Analyzing the Effect of Changing Feed-Beef Price Relationships on Beef Production Management Strategies in Hawaii: A Dynamic Programming Approach

H. Walter van Poollen and PingSun Leung

A dynamic programming approach was used to evaluate the effect of changing the feed input to product price relationship on the beef production management decision process. The dynamic programming model consists of nine submodels describing and analyzing the time-dependent beef production management decision process. The model incorporates biological functions and economic principles. Results clearly showed the importance of the feed-beef price relationships in management decision making. Optimal beef production management strategies were generally consistent with beef production management practices followed in Hawaii under those feed-beef price relationships.

Key words: beef, dynamic programming, management, prices.

Agricultural producers base management decisions on the product and input prices facing them. They adjust their farm business to changes in the relative price structure. Researchers have used linear programming and/ or input-output analyses to assess impacts of input price increases and quantity restrictions on agricultural production activities (Miranowski; Kliebenstein and Chavas; Mapp and Dobbins; Dvoskin and Heady 1976, 1977; Brokken, O'Connor, and Nordblom).

Beef production management systems are a sequence of interrelated decisions. Management systems with interrelated decisions can be analyzed using dynamic programming. The dynamic programming approach has been used to examine the management problems in beef production. Kennedy found dynamic programming to be a flexible tool for dealing with these management problems. His model solves for the optimal marketing and feeding strategies for feedlot animals. Similarly, Meyer and Newett and Yager, Greers, and Burt applied dynamic programming to feedlot feeding and marketing, while Clark and Kumar used it to determine optimal feeding and marketing strategies for pasture-fed beef.

Typically, dynamic programming is used to examine specific segments of the overall production system (i.e., feedlot, pasture finishing, or culled cows). In Hawaii, it is common for the rancher to retain ownership of the animal throughout the production process. In this case, a model which looks at the entire management system is most appropriate. Because numerous management decisions occur prior to decisions related to the feedlot (or pasture) feeding and marketing of beef cattle, a dynamic programming model that deals with the overall management system is used in this study.

The sensitivity of Hawaii's beef industry to relative input and output price changes is currently unknown. Two important aspects relat-

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ing to Hawaii's geographical location make its $28.1 million beef industry potentially sensitive to changes in the relative price structure. They are: (*a*) normal weather conditions in Hawaii generally allow for pasture grazing all year, thereby giving the beef production manager the flexibility to utilize less energy-intensive beef production systems and to have year-round breeding, and (*b*) much of Hawaii's feedlot feed is imported. Transportation of this feed adds an additional charge to the feedlot feeding costs, thereby making feedlot feeding even more energy-intensive and conditional on energy prices.

This paper presents a dynamic model of beef production management decision processes for the entire production system from the ranch to the feedlot. It also presents the results of utilizing the model in a comparative static approach to evaluate the impact of feed and beef price changes on the beef production management strategies in Hawaii. Management strategies considered by the model include breeding, culling, weaning, and post-weaning feeding decisions. The model generates results which are consistent with economic theory and hence can be used to provide general guidelines regarding production management strategies for feedlot operators and ranchers.

The Model

The dynamic programming model used to determine optimal beef strategies consists of nine submodels which allow the interrelationship of time-sequential biological and economic functions in Hawaii beef management. The submodels are the objective function submodel, cash flow submodels, cull cow submodel, calf submodel, feeding management submodel, stocker submodel, pasture submodel, feedlot submodel, and a least-cost gain ration submodel. Figure 1 illustrates the relationships among the various submodels within the overall model.

The time-dependent interrelated decisions for the brood cow and all of its calves are used to determine an optimal set of management decisions. The model determines the following management strategies for each year of the cow's life: whether to breed the cow or cull the cow; when to breed; optimal weaning age and weight of the calves produced; the best feeding policy for each calf; optimal rates of gain for

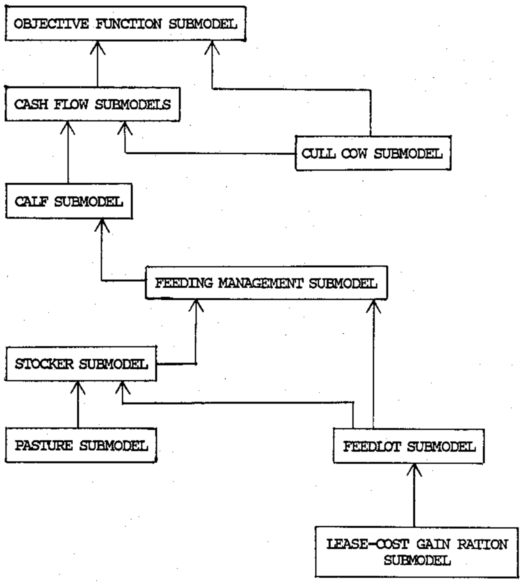

Figure 1. Model structure

each animal in each period; least-cost gain ration; optimal selling weight, and month. The determination of an optimal management strategy is based on maximization of the expected net present value of the cow. Specific details of the model can be found in van Poollen.

The model evaluates yearly returns from culling an animal and returns from breeding the animal that year and all subsequent years. If the return is higher from culling the animal, the model recommends culling. These investment decisions are made for each cow of a certain age bred in a certain month, e.g., a four-year-old (at conception) cow bred in March or an eight-year-old (at conception) cow bred in September. These investment decisions are then used for long-term culling management strategies. The model also determines short-run management strategies for breeding, weaning, and post-weaning feeding.

Objective Function Submodel

The objective function submodel is a backward dynamic program which makes the decision to invest or abandon.[1] The decision to invest means the cow is kept and bred, while the decision to abandon means the cow is

[1] This follows the procedure presented by Bonini.

Table 1. The States of the System (S_j)

State	Description
A.	The decision is made to breed the cow in the current month:
1	The cow conceives from the first service, and the calf lives and is weaned.
2	The cow conceives from the first service, yet the calf dies prior to weaning.
3	The cow conceives from the second service, and the calf lives and is weaned.
4	The cow conceives from the second service, yet the calf dies prior to weaning.
5	The cow does not conceive after the second service.
B.	The decision is made to delay breeding by one month. States 6–10 are similar to states 1–5, respectively.

culled. There is a finite set of possible cash flows that may occur for each time period. Each possible cash flow results from a particular state of the system, which is designated as S_j for the jth state. It is assumed that cash flows in different time periods are independent of one another in this analysis. The following equations are used in this submodel:

$$(1) \quad f_{16}^* = CV_{16} = f(\text{month, age of dam})$$

where f_{16}^* is the present value (terminal value) of the cow in the sixteenth year, and CV_{16} is the cull value in the sixteenth year.

Sixteen years was chosen to represent the maximum life of the investment (cow) because data were not available for cows over fifteen years of age.

$$(2) \quad f_{15}^* = \max\left(CV_{15};\ \alpha\left\{\sum_{j=1}^{d} P_{ja}[CF_{15}(S_j)] + f_{16}^*\right\}\right)$$

where f_{15}^* is the expected present value of the cow in the fifteenth year, CV_{15} is the cull value in the fifteenth year, j is the particular state of the system number (1 to 10), d is the number of possible cash flows (states), $CF_{15}(S_j)$ is the numerical value of the jth state cash flow for the fifteenth year, P_{ja} is the probability of the jth state existing given the age of dam (a), α is the discount factor = $1/(1 + i)$, and i is interest rate. A choice is made in the fifteenth year between culling the cow with a value of CV_{15} and keeping the cow with a value of

$$\left\{\sum_{j=1}^{d} P_{ja}[CF_{15}(S_j)] + f_{16}^*\right\} \text{ discounted by } \alpha.$$

This choice is made every year using the following general equation:

$$(3) \quad f_t^* = \max\left(CV_t;\ \alpha\left\{\sum_{j=1}^{d} P_{ja}[CF_t(S_j)] + f_{t+1}^*\right\}\right).$$

The final step in this analysis is calculated using the following equation:

$$(4) \quad f_1^* = \alpha\left\{\sum_{j=1}^{d} P_{ja}[CF_1(S_j)] + f_2^*\right\} - CI_1$$

where f_1^* is the expected net present value of the cow, and CI_1 is the purchase cost of the cow.

There are ten distinct possible states (S_j) of the system. These are presented in table 1. The probability of each state occurring varies with the age of the cow and is based on conception and weaning rates (Cunha, Warnick, and Roger).

Cash Flow Submodels

There is one cash flow submodel corresponding to each state of the system. These submodels make monthly decisions to breed or delay breeding by one month and determine the cash flows of the possible states of the system. The cash flows are then used as input data in the objective function submodel. Cash flow for a particular state is determined by subtracting the variable costs associated with that state from net revenue generated by the calf or culled cow submodel. For example, the cash flow for state 1 equals the net revenue from the calf submodel minus the breeding cost, branding cost, a nine-month feeding cost for a gestating cow, and a three-month feeding cost for a lactating cow.

The decision to delay breeding by one month is based on the concept of marginal revenue versus marginal cost of breeding, thereby allowing an intentional decision to delay breeding for numerous consecutive months. Breeding is allowed to occur in any month of the year. Two months after the decision to breed, bulls are removed and the cow is culled if it has not conceived. State 5 represents this case where cash flow equals the net revenue generated from the cull cow submodel minus two breeding costs and two months of feeding costs for an open cow.

Cull Cow Submodel

The cull cow submodel determines the net revenue from selling a cow as a slaughtered animal and is calculated as the product of the actual monthly price received when the animal is sold and the weight of the animal. A safeguard is incorporated to insure that culling does not occur prior to calf weaning. Results from the cull cow submodel and cash flow submodel are used in the objective function submodel and cash flow submodels 5 and 10.

Calf Submodel

The calf submodel is a backward dynamic program which determines the optimal weaning ages and weights of the calves. Net revenues are used as input data for cash flow submodels 1, 3, 6, and 8. This submodel receives net revenues as input data from the feeding management submodel. The weaning weight is a function of the age of the dam and the weaning age of the calf, assuming proper nutrition weaning occurs between six and eleven months of age, with weaning weight (adjusted for shrinkage) ranging between 350 and 595 pounds.[2]

Feed Management Submodel

The feeding management submodel chooses the best feeding alternative for the weaned calf. This model connects the stocker, pasture, and feedlot submodels and selects the optimal feeding strategy among these major feeding alternatives. Possible feeding alternatives are (*a*) pasture feeding from weaned weight to slaughter weight (pasture only), (*b*) feedlot feeding from weaned weight to slaughter weight (feedlot only), and (*c*) pasture feeding from weaned weight to around 710 pounds, then finishing to slaughter weight in the feedlot (pasture-feedlot).

Pasture Submodel

The pasture submodel projects monthly costs and returns for the feeding alternatives of pasture feeding from weaned weight to slaughter weight. This submodel is a forward dynamic program. The state of the system in any period (month) can be one liveweight out of a range of fifty-eight possible liveweight states (350 to 1,220 pounds at 15-pound intervals). The liveweight states may be changed between periods by exercising one of the following decisions: (*a*) continue the animal on pasture during the next period, or (*b*) sell the animal if the animal is 710 pounds or heavier.

The decision is based on the marginal revenue versus marginal cost concept. As long as the expected marginal revenue is greater than the expected marginal cost, one would continue to feed the animal. After a decision to sell has been found to be optimal, the decision process is terminated, thereby determining the optimal slaughter weight.

Feedlot Submodel

The feedlot submodel is a forward dynamic program in which the state of the system in any period can be one liveweight out of a range of fifty-eight possible liveweight states (350 to 1,220 pounds at 15-pound intervals).[3] The liveweight state may be changed between periods by exercising one of the following decisions: (*a*) continue the animal at one of the seven possible rates of gain (0–3.0 pounds per day at .5 pound intervals) during the next period, or (*b*) sell the animal for slaughter if the animal is 710 pounds or heavier.

The feedlot submodel projects monthly costs and returns for feeding alternatives of (*a*) feedlot feeding from weaned weight to slaughter weight, and (*b*) feedlot feeding from around 710 pounds to slaughter weight. Feeding costs are determined by a least-cost gain ration subprogram.

Stock Submodel

The stock submodel computes monthly costs of pasture feeding from weaned weights to approximately 710 pounds, at which weight the animal is transferred to the feedlot. The feedlot submodel is used to determine monthly cost from the transfer weight to slaughter weight. The stocker and feedlot submodels are used in combination to determine the feeding costs and marketing strategy for the pasture-feedlot alternative.

The pasture and feedlot submodels determine whether potential marginal revenue from feeding is greater than the marginal cost of

[2] The weight intervals used in this model are chosen so as to utilize the growth and nutritional information in Cunha, Warnick, and Roger; and O'Mary and Dyer.

[3] This section follows the procedures developed by Kennedy, Meyer and Newett, and Clark and Kumar. This submodel requires at least four months feedlot feeding for all feeding alternatives to assure the assumed dressing percentages, associated grades (choice, good, etc.), and prices.

Table 2. Feed and Beef Prices, 1973-78 Period and 1981

	1973–78 Period	1981
Selected feed prices ($/ton):[a]		
Alfalfa cubes	132.09	170.00
Fish meal	253.00	350.00
Ground barley	171.21	272.00
Guinea grass hay	55.93	96.00
Soybean meal	275.10	390.00
Wheat grain	192.00	282.65
Beef prices (¢/lb.):[b]		
Cows	21.9–23.0	39.6–41.7
Steers and heifers		
Feedlot finished, 915–1,115 lb.	38.5–42.7	60.6–64.4
Feedlot finished, 710–914 lb.	36.4–40.5	57.4–63.5
Range finished, 915–1,115 lb.	31.0–33.4	47.8–51.6
Range finished, 710–914 lb.	29.2–31.5	45.1–48.7

Sources: Feed prices are from Department of Animal Science's price bids, University of Hawaii; beef prices are from Statistics of Hawaiian Agriculture, Hawaiian Agricultural Reporting Services.
[a] Feed prices shown are annual averages.
[b] Beef prices shown are ranges of monthly averages.

feeding. If it is, the decision to feed will be taken. The decision made during one time period controls the state of the process in the next time period. After a decision to sell has been found to be optimal, the decision process is terminated, thereby determining the optimal slaughter weight.

Least-Cost Gain Ration Submodel

The least-cost gain ration submodel uses linear programming to determine least-cost gain rations for all allowable rates of gain and liveweights for use in the feedlot submodel. Feed prices change monthly and are based upon actual monthly prices.

Assumptions

Three applications of the model were made for price changes occurring between the 1973–78 period and 1981 (see table 2). The model was first applied using 1973–78 average feed and beef prices in Hawaii to evaluate the model's performance. This base scenario can be considered to be a low-to-low feed-beef price relationship.

In the second application of the model, it is assumed that feed costs increased to their 1981 levels. Between the 1973–78 period and 1981, these increases were as follows: grains, 72%; harvested roughages, 40%; meals, 56%; and other feedlot feeds, 46%. Table 2 shows the average feed costs for some selected feeds during the 1973–78 period and 1981. In this application beef prices are assumed to be held at the 1973–78 average levels. This feed-beef price relationship can be considered to be a high-to-low feed-beef price relationship.

The third application of the model is the high-to-high feed-beef price relationship. This scenario determines optimal production management strategies assuming beef and feed prices are at their 1981 levels.

As shown in table 2, there were five beef price categories depending on type of animal, weight, grade, and method of gain. The assumed dressing percentages for the categories are commercially slaughtered cows, 51.8%; feedlot-finished steers and heifers 915–1,115 pounds, 58%; feedlot-finished steers and heifers 710–914 pounds, 54.9%; range-finished steers and heifers 915–1,115 pounds, 54.9%; and range-finished steers and heifers 710–914 pounds, 51.8%.

The feeds considered in the least-cost gain ration model are alfalfa hay, alfalfa meal, barley grain, ground barley, rolled barley, rolled corn, corn silage, cottonseed meal, fish meal, guinea grass hay, meat and bone meal, pineapple bran, pineapple greenchop, pineapple silage, oats, rolled oats, sorghum (milo), soybean meal, heat grain, wheat middling, molasses with urea, and limestone. Average annual prices for selected feeds are shown in table 2. Detailed tabulation can be found in van Poollen.

The prices used in the model were average monthly prices. The operator was assumed to be working under known past prices, which were assumed in this study to continue in the future. The power of this dynamic programming approach is its ability to reevaluate management strategies as new information becomes available.

The disadvantage of this approach is that it is difficult to uncover cause and effect relationships because of the interdependencies among seasonality of prices, time value of money, and possible biological relationships. For example, a change in the corn price will change the relative price structure among the twenty-three feeds, which may change the feed ration and thus the feed cost. The values of all subsequent decision variables may be affected.

Results

The optimal breeding management strategy was to breed a heifer or cow as soon as she comes into heat. Although the model determines whether it is better to breed in the current month (any of the twelve months for Hawaii) or to delay breeding for one month, at no time was it optimal to delay breeding until the following month. Delayed breeding was originally considered because of the unique climate in Hawaii allowing for year-round breeding.

The expected net present value for breeding at fifteen months of age is about $9 to $57 higher per animal compared to breeding at twenty-four months (table 3). The average difference is about $30 with a low-low feed-beef price relationship; while with a high-low feed-beef price relationship, the average difference is about $25. The average difference in expected net present values with a high-high feed-beef price relationship is $12. The additional costs of breeding at twenty-four months probably exceed the comparative advantage of breeding at fifteen months in Hawaii because of the situation of a high input to high output price relationship.

In Hawaii, there seems to be a slight advantage gained by breeding during the months of February to August with a low-low feed-beef price relationship (table 3). But when one examines the other possible price relationships, it becomes obvious that it is not optimal to practice seasonal breeding in Hawaii. In fact, the largest difference between any two values for a high-high price relationship is less than $25.

The optimal culling management strategy is shown in table 4. Cows between four to thirteen years of age at conception which lose a calf or produce calves with below-average weaning weights should be culled with a low beef price situation. This exceeds the normal culling practice which recommends culling a cow if she has not conceived after the second service. With a high beef price situation, a manager can afford a less intensive or severe culling practice. Cows fourteen years old at conception should be culled after their calves are weaned. Fifteen- and sixteen-year-old cows should not be bred but should be culled immediately.

In addition to optimal culling strategy, the model determines the optimal weaning man-

Table 3. Optimal Breeding Management Strategy

Month Breeding Started	Expected Net Present Value. Beginning Breeding at 15 Months of Age	Expected Net Present Value. Beginning Breeding at 24 Months of Age	Difference
	($)		
Low-Low Feed-Beef Price Relationship			
January	83.38	57.75	25.63
February	102.49	73.86	25.63
March	144.96	88.56	56.40
April	100.59	76.73	23.86
May	99.05	74.64	24.41
June	97.37	71.42	25.95
July	95.39	67.57	27.82
August	100.71	70.67	30.04
September	84.16	54.80	29.36
October	74.34	47.61	26.73
November	84.32	48.26	36.06
December	78.52	54.26	24.26
		Average difference =	$29.93
High-Low Feed-Beef Price Relationship			
January	5.40	−25.89	31.29
February	−49.60	−78.75	26.15
March	−32.84	−57.56	24.74
April	−15.21	−28.30	13.09
May	−12.29	−38.88	26.59
June	11.71	−15.01	26.72
July	−31.34	−57.00	25.66
August	−30.82	−58.18	27.36
September	−25.73	−49.64	23.91
October	−35.54	−59.43	23.89
November	−3.37	−33.42	30.05
December	41.39	13.42	27.97
		Average difference =	$25.62
High-High Feed-Beef Price Relationship			
January	381.15	366.58	14.57
February	382.64	369.39	13.25
March	393.37	383.97	9.40
April	390.87	381.50	9.37
May	384.59	373.59	11.00
June	388.13	377.46	10.67
July	378.61	366.75	11.86
August	386.85	376.63	10.22
September	388.65	379.57	9.08
October	383.67	370.69	12.98
November	402.02	386.38	15.64
December	391.73	375.78	15.95
		Average difference =	$12.00

Table 4. Optimal Culling Management Strategy

Month Breeding Started	Age of Dam at Conception (years) 1[a]	2	3	4–13	14	15	16
Low-Low Feed-Beef Price Relationship							
January	B	B	B	A	B/C	C	C
February	B	B	B	A	B/C	C	C
March	B	B	B	A	B/C	C	C
April	B	B	B	A	B/C	C	C
May	B	B	B	A	B/C	C	C
June	B	B	B	A	B/C	C	C
July	B	B	B	A	B/C	C	C
August	B	B	B	A	B/C	C	C
September	B	B	B	A	B/C	C	C
October	B	B	A	A	B/C	C	C
November	B	B	A	A	B/C	C	C
December	B	B	A	A	B/C	C	C
High-High Feed-Beef Price Relationship							
January	B	B	B	B	B/C	C	C
February	B	B	B	B	B/C	C	C
March	B	B	B	B	B/C	C	C
April	B	B	B	B	B/C	C	C
May	B	B	B	B	B/C	C	C
June	B	B	B	B	B/C	C	C
July	B	B	B	B	B/C	C	C
August	B	B	B	B	B/C	C	C
September	B	B	B	B	B/C	C	C
October	B	B	B	B	B/C	C	C
November	B	B	B	B	B/C	C	C
December	B	B	B	B	B/C	C	C

	Age of Dam at Conception (years) 1[a]	2	3	4–12	13	14	15	16
High-Low Feed-Beef Price Relationship								
January	B	B	A	A	A	B/C	C	C
February	B	A	A	A	B/C	C	C	C
March	B	A	A	A	A	B/C	C	C
April	B	B	A	A	B/C	C	C	C
May	B	A	A	A	A	B/C	C	C
June	B	B	A	A	A	B/C	C	C
July	B	A	A	A	A	B/C	C	C
August	B	B	A	A	A	B/C	C	C
September	B	A	A	A	A	B/C	C	C
October	B	A	A	A	A	B/C	C	C
November	B	A	A	A	A	B/C	C	C
December	B	B	A	A	A	B/C	C	C

Notes: C—Cull cattle of this age group. B—Breed cattle of this age group. B/C—Cull those cattle that are open immediately while those that are pregnant, cull when the calf is weaned. A—Cull those cattle of this age group which lose a calf or produce calves with below-average weaning weights (above normal culling).

[a] Based on a 15-month-old heifer.

Table 5. Optimal Feeding Policies for Weaned Calves

Month Breeding Started	Age of Dam at Conception 15 months	2, 3, 4 years	5, 6, 7 years	8–15 years
Low-Low Feed-Beef Price Relationship				
January	P	P[a]	PF	P
February	F	F	PF	F
March	F	F	PF	F
April	F	F	PF	F
May	F	F	F	F
June	F	F	F	F
July	PF	F	F	PF
August	PF	PF	F	PF
September	PF	PF	F	PF
October	PF	PF	F	PF
November	PF	PF	PF	PF
December	PF	PF	PF	PF
High-Low Feed-Beef Price Relationship				
January	P	P	PF	P
February	P	P	PF	P
March	P	P	PF	PF
April	P	P	P	P
May	P	P	P	P
June	P	P	P	P
July	P	P	PF	P
August	PF	PF	P	PF
September	PF	P	PF	PF
October	PF	P	PF	PF
November	PF	P	PF	PF
December	P	PF	PF	P
High-High Feed-Beef Price Relationship				
January	PF	PF	PF	PF
February	PF	PF	PF	PF
March	PF	PF	PF	PF
April	F	PF	PF	F
May	PF	F	PF	F
June	F	PF	PF	F
July	F	F	PF	F
August	F	PF	F	F
September	PF	PF	F	PF
October	PF	PF	F	PF
November	PF	PF	F	PF
December	PF	PF	F	PF

Notes: P—feeding on pasture from weaning to slaughter; PF—feeding on pasture from weaning to approximately 710 pounds, then feeding in the feedlot to slaughter; F—feeding in the feedlot from weaning to slaughter.

[a] The net cash flows from the three feeding alternatives were nearly equal, and the alternative chosen was extremely sensitive to changes in feed costs. Had the feed cost been $1 less per month for feedlot feeding, the optimal feeding policy would have been "F."

agement strategy. Results indicate that weaning at heavier weights and older ages is more profitable, although for the high feed to low beef price situation the recommended weaning ages were younger. There was no significant difference in weaning age due to the price relationship.

The optimal weaning age for the low-low and high-high feed-beef price relationships ranges from 9 to 11 months depending on the age of the dam and the month breeding started. The average is 10.8 months.

The optimal weaning age for the high-low feed-beef price relationship ranges from 7 to 11 months depending on the age of the dam and the month breeding started. The average is 10.3 months.

Profitability of the overall management system is sensitive to changes in weaning weight and age. Cash flow is increased by $35 to $70 each year of the cow's life by weaning at eleven months rather than eight months. The size of the difference depends on the age of the dam and the month in which breeding occurs.

The optimal feeding policy developed by the model is a combination of three feeding alternatives: pasture-only, pasture-feedlot, and feedlot-only. The specific optimal policy depends on the age of the dam at conception and the month breeding occurred. A summary of the optimal post-weaning feeding strategies is presented in table 5.

In the case of a low-low feed-beef price relationship, feedlot-only and pasture-feedlot feeding were the two optimal feeding policies. The specific post-weaning feeding strategy differed for various groups of weaned calves. Post-weaning feeding management strategies are similar for calves born to cows that are fifteen months to four years old at conception and calves born to cows that are eight to fifteen years old at conception. Feedlot-only feeding is the optimal choice for calves from cows bred during February through June. The post-weaning feeding strategy for calves from cows that are five to seven years old at conception is different than the strategy for other calves. For calves born to cows bred during May through October, the feedlot-only feeding alternative is optimal.

The feeding management strategy generated by the model for the low-low feed-beef price situation suggests that the optimal length of stay in the feedlot for both the feedlot-only and pasture-feedlot feeding alternatives was generally four months. The optimal rates of gain in the feedlot were 1.5 to 2.5 pounds per day depending on the weight of the animal.

With the high-low feed-beef price relationship, the feeding management strategy for the weaned calves is heavily dependent on pasture usage (table 5). The feeding management strategy generated by the model suggests the optimal length of stay in the feedlot is four months, when this is part of the optimal strategy. The optimal rate of gain in the feedlot is one pound per day for all weight classes. The least-cost gain rations consisted of guinea grass hay and pineapple bran. Therefore, the feedlot segment of the pasture-feedlot feeding alternative is very dependent on roughage. As shown in table 5, the pasture-feedlot alternative (PF) for the high-low feed-beef price case is a combination of pasture-only feeding and high-roughage feeding.

Given the high-high feed-beef price condition, the feeding management strategy for the weaned calves includes some feedlot feeding regardless of age of dam at conception or month that breeding started. In two-thirds of the possible cases, pasture-feedlot feeding is considered the optimal feeding strategy. The feedlot-only alternative is optimal for two different groups of weaned calves: those born to older dams (8 to 15 years at conception) bred in April through August, and those born to younger dams (5 to 7 years at conception) bred in August through December. Pasture-feedlot feeding for weaned calves from younger dams is generally the optimal feeding strategy. At no time is pasture-only feeding optimal. The feeding management strategy generated by the model suggests that the optimal length of stay in the feedlot is generally four months. The optimal rates of gain in the feedlot range from two to three pounds per day depending on the weight of the animal.

Conclusions

The results of the three applications clearly show the importance of feed-beef price relationships on the beef production management decision process. With a high-to-high, or low-to-low input-product price relationship, one would not expect much difference in the general beef production management strategy since the relative price relationships are similar. Results of the model support this conclusion. The optimal beef production management strategy is generally consistent with beef production management practices followed in Hawaii (Jenkins, Davidson, and Ball).

From economic theory one would expect a shift in the feed-beef price relationship to cause changes in the beef production management strategy. The analysis described here supports this view. The results suggest that, if feed prices increase relative to beef prices, one can expect the beef industry to become less profitable, breeding herds to be liquidated, and less energy-intensive feeding alternatives to be employed. In addition, a higher ratio of feed-to-beef prices yields lower net present values and cash flows, higher culling rates, and more dependence on pasture use for post-weaning feeding. The model developed in this study demonstrates that the optimal management strategies for feedlot operators and ranchers will change in response to changes in feed-beef price relationships.

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