild winter and a harsh winter were 2.6 times greater in the March calving model than the corresponding range in the May calving model. These results demonstrate that feed cost savings resulting from late calving is directly related to the severity of winter weather.

For late calving to be economically feasible, any cost reduction should be greater than any adverse effects on the value of calf production. At the 1992-1996 average price for 4-500 pound steer calf ($0.85/lb), average weaned calf per cow for a March calving herd would need to be 23 pounds higher than the May calving herd to offset the increased feed cost of $19.84 per cow.

Energy stored in fat reserves were an important part of the feeding program in each calving system. Figure 1 shows changes in total energy reserves for cows under each calving system. The range between the highest and lowest level of cumulative energy reserves was similar for each calving system. Each month calving was delayed resulted in a downward shift in the curve. Earlier calving systems required the cow to be maintained at a higher average body condition throughout the year. February calving cows would gain condition during the summer, reach a body score of 7 by September, and drop to a score of 5 by calving, never moving below the calving time condition score. Later calving cows gained less weight during the summer months, dropped below a body score of five during the winter, and returned to a body condition score of 5 prior to calving. The constraint preventing body condition from dropping below a score of 3 was binding only in the July calving model. The constraint preventing the loss of more than one condition score in a single month was non-binding in the early calving models but binding in the late calving models.

Availability of relatively low-cost/high quality forage was an important factor in the relative feed costs of early and late season calving. For example, when alfalfa (65% TDN and 14% CP) was available in unlimited quantities at a cost of $50 or less per ton, the optimal solution was to feed hay during winter for all calving programs. In this situation, later calving systems required slightly less hay than earlier systems and the savings generated by late calving were insignificant. This implies that ranchers with higher quality inexpensive winter forage alternatives should experience less benefit from late calving than producers with relatively low quality winter forage.

Table 1 shows a distinct trend away from hay toward grazing resources each month calving is delayed. May calving required half the amount of alfalfa per cow as March calving. Basin wildrye and windrowed hay were not utilized in the early or late calving models due to a lower nutritional quality to cost ratio. Winter-feed alternatives entering the least-cost solution for the March calving system were irrigated pasture during fall and native range supplemented with alfalfa hay during winter. In the March calving model, range cake was required in April, one month after calving, when the peak protein requirements occur.

Like the March calving system, May calving selected irrigated pasture during the fall, while native range and alfalfa comprised the winter diet. However, May calving allowed increased grazing and required less hay. Shifting from hay to grazing resources required more acreage per cow. This implies that the cost savings resulting from late calving is influenced by the cost of acquiring additional grazable forage. Holding other factors constant, relatively high land or grazing lease costs would favor early calving.

The optimal feeding strategy and associated costs depended on the size of the operation. A herd of 400 cows did not require enough hay to justify incurring the fixed production costs given a yield of 1 ton per acre for native hay and 3 tons for alfalfa. Alfalfa hay purchased at $97/ton including shipping was less expensive on a per nutrient basis than producing native or alfalfa hay for 400 cows. Both native and alfalfa hay entered the least-cost solution in the March calving model, however, when the herd was increased to 800 cows. Relative dry matter yields between basin wildrye and native grasses have not been well documented. Basin wildrye establishment costs were incurred on a per acre basis and cost per pound of dry matter, therefore, is highly dependent on the yield. The protein and energy content of standing basin wildrye was assumed to be similar to winter range estimates contained in the NRC feed library. Sensitivity analysis was conducted to estimate the yield ratio that would allow basin wildrye to enter the least-cost feeding system. If native grasses yield 0.2 AUMs per acre, a yield of 0.55 AUMs of dry matter per acre would be required for basin wildrye to enter the least-cost solution at any level in the March or May calving system. This corresponds to a basin wildrye to native range yield ratio of 2.75 or greater before basin wildrye establishment is economically justified.

Windrowed hay did not enter the least-cost solution in any model. Experimental research evaluating relative nutritional quality between windrowed hay and baled hay is limited. However, producers who use windrowed hay in their management scheme consistently report TDN levels near 50 percent and crude protein levels near five to six percent for windrowed hay, while baled and stacked hay averages 56 percent TDN and 8 to 9 percent crude protein. The cost savings from allowing cows to graze windrowed hay was not enough to offset the increased cost of portable electric fencing, additional supplement, and herding.

Conclusions

This model demonstrates that feeding costs can be reduced if calving is delayed into late spring. The magnitude of the cost reduction depends on winter weather conditions and the forage resource endowment. Feeding variables included in the optimal solution were similar for early and late calving. However, the relative proportions included in the ration shifted from hay to grazed forages as calving was shifted later into the season.

Table 1. Results of Production and Feeding Variables, and Feeding Costs for Each Calving Month.

		Calving Month					
	Units	Feb	Mar	Apr	May	Jun	Jul
Forest Service Lease	AUMs	5414	10066	10749	10994	6970	6504
Grazed Native Rangeland	Acres	7800	7459	8727	9014	10808	10850
Basin Wildrye on Rangeland	Acres	0.0	0.0	0.0	0.0	0.0	0.0
Basin Wildrye, Good Irrigated Land	Acres	0.0	0.0	0.0	0.0	0.0	0.0
Basin Wildrye, Marginal Irrigated	Acres	0.0	0.0	0.0	0.0	0.0	0.0
Windrow Hay, Good Irrigated Land	Acres	0.0	0.0	0.0	0.0	0.0	0.0
Windrow Hay, Marginal Irrigated	Acres	0.0	0.0	0.0	0.0	0.0	0.0
Native Hay on Good Irrigated Land	Acres	0.0	0.0	0.0	0.0	0.0	0.0
Native Hay on Marginal Irrigated	Acres	0.0	0.0	0.0	0.0	0.0	0.0
Total Native Hay Production	Tons	0.0	0.0	0.0	0.0	0.0	0.0
Purchased Native Hay	Tons	0.0	0.0	0.0	0.0	0.0	0.0
Total Native Hay Fed Per Cow	Tons	0.0	0.0	0.0	0.0	0.0	0.0
Native Hay Aftermath	AUMs	0.0	0.0	0.0	0.0	0.0	0.0
Alfalfa Hay Aftermath	AUMs	0.0	0.0	0.0	0.0	0.0	0.0
Alfalfa Hay on Good Irrigated Land	Acres	0.0	0.0	0.0	0.0	0.0	0.0
Total Alfalfa Production	Tons	0.0	0.0	0.0	0.0	0.0	0.0
Purchased Alfalfa Hay	Tons	383.0	239.2	143.4	119.1	89.4	88.6
Total Alfalfa Fed Per Cow	Tons	1.0	0.6	0.4	0.3	0.2	0.2
Range Cake Fed Per Cow	LBS	161.9	128.0	0.0	0.0	11.9	0.0
Grazed Good Quality Irrigated Land	Acres	195.0	186.5	218.2	225.4	270.2	271.3
Grazed Marginal Quality Irrigated	Acres	195.0	186.5	218.2	225.4	270.2	271.3
Annual Dry Matter Intake Per Cow	LBS	7004.6	7064.6	7311.3	7399.6	7401.6	7314.4
Total Annual Protein Consumption	LBS	870.5	840.5	848.0	856.2	855.1	839.2
Average Crude Protein Level in Feed	%	12.43	11.90	11.60	11.57	11.55	11.47
Number of Cows	Head	400.0	400.0	400.0	400.0	400.0	400.0
Cost Per Cow	$	234.45	212.97	194.91	193.13	187.71	184.69
Cost Savings Relative to March	$	-21.47	0.00	18.06	19.84	25.26	28.28
Cost Savings Relative to March	%	-10.1	0.0	8.5	9.3	11.9	13.3

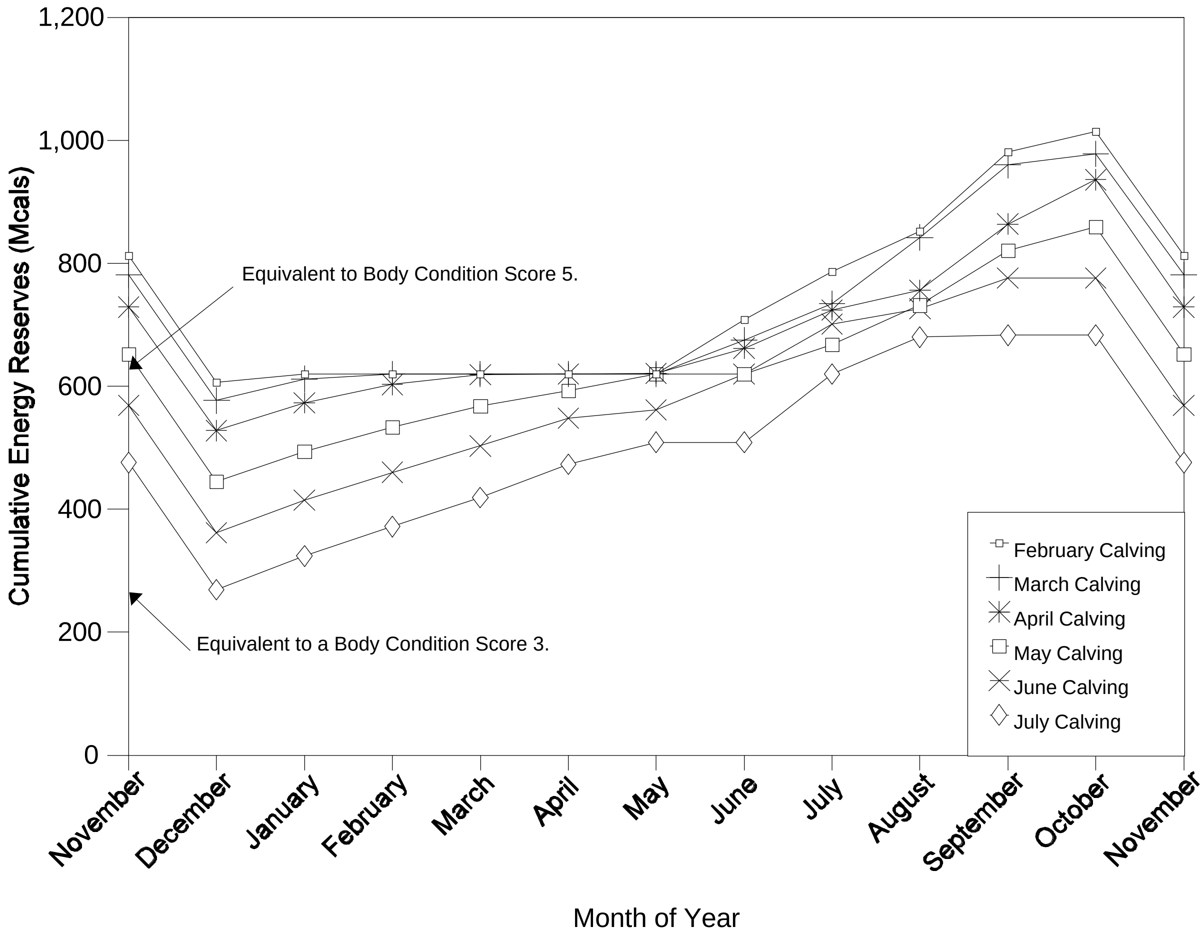

Figure 1. Energy Reserve Fluctuations by Calving Month.

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