IMPACTS OF PRICE CHANGES ON OPTIMAL FEEDING PERIODS FOR SLAUGHTER YEARLINGS

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The economic theory to be applied in optimizing feeding periods for finishing slaughter cattle is well developed both for cases in which only one group of cattle is finished and for cases in which each group of finished animals sold is replaced in the feedlot by another group of feeder animals [3, pp. 71-76; 4]. According to received theory the operator who plans to replace the finished animal with another feeder should feed to the point in time at which marginal net revenue equals average net revenue (maximizes returns to time). The operator who does not intend to replace the finished animal with another should continue feeding until marginal net revenue is zero (maximizes returns to the animal).

The implications of the two concepts and the differences between them have not been fully explored and are not widely appreciated even though the replacement decision has been analyzed by other researchers [10, 11]. Consequently, various rules of thumb are used for determining appropriate marketing times. Some of the rules relate to minimum or fixed times on feed, to body composition, and to attempts to achieve a consistent low Choice quality grade without due regard for cost-price relationships and quality and yield grade-related price differences. Though general profitability experience underlies these rule-of-thumb indicators of appropriate slaughter points, they appear unlikely to result in consistently optimal decisions in a variety of situations.

A study was undertaken to explore appropriate adjustments by both types of cattle feeders in response to changes in cost-price conditions. More specifically, the objective was to investigate the effects of changing combinations of prices for feed, feeder animals, and beef carcasses on optimal length of feeding period for slaughter yearlings for the commercial feedlot (assuming replacement) and for the operator who does not intend to replace the finished animal with another feeder. The magnitude and direction of appropriate optimizing adjustments were analyzed and compared for the two types of cattle feeders. This analysis necessitated the development of a method for simulating the physical and economic factors to be considered in choosing the optimum length of feeding period.

SIMULATION MODEL

The approach used was to develop a model to estimate the relevant physical factors and then apply appropriate cost and price information to arrive at average and marginal net revenue estimates at intervals during the feeding process. The average and marginal net revenues with respect to time were used as the appropriate decision criteria for optimizing the length of the feeding period.

Basic physical relationships necessary for the model included equations to estimate live weight and feed consumption at intervals during feeding. Because the animals produced were valued on a carcass basis, an indicator of the quality of the carcass produced was also necessary. Backfat thickness was chosen as the best single estimator of carcass quality. Marbling score and yield grade equations were developed on the basis of backfat thickness. Dressing percentage was then related to marbling score to complete the physical information needed to describe the carcass produced at various points during feeding.

Required price and cost information consisted of (1) a method for pricing feeder animals entering the feeding process and at various points until the animal could reasonably be considered for slaughter, (2) a method for pricing carcasses of widely varying quality, yield, and weight characteristics which could be produced at points during the feeding process, (3) feed prices, and (4) estimates of several less important cost factors.

The feeding process was assumed throughout to have already begun for the group of animals being simulated. Therefore, no costs were included for land, facilities, or fixed equipment expenses.

Physical Model

Functions which estimate live weight and

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backfat thickness at the 12th rib were obtained from an analysis of experiment station feeding trials reported by Onks [12]. Data from Onks' study also were used to estimate an appropriate feed consumption equation.

Onks analyzed the individual feeding of 114 Angus calves during the 1970-1974 period.[1] The relationships used in the current study were based on the 63 steers included in the Onks group. The calves were born at the experiment station from 62 cows and 25 sires and were creep-fed until weaning at an average age of 253 days and an average weight of 483.5 lbs. After weaning the steers were individually fed, *ad libitum*, a complete growing and finishing ration (57 percent TDN) until slaughter at an average of 263 days after weaning.[2] The feeding of the same ration from weaning until slaughter is not typical of most cattle finishing because cattle are usually subjected to a growing period based on a high roughage ration. However, this difference in source of nutrients should not affect the principal conclusions of the study.

The relationships developed by Onks for live weight (WT) in pounds and backfat thickness (FT) in inches (ultrasonic) are quadratics on age of the animal (A).[3] Data for the relationships were collected on individual animals at two-week intervals. The equations estimated by Onks follow.

$$(1)\quad WT_a = \underset{(43.0453)}{-325.5156} + \underset{(0.22730)}{3.66669A} - \underset{(0.0002905)}{0.0019171A^2} \qquad R^2 = 0.84$$

$$(2)\quad FT_a = \underset{(0.10447)}{0.11719} - \underset{(0.000547)}{0.001381A} + \underset{(0.0000006937)}{0.0000048949A^2} \qquad R^2 = 0.63$$

An equation to estimate feed consumption (FD) based on live weight was fitted by ordinary least squares on feed data from Onks' study. Feed consumption by individual animals was measured at three- to five-week intervals early in the feeding process and at 14-day intervals after the animals reached approximately 700 lbs. The quadratic form was also used in this regression because it provided the best fit among several alternatives.

$$(3)\quad FD_a = \underset{(92.2998)}{-1278.2046} + \underset{(0.24899)}{0.873991WT} + \underset{(0.0001607)}{0.0039037WT^2} \qquad R^2 = 0.96$$

This relationship estimates total growing and finishing ration consumed by the animal from weaning to the a^{th} age.

Information relating to carcass quality and yield grade can be derived from the estimates of backfat thickness provided by equation 2, because both yield grade and marbling score are considered to be highly correlated with backfat [6, 7, 8]. However, the data needed to estimate relationships between yield grade and backfat and marbling score and backfat at various points during feeding would be available only from experiments using serial-slaughter methods. Data for this purpose were available from Zinn [18, 19] who reported carcass characteristics on 200 Hereford steers and heifers serially slaughtered at 30-day intervals from 0 to 270 days on feed.

Simple linear regression using the 20 interval means from the Zinn data produced the following equations relating yield grade (YG) and marbling score (MS) to backfat thickness over the 12th rib.

$$(4)\quad YG_a = \underset{(0.1351)}{1.2563} + \underset{(0.2581)}{3.5152FT_a} \qquad R^2 = 0.91$$

$$(5)\quad MS_a = \underset{(0.3602)}{0.5942} + \underset{(0.6880)}{6.7708FT_a} \qquad R^2 = 0.84$$

This method of estimating yield grade was chosen instead of the official USDA equation because of the complexity of developing estimators of kidney-pelvic-heart fat and rib-eye area at points during the feeding process and because backfat thickness is the most important of the four official USDA estimators of yield grade [2, 6].

A comparison of estimates from equation 5 with the marbling scores of the Onks cattle at slaughter indicated that the equation seriously underestimated marbling scores of the Onks group. This discrepancy may be attributable to breed differences because the Zinn cattle were Herefords and the Onks group were Angus. Previous work has indicated that Herefords tend to have lower marbling scores than do Angus under similar circumstances [7, 15]. To bring the marbling score equation into consistency with the Angus data used to fit equations 1 through 3, the intercept value in equation 5 was increased so that the equation passed through the mean marbling score for the Onks cattle at slaughter.

$$(5a)\quad MS_a = 2.0 + 6.7708FT_a$$

[1]The fact that the growth, fatness, and consumption relationships were based only on Angus cattle implies that some numeric results of the analysis may not be applicable to other breeds. However, this fact should not affect the primary conclusions.

[2]The ration consisted of 41.4% corn, 13.75% soybean oil meal, 33% cottonseed hulls, 5% alfalfa pellets, 5% dried molasses, 1% animal fat, and 0.85% limestone and trace mineralized salt.

[3]The Onks equation for backfat thickness was originally estimated in millimeters but was converted to inches for consistency with other phases of this study.

The adjustment of the marbling score equation (5a) and the dressing percentage equation (6a, to be discussed hereafter) make the quantitative results of the analysis more realistic, but they should not affect the direction of optimizing responses of cattle feeders to price changes.

By equation 4, an average animal would reach minimum yield grade 2 at 0.22 inches backfat, minimum yield grade 3 at 0.5 inches backfat, and minimum yield grade 4 at 0.78 inches backfat. By equation 5a, an average animal would grade minimally Standard with no backfat, minimally Choice at 0.45 inches backfat, and minimally Prime at 0.89 inches backfat.[4]

To achieve a more realistic representation of changes in yield and quality grades during the feeding period for groups of cattle, the distribution of yield grades and marbling scores around equations 4 and 5a was estimated and probabilities were derived for each yield and quality grade over the relevant range of backfat thicknesses by use of the normal cumulative distribution function [1, p. 517; 9, pp. 239-242].[5] Resulting representative probabilities and associated ages, weights, and backfat levels are shown in Table 1 for the Onks steers.

TABLE 1. PROBABILITY OF GIVEN QUALITY AND YIELD GRADES AT SELECTED AGES WITH CORRESPONDING MEAN BACKFAT THICKNESS AND LIVE WEIGHT

			Quality Grade			Yield Grade		
Age (days)	Fat Thickness (inches)	Weight (lbs.)	Prob. Std.	Prob. Gd.	Prob. Ch. & Pr.	Prob. <3	Prob. 3	Prob. >3.99
350	0.23	723	0.748	0.240	0.012	0.930	0.069	0.001
400	0.35	834	0.280	0.575	0.145	0.803	0.190	0.006
450	0.49	936	0.016	0.295	0.689	0.521	0.436	0.043
500	0.65	1029	0.000	0.011	0.989	0.188	0.585	0.228
550	0.84	1111	0.000	0.000	1.000	0.032	0.345	0.623

This approach avoids the discontinuities in the animal value function associated with discrete changes in yield and quality grades.

The final step necessary to obtain estimates of the relevant carcass characteristics was a method for determining dressing percentage as weight and fatness change. The data from Zinn were also used for that purpose. Exploratory analyses regressing interval mean dressing percentage (DP) from Zinn [18, 19] on weight, backfat thickness, and marbling score indicated that marbling score was a better predictor of dressing percentage than either of the other variables. This analysis resulted in the following relationship.

$$(6)\quad DP_a = \underset{(0.7015)}{51.4793} + \underset{(0.1694)}{1.65999}MS_a \qquad R^2 = 0.84$$

Comparisons of this equation with slaughter data on the Onks cattle and with information in the USDA *Livestock Marketing Handbook* [16, p. 18] indicated that this relationship tended to underestimate the USDA percentages and underestimated the dressing percentage of the Onks group after the full feeding period. As in the case of the marbling score relationship, the intercept of the dressing percentage equation was adjusted upward by 1.7 so that it passed through the mean dressing percentage of the Onks cattle at slaughter.

$$(6a)\quad DP_a = 53.1793 + 1.65999MS_a$$

The resulting estimate of dressing percentage (DP) combined with live weight (WT) and a 4 percent shrink allowance gives an estimate of carcass weight (CWT) at the a^{th} age.

$$(7)\quad CWT_a = 0.96WT_aDP_a$$

Prices and Costs

To provide a method for costing the feeder steers entering the feeding process, quarterly summary data collected on organized feeder cattle sales in Tennessee for 1976 and 1977 were analyzed to determine price differentials for grade and weight [13]. An ordinary least squares regression was developed.

$$(8)\quad FI_{ij} = \frac{P_{ij}}{P_{c5}} = \underset{(0.0082)}{0.9017} + \underset{(0.0062)}{0.0481}G + \underset{(0.0010)}{0.0487}W_3 + \underset{(0.0098)}{0.0602}W_4 + \underset{(0.0098)}{0.0501}W_5 + \underset{(0.0098)}{0.0247}W_6 \qquad R^2 = 0.91$$

where

FI_{ij} = the quarterly feeder steer price index for the i^{th} grade and the j^{th} weight based on the price of Choice, 500-600-lb steers

P_{ij} = the raw quarterly average price of steers of the i^{th} grade and j^{th} weight

P_{c5} = the raw quarterly average price of Choice 500-600-lb steers

[4]Marbling scores 2 to 3.99 are Standard, 4 to 4.99 are Good, 5 to 7.99 are Choice, and 8 and higher are Prime.

[5]Plots of residuals from the yield grade and marbling score equations show no evidence that the normal distribution is inappropriate [5, pp. 86-88].

G = a 0, 1 dummy variable differentiating Good (0) and Choice (1) grades

W_3--W_6 = a set of 0, 1 dummy variables differentiating weight classes from 300-400 lbs through 700-800 lbs.

The index derived from equation 8 is shown in Table 2. Use of this index allows valuation of different categories of animals based on postulation of a single price for the base category (Choice 500-600 lbs). The relationships among prices for the indexed categories are assumed to be in fixed proportion to price level, which may not be realistic over a wide range of situations.

TABLE 2. INDEX OF FEEDER STEER PRICES BY GRADE AND WEIGHT ON ORGANIZED SALES IN TENNESSEE DURING 1976-77, BASED ON CHOICE 500-600-LB PRICES

Grade	Weight Class (pounds) 3-400	4-500	5-600	6-700	7-800
Choice	0.998	1.010	1.000	0.974	0.950
Good	0.950	0.962	0.952	0.926	0.902

The method for valuing the carcass produced at various points during the feeding process was similar to that described for feeder animal prices. Price differentials are assumed to be constantly proportional to price level. Data were taken from USDA's *Livestock Meat Wool Market News Weeklies* for 1976 for wholesale dressed meat prices in the Midwest and on the East Coast [17]. Ordinary least squares was used to fit the following relationship to determine price differentials for carcass weight, yield grade, and quality grade.

$$(9)\quad SI_{ijw} = \frac{P_{ijw}}{P_{c36}} = \underset{(0.1141)}{98.2476} - \underset{(0.1352)}{4.6062CG} + \underset{(0.1781)}{3.0226Cy_2} + \underset{(0.1058)}{1.5121CY_3} - 4.5347CY_4 + \underset{(0.1433)}{0.4298W_5} + \underset{(0.0865)}{0.2504W_6} + \underset{(0.1283)}{0.2491W_7} - 0.9292W_8 \qquad R^2 = 0.74$$

where

SI_{ijw} = the index of weekly steer carcass prices for the i^{th} quality grade, the j^{th} yield grade, and the w^{th} weight

P_{ijw} = the raw weekly average price for steer carcasses of the i^{th} quality grade, the j^{th} yield grade, and the w^{th} weight class

P_{c36} = the raw weekly average price for Choice, yield grade 3, 600-700-lb steer carcasses

CG = a 0, 1 dummy variable differentiating Good (1) and Choice (0) carcass grades

CY_2--CY_4 = a set of 0, 1, -1 dummy variables differentiating carcass yield grades 2, 3, and 4

W_5--W_8 = a set of 0, 1, -1 dummy variables differentiating carcass weight classes from 500-600 lbs to 800-900 lbs.

The USDA data used to fit equation 9 did not contain prices for Standard grade carcasses or for 400-500-lb carcasses. However, because the objective was to evaluate the decision of whether to continue feeding over a wide range of the feeding period and because the Onks cattle were placed on feed at weaning, it was desirable to be able to price carcasses produced at low weights and at Standard grade. The index derived from equation 9 was expanded to apply to Standard and 400-500-lb carcasses on the basis of a telephone survey of customary discounts among area packers.

TABLE 3. INDEX OF STEER CARCASS PRICES BY WEIGHT, YIELD, AND QUALITY GRADE, BASED ON CHOICE, YIELD GRADE 3, 600-700-LB PRICES AT MIDWEST AND EAST COAST MARKETS, 1976

Carcass	Standard		Good			Choice		
Weight	YG2	YG3	YG2	YG3	YG4	YG2	YG3	YG4
4-500	83.33	81.82	93.49	91.98	85.94	98.10	96.59	90.54
5-600	86.93	85.42	97.09	95.58	89.54	101.70	100.19	94.14
6-700	86.75	85.24	96.91	95.40	89.36	101.52	100.01	93.96
7-800	86.75	85.24	96.91	95.40	89.36	101.52	100.01	93.96
8-900	85.57	84.06	95.73	94.22	88.18	100.34	98.83	92.78

Use of this index (Table 3) allowed valuation of carcasses of varying characteristics on the basis of a single price for Choice, yield grade 3, 600-700-lb carcasses. No premium was assumed for Prime carcasses.

With the carcass price and grade analysis to this point, the composite price (CP_a) of the carcass produced at any given age (a) is given by the following expression:

$$(10)\quad CP_a = (XPS)\left[\sum_{i=1}^{3}\ \sum_{j=2}^{4} Q_{ia}Y_{ja}SI_{ija}\right]$$

where

XPS = an exogenous postulated price for Choice, yield grade 3, 600-700-lb steer carcasses

Q_{ia} = the quality grade elements of an enlarged Table 1 (the probability of a given quality grade i at a given weight or age a)[6]

Y_{ja} = the yield grade elements of an enlarged Table 1 (the probability of a given yield grade j at a given weight or age)

SI_{ija} = the elements of Table 3 (the price index for valuing carcasses of varying grades and weights).

Various miscellaneous costs also must be considered. The levels of these costs are based primarily on the figures of Ray and Walch [14]. Feeder animal shrinkage at purchase and death loss totaled 3 percent. A $1 per head feeder procurement cost was also included. Veterinary and medical costs were set at $2.50 per head. Interest was charged against the value of the animal not sold at each decision point at an annual rate of 9 percent. For interest purposes the animal was valued at its feeder value up to 700 lbs and at its slaughter value thereafter. Variable cost of tractor used for feeding was set at $0.0117 per head per day based on one-half hour per day for 50 head. Labor cost was 0.124 per head per day based on 2.07 hours per day for 50 head at $2.50 per hour. Finally, a $2.25 per head cost was allowed for transporting the finished animal to the point of sale.

ANALYSIS

The simulation structure was used to arrive at marginal net revenue and average net revenue estimates with respect to time or age at five-day intervals during the feeding process under several alternative price and cost situations. The analysis centered around the midpoint between mean Good and Choice feeder steer prices for 1976-1977 on organized feeder cattle sales in Tennessee ($40.40), mean actual feed cost figures for 1976 for the ration used in the Onks experiment ($133 per ton), and mean Choice, yield grade 3, 600-700-lb carcass prices on midwestern and east coast markets for 1976 ($63.72). These exogenous factors were varied systematically around their mean values to represent feeding under varying economic conditions.

The simulated optimal slaughter ages are shown in Table 4 classified by feed, feeder, and carcass price. These ages include the preweaning period which averaged 253 days. The column headed "Without Replacement" indicates the age at which the marginal net revenue of an additional five days of feeding is

TABLE 4. SIMULATED OPTIMAL SLAUGHTER AGES AT FIVE-DAY INTERVALS FOR YEARLING STEERS UNDER VARYING CONDITIONS OF FEED, FEEDER ANIMAL, AND CARCASS PRICES, WITH AND WITHOUT REPLACEMENT OF THE SLAUGHTERED ANIMAL BY ANOTHER FEEDER[a]

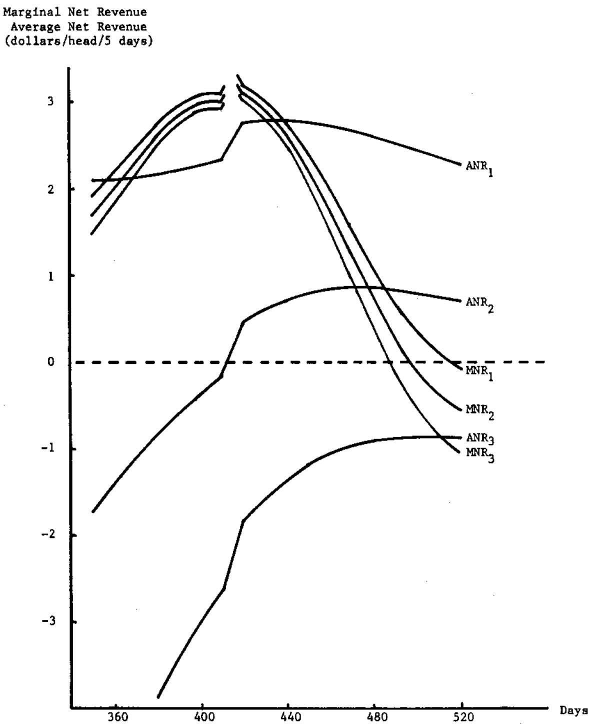
		Feeder Animal Price (Per Cwt.)									
		$30		$40		$50		$60		$70	
Feed Price	Carcass Price	W/o Replacement	With Replacement	W/o Replacement	With Replacement	W/o Replacement	With Replacement	W/o Replacement	With Replacement	W/o Replacement	With Replacement
(per ton)	(per cwt.)					(number of days)					
	$55	470	465	470	510	470	570	470	570	470	570
	65	490	450	490	475	490	570	490	570	490	570
$ 75	75	515	435	515	465	515	490	515	570	515	570
	85	570	415	570	455	570	475	570	500	570	570
	95	570	415	570	445	570	465	570	475	570	515
	55	440	465	440	505	440	570	440	570	440	570
	65	465	450	465	475	465	570	465	570	465	570
100	75	475	435	475	465	475	490	475	570	475	570
	85	495	415	495	455	495	475	495	500	495	570
	95	515	415	515	440	515	465	515	475	515	510
	55	415	465	415	500	415	570	415	570	415	570
	65	435	445	435	475	435	570	435	570	435	570
125	75	460	430	460	465	460	475	460	570	460	570
	85	470	415	470	450	470	475	470	500	470	570
	95	485	415	485	440	485	465	485	475	485	510
	55	--	460	--	500	--	570	--	570	--	570
	65	--	445	--	475	--	570	--	570	--	570
150	75	430	425	430	460	430	475	430	570	430	570
	85	455	415	455	450	455	470	455	495	455	570
	95	465	415	465	435	465	460	465	475	465	505

[a]The range of possible ages in the simulation was from 345 to 570 days. These ages correspond to live weights of 711 and 1142 pounds and to backfat thicknesses of 0.22 and 0.92 inches, respectively. Days on feed may be obtained by subtracting 253 (average weaning age) from the age shown.

[6]Either weight (WT) or age (a) can be used to identify a particular point during the feeding process because weight is a single valued function of age (equation 1).

zero. The column headed "With Replacement" shows the age at which the marginal net revenue (averaged over days). Marginal and average net revenue functions for three representative price situations are depicted graphically in Figure 1.

FIGURE 1. MARGINAL AND AVERAGE NET REVENUE FROM SIMULATED CATTLE FEEDING FOR THREE SELECTED PRICE SITUATIONS[a]



[a]Base price situations reflected are: Subscript 1 - feeder $30/cwt., feed $75/ton, carcass $75/cwt.; subscript 2 - feeder $50/cwt., feed $100/ton, carcass $85/cwt.; subscript 3 - feeder $70/cwt., feed $125/ton, carcass $95/cwt. Discontinuities in the functions were caused by an abrupt carcass price increase when carcass weight reached 500 lbs.

From Table 4 several salient features are apparent. First, as expected, changes in feeder prices *ceteris paribus* have no effect on the without-replacement optimum. However, increases in feeder prices increase the with-replacement optimum slaughter point, because this adjustment allows use of less of the more expensive input per unit of time.

Increasing carcass prices increase the optimal slaughter age without replacement because marginal revenue shifts positively. However, the opposite effect is observed with replacement. This outcome reflects the fact that an increasing carcass price shifts the average net revenue curve more than the marginal net revenue curve.

Rising feed prices, with other things constant, reduce the optimal slaughter age for the without-replacement situation because marginal net revenue is reduced. Also, rising feed prices decrease the optimal slaughter age with replacement, but this reduction is small and is not detectable for many of the price changes shown in Table 4 with the five-day age increment. This reduction reflects the rather gradual decline in feed efficiency as weight increases. The declining feed efficiency becomes economically more important as the cost of feed increases.

Probably the most interesting principle demonstrated is that the appropriate adjustments for the two types of decision makers may well be in opposite directions in response to the same stimulus. This is the case for changes in carcass prices. It is also partially true for changes in feeder prices in that the "one-batch" operator treats the feeder as a fixed cost once feeding has begun whereas the "continuous" operator should pay close attention to feeder prices when deciding on the appropriate length of feeding period.

Another point drawn from the results of the simulation in Table 4 is that, under the particular conditions of this simulation, the optimizing adjustments are rather sizeable. A $10 change in the price of feeders *ceteris paribus* may indicate a 30-day change in the age at slaughter with replacement even within the middle ranges of the analysis. This finding implies that physical rules of thumb for finishing cattle may be grossly erroneous under conditions of variable prices. For example, within judgmentally reasonable ranges of price combinations, optimal backfat thicknesses ranges from a low of 0.39 inches to a high of 0.92 inches with replacement. These extremes corresponded to quality grades of middle Good to low Prime and live weights of 866 to 1,142 lbs.

The large size of the appropriate optimizing adjustments is due in part to the fact that the marginal cost curve over time is very flat, a feature which may or may not be peculiar to this particular group of cattle. Study of other groups of animals is necessary to ascertain whether it is typical.

CONCLUSIONS

Under the limited conditions of the analysis presented, adjustments in the length of feeding period which will maximize net revenue for slaughter yearlings when certain input or output prices change may be relatively large and in different directions for the two types of feedlot operators. This finding implies that popular notions about appropriate lengths of feeding period are erroneous under variable price conditions.

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