A COMPARISON OF LIVEWEIGHT, CARCASS AND LEAN MEAT CRITERIA FOR THE FEEDLOT REPLACEMENT DECISION*

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In recent months, several developments have prompted increased interest in the feedlot replacement decision. Among the more important are the high prices for feeder cattle and feed grains, the narrow (and often negative) profit margins confronting the feedlot manager and the increasingly apparent need to produce lean meat with maximum efficiency.

To date, replacement criteria for cattle feeding operations have been based on estimated net revenue streams for live cattle. In 1960, Faris [6] reported a criterion which can be paraphrased as follows:

> Replace when the decreasing marginal net revenue per unit of time for the group on feed is equal to the maximum of the expected average net revenue for the replacement group.

All production relationships, costs and prices employed by Faris in estimating the necessary net revenue functions were based on live cattle.

More recent developments to the general theory of replacement decisions have been offered by Chisholm [3] and by Perrin [16]. Chisholm called for more attention to the opportunity costs tied up in the production process. Perrin suggested modifications of the original Faris formulation to cover issues such as technologically improved assets. Neither of the modifications appear to be crucial for the short planning horizon confronting the cattle feeder, however.

In an earlier analysis [13] the Faris criterion was employed in generating empirical support for the developing replacement theory. The results provided empirical support for its applicability. Net revenue functions were estimated for two groups of cattle and a small-scale simulation model was developed to generate estimates of the correct replacement points if the objective is to maximize returns to the cattle feeding operation over time.

THE EXPANDED REPLACEMENT PROBLEM

A continuing and growing dissatisfaction with a replacement criterion based strictly on live-cattle variables prompted further investigation. Continuing efforts by the beef industry to move toward pricing on the basis of lean meat, not live weight, supported the need for further work. The attempts of packers, such as Iowa Beef Processors, to introduce the "boxed beef" method of distribution may hasten the time when packers will be basing price offers on the expected yield of lean retail cuts of beef. The purpose of this paper is to develop, demonstrate and infer the possible implications of the Faris replacement criterion when applied to carcass characteristics or the expected yield of lean retail cuts as well as live cattle characteristics.

The Growth Process

Understanding of the growth process and related matters of composition for beef cattle is not complete. A summary of the available literature on the subject(s) has been compiled by Hedrick [8].

Among the more important areas in which the authorities are not in complete agreement are the

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causes of differences in size, composition and efficiency of conversion in beef cattle. Conversely, there are general relationships which are widely accepted. Among these are the following:

1. The growth curve or schedule of weight along a time continuum has a characteristic sigmoid shape, and
2. The production of bone, muscle and fat reaches mature levels in succeeding order – i.e., bone is early maturing, muscle intermediate and fat is late maturing.

During the growth process fat becomes an increasing percentage of carcass weight while bone and muscle decrease in terms of percentage of carcass weight. Figure 1 depicts the normal growth relationships as they are often presented [20].

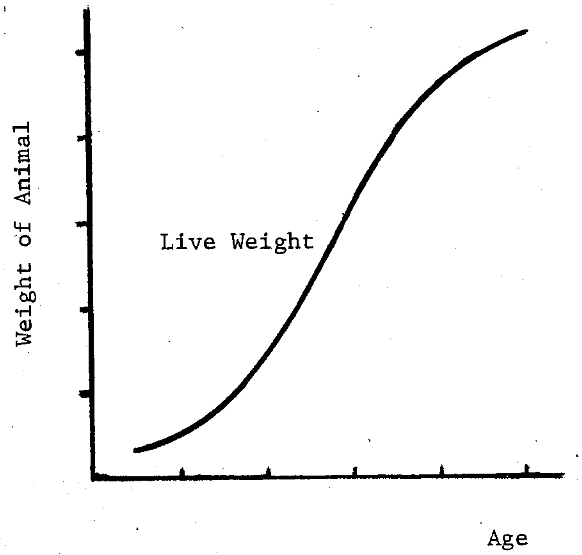

Fig. 1a. GROWTH CURVE FOR CATTLE

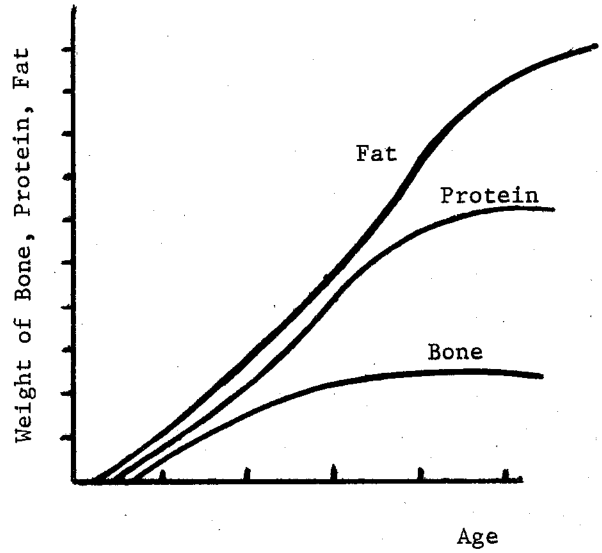

Fig. 1b. RELATIVE GROWTH OF PROTEIN, FAT AND BONE IN CATTLE

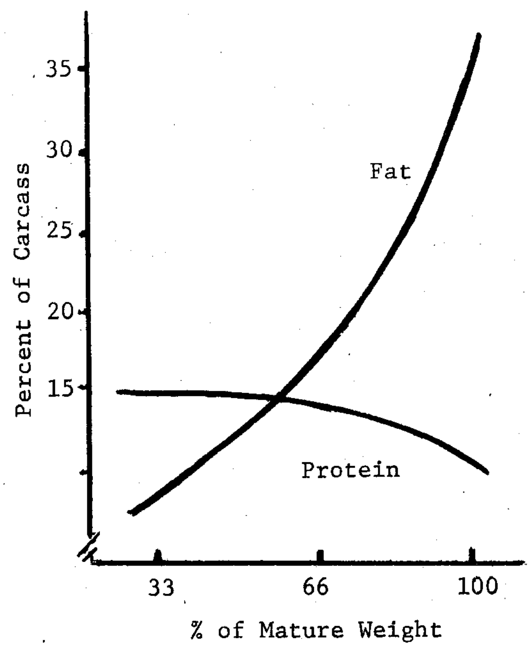

Fig. 2a. CARCASS COMPOSITION IN CATTLE AS IT MAY RELATE TO THEIR MATURE WEIGHT

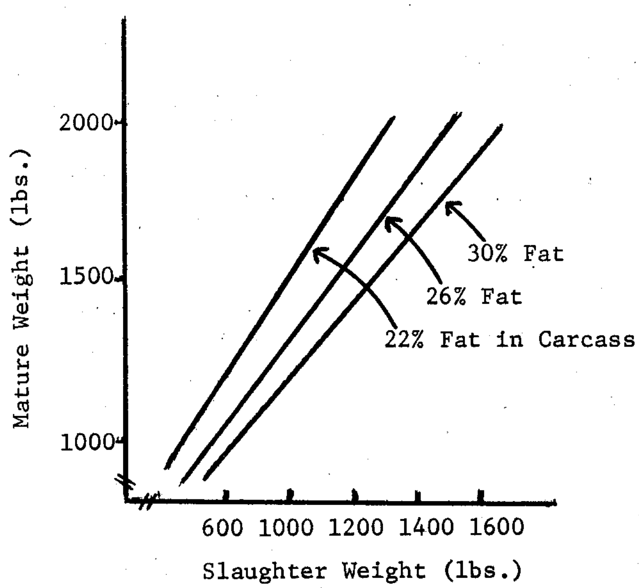

Fig. 2b. FAT COMPOSITION IN CATTLE CARCASSES AS INFLUENCED BY SLAUGHTER AND MATURE BODY WEIGHT

There is less agreement about the effect of varying levels of nutrition on composition at slaughter and on the degree to which fat may be redistributed by selective breeding, between intramuscular and trimmable fat. Recent work by Preston [18] suggests fattening is part of the growth process and is not due to excessive caloric intake. Pomeroy [17] concurs and suggests any attempt to distinguish between growth and fattening is arbitrary. The following paraphrase from Preston [18, p. 37] states a fundamental assumption underlying our analysis:

> The plane of nutrition, within practical reality, will have little or no effect on the body composition of cattle at normal slaughter weights. Therefore, instead of thinking that live weight or carcass weight determines the percentage of fat and protein, it may be more correct to say that body composition is a function of the proportion of mature body weight which has been attained at any given live weight.

Figure 2 displays the relationship between fat and mature weight consistent with the position adopted by Preston.

The Growth Model

Several mathematical models of the growth process and the composition of beef cattle have been proposed [1, 9, 15, 22]. As noted in the earlier analysis [13], the Gompertz curve is widely supported in the literature as a reasonable and appropriate representation of the growth process [9, 10, 11]. Applicability of this particular function is supported where use is to be made of the percent of mature weight because (1) the Gompertz curve conforms to the sigmoid growth shape, and (2) the Gompertz curve has an easily computed asymptote to represent mature weight.

The basic Gompertz function and resulting growth relationships employed in the analysis follow:

$$LW_t = W_O e^{\frac{A}{\alpha}(1-e^{-\alpha t})},$$

$$\Delta LW_t = LW_t - LW_{t-1},$$

$$CW_t = \left[DP_t \cdot \frac{PMT_t}{100}\right] .985,$$

$$BW_t = \frac{\left[18.61 - 7.48\left[\frac{PMT_t}{100}\right]\right] CW_t}{100}$$

$$FW_t = \left[\left[\left(.236 - \frac{.4PMT_t}{100} + \frac{.566PMT_t}{100}\right)^2\right] - .07\right] \cdot CW_t,$$

$$MW_t = CW_t - FW_t - BW_t,$$

$$OW_t = LW_t - CW_t;$$

where

LW_t	=	live weight at time t (lbs.),
W_O	=	weight at time t = 0, an estimated parameter,
A, α	=	parameters estimated by non-linear regression, (parameters are unique to each breed group),
ΔLW_t	=	change in weight at time t (lbs.),
CW_t	=	carcass weight at time t (lbs.),
BW_t	=	bone weight at time t (lbs.),
DP	=	dressing percentage,
PMT_t	=	percent mature weight or the ratio of attained live weight to asymptotic mature weight,
FW_t	=	trimmable fat weight at time t (lbs.),
MW_t	=	muscle weight at time t (lbs.),and
OW_t	=	offal weight at time t (lbs.).

Construction of the growth model and derivation of the above growth relationships involved the following major steps:

1. Using fat content from published serial slaughter data [21] and the relationships presented by Preston [18] to determine a mature weight for three sets of cattle;
2. The use of nonlinear regressions to estimate the parameters of the Gompertz growth curve; and
3. The use of ordinary least squares regressions of several factors on "percent mature weight" to estimate composition.

Before the model could be applied as a replacement model, the relevant cost and revenue functions had to be constructed.

Cost Relationships

Costs are based on the energy system, with maintenance requirements from Lofgreen and Garrett [12], and production requirements as adapted by Witz [22] from Hafez and Dyer [7].

$$EMN_t = .077\left[\frac{LW_t}{2.2}\right]^{.75}$$

$$EBG_t = \left[\frac{2.2}{2.2}\right]\Delta BW_t$$

$$EFG_t = \left[\frac{10.1}{2.2}\right]\Delta FW_t$$

$$EMSG_t = \left[\frac{1.2}{2.2}\right]\Delta MW_t,$$

$$EOG_t = \left[\frac{1.2}{2.2}\right] \Delta OW_t,$$

$$MC_t = EMN_t \cdot PEM + (EBG_t + EFG_t + EMSG_t + EOG_t) \cdot PEG + NFC + IVC,$$

$$TC_t = LW_{205} \cdot PFC + 7.50 + \sum_{t=205}^{T} MC_t;$$

where

EMN_t	=	energy required for maintenance in time t in megcal,
EBG_t	=	energy required for production of bone in time t in megcal,
EFG_t	=	energy required for production of fat in time t in megcal,
$EMSG_t$	=	energy required for production of muscle in time t in megcal,
EOG_t	=	energy required for production of offal in time t in megcal,
MC_t	=	marginal cost, i.e., addition to total cost in time t,
PEM	=	price of energy for maintenance, $.027/megcal,
PEG	=	price of energy for production, $.042/megcal,
NFC	=	Non-feed cost, $.15 per day,
IVC	=	investment charge, (.08 • $40)/365,
TC_t	=	total cost to time t, and
PFC	=	price of incoming feeder cattle, $34.75/cwt.

Revenue Relationships

The revenue relationships employed were as follows:

$TRL_t = LW_t \cdot PL_{q,w}$,
$TRC_t = CW_t \cdot PC_{q,wc}$,
$TRM_t = MW_t \cdot PM_Q$,
$NRL_t = TRL_t - TC_t$,
$NRC_t = TRC_t - TC_t$,
$NRM_t = TRM_t - TC_t$,
$MNRL_t = NRL_t - NRL_{t-1}$,
$MNRC_t = NRC_t - NRC_{t-1}$,
$MNRM = NRM_t - NRM_{t-1}$,
$ANRL_t = NRL_t/t-205$,
$ANRC_t = NRC_t/t-205$, and
$ANRM_t = NRM_t/t-205$.

where

TRL_t	=	total revenue on live sale at time t,
PL_{qw}	=	price of live steers by quality grade and weight range,
TRC_t	=	total revenue on carcass sale at time t,
$PC_{q,wc}$	=	price of steer carcasses by quality grade and weight range,
TRM_t	=	total revenue on lean meat sale at time t,
PM_q	=	price to feeder for lean meat by quality grade,
NRL_t	=	net revenue on live sale in time t,
NRC_t	=	net revenue on carcass sale in time t,
NRM_t	=	net revenue on lean meat sale in time t
$MNRL_t$	=	marginal net revenue or addition to net revenue feeding time t for live sale,
$MNRC_t$	=	marginal net revenue or addition to net revenue feeding time t for carcass sale,
$MNRM_t$	=	marginal net revenue or addition to net revenue feeding time t for lean meat sale,
ANRL	=	net revenue per day of feeding period for live sale,
ANRC	=	net revenue per day of feeding period for carcass sale, and
ANRM	=	net revenue per day of feeding period for lean meat sale.

THE ANALYSIS

Employing the cost and revenue relationships described above, estimates of marginal net revenue, average net revenue, and related informational series were estimated daily for each of three groups of cattle and reported in ten-day intervals.

Data on the three groups of cattle were taken from the January, 1973 report of the U.S. Meat Animal Research Center located at Clay Center, Nebraska [21]. The three groups selected consisted of 50 Herefords, 57 Charolais-Hereford crosses, and 65 Jersey-Angus crosses.[1] From these data, Gompertz functions were estimated.[2] The lack of a distinctive and the theoretically expected sigmoid shape underlying the revenue functions in Tables 1 and 2 is likely due to the absence of intermediate observations between weights at very early ages and weights at later scheduled and sequential slaughter weights.

Price and cost data used were averages for the year 1971. Choice grade 550-750 feeder steers averaged $34.75 per hundred pounds at Omaha for 1971. Average prices for 900-1100 pound slaughter steers at Omaha during 1971 were $32.39 and $29.58 for Choice and Good grades respectively. Prices for Choice and Good grade 1100-1300 pound slaughter steers at Omaha were $32.39 and $29.75 respectively.

Table 1. NET REVENUE FUNCTIONS AND REPLACEMENT POINTS FOR THREE GROUPS OF CATTLE: PRICE DIFFERENTIAL FOR QUALITY GRADE

	Hereford (HH)						Charolais-Hereford (CH)						Jersey-Angus (JA)					
Days	Live		Carcass		Lean		Live		Carcass		Lean		Live		Carcass		Lean	
	MNR	ANR	MNR	ANR	MNR	ANR	MNR	ANR	MNR	ANR	MNR	ANR	MNR	ANR	MNR	ANR	MNR	ANR
298	$.21	$-.09	$.20	$-.14	$.15	$.01	$.32	$.00	$.31	$-.06	$.33	$.14	$.14	$-.14	$.14	$-.19	$.03	$-.08
308	.18	-.06	.18	-.11	.11	.02	.30	.03	.29	-.03	.30	.15	.12	-.12	.11	-.16	-.01	-.08
318	.16	-.04	.16	-.08	.08	.03	.28	.05	.27	.00	.27	.17	.10	-.10	.09	-.14	-.04	-.07
328	.14	-.02	.14	-.06	.04	.03	.26	.07	.25	.02	.23	.17	.07	-.08	.07	-.12	-.08	-.07
338	.12	-.01	.12	-.05	.01	.03	.24	.08	.24	.04	.20	.18	.05	-.07	.05	-.11	-.11	-.07
348	.10	.00	.10	-.04	-.02	.03	.23	.09	.22	.05	.17	.18	.03	-.06	.03	-.10	-.14	-.08
358	.08	.00	.08	-.03	-.06	.02	.21	.10	.20	.06	.14	.18	.01	-.06	.01	-.09	-.17	-.08
368	.06	.01	.06	-.02	-.09	.02	.19	.11	.18	.07	.11	.17	-.01	-.05	-.01	-.08	-.19	-.09
378	.04	.01	.04	-.02	-.12	.01	.17	.11	.16	.08	.07	.17	.01	.10	.00	.04	-.21	-.02
388	.02	.01	.02	-.02	-.14	.00	.15	.11	.14	.08	.04	.16	-.01	.09	-.02	.04	-.23	-.03
398	.00	.01	.00	-.02	-.17	-.01	.13	.11	.12	.08	.01	.15	-.03	.08	-.04	.04	-.25	-.04
408	-.02	.01	-.02	-.02	-.19	-.01	.11	.11	.10	.09	-.02	.15	-.05	.08	-.06	.03	-.27	-.05
418	-.04	.01	-.04	-.02	-.22	-.02	.09	.11	.08	.09	-.05	.14	-.07	.07	-.07	.03	-.29	-.06
428	-.01	.13	-.02	.09	-.23	.03	.07	.11	.06	.08	-.08	.13	-.08	.07	-.09	.02	-.31	-.08
438	-.03	.13	-.04	.08	-.25	.02	.05	.12	.05	.08	-.11	.12	-.10	.06	-.11	.02	-.32	-.09
448	-.05	.12	-.06	.08	-.27	.01	.03	.12	.03	.08	-.13	.11	-.12	.05	-.12	.01	-.34	-.10
458	-.07	.11	-.07	.07	-.29	.00	.02	.11	.01	.08	-.16	.10	-.13	.04	-.14	.01	-.35	-.11
468	-.08	.10	-.09	.07	-.30	-.01	.00	.11	-.01	.08	-.19	.09	-.15	.04	-.15	.00	-.36	-.12
478	-.10	.10	-.10	.06	-.32	-.03	-.02	.10	-.03	.07	-.21	.08	-.16	.03	-.17	-.01	-.37	-.12
488	-.11	.09	-.12	.05	-.33	-.04	-.04	.10	-.04	.07	-.23	.07	-.17	.02	-.18	-.01	-.38	-.13
498	-.13	.08	-.13	.05	-.35	-.05	-.01	.20	-.02	.16	-.24	.11	-.19	.02	-.19	-.02	-.39	-.14
508	-.14	.08	-.15	.04	-.36	-.06	-.03	.20	-.04	.15	-.26	.10	-.20	.01	-.20	-.02	-.40	-.15
518	-.15	.07	-.16	.03	-.37	-.07	-.05	.19	-.06	.14	-.28	.09	-.21	.00	-.21	-.03	-.40	-.16
528	-.17	.06	-.17	.03	-.38	-.08	-.06	.18	-.07	.14	-.30	.08	-.22	.00	-.22	-.03	-.41	-.17
538	-.18	.05	-.18	.02	-.39	-.09	-.08	.17	-.09	.13	-.32	.07	-.23	-.01	-.23	-.04	-.41	-.17

[1] Selections were made by the authors from several possible sets of data. The results of this analysis should in no way be interpreted as a test of breeds or cross breeding programs nor should the results and inferences presented be connected in any way with the Clay Center U.S. Meat Animal Research Center.

[2] Estimates of the parameters and associated standard deviations of the estimates, in parentheses, are as follows for the three sets of cattle:

Cattle	Estimates of Parameters: W_0	A	α
Hereford	90.7 (47.3)	.0142 (.00181)	.00532 (.000419)
Charolais–Hereford	96.0 (53.0)	.013 (.00155)	.00468 (.000398)
Jersey–Angus	88.0 (52.0)	.0154 (.00237)	.00594 (.000536)

Table 2. **NET REVENUE FUNCTIONS AND REPLACEMENT POINTS FOR THREE GROUPS OF CATTLE: NO PRICE DIFFERENTIAL FOR QUALITY GRADE**

	Hereford (HH)						Charolais-Hereford (CH)						Jersey-Angus (JA)					
Days	Live		Carcass		Lean		Live		Carcass		Lean		Live		Carcass		Lean	
	MNR	ANR	MNR	ANR	MNR	ANR	MNR	ANR	MNR	ANR	MNR	ANR	MNR	ANR	MNR	ANR	MNR	ANR
298	$.27	$.15	$.25	$.06	$.17	$.14	$.39	$.24	$.37	$.14	$.36	$.27	$.20	$.09	$.18	$.00	$.05	$.04
308	.25	.16	.23	.07	.14	.14	.37	.25	.35	.16	.33	.28	.17	.10	.16	.02	.01	.04
318	.22	.16	.21	.09	.10	.14	.35	.26	.33	.18	.30	.28	.15	.11	.14	.03	-.02	.03
328	.20	.17	.19	.10	.07	.13	.33	.27	.31	.19	.27	.28	.12	.11	.11	.04	-.06	.03
338	.18	.17	.16	.10	.03	.13	.31	.27	.29	.20	.24	.28	.10	.11	.09	.04	-.09	.02
348	.16	.17	.14	.11	.00	.12	.29	.28	.27	.20	.20	.28	.08	.11	.07	.05	-.12	.01
358	.13	.17	.12	.11	-.04	.11	.27	.28	.25	.21	.17	.27	.05	.10	.04	.05	-.15	.00
368	.11	.16	.10	.11	-.07	.10	.25	.28	.23	.21	.14	.26	.03	.10	.02	.05	-.18	-.01
378	.09	.16	.08	.11	-.10	.09	.23	.27	.21	.21	.10	.25	.01	.10	.00	.04	-.21	-.02
388	.07	.16	.06	.10	-.13	.08	.21	.27	.19	.21	.07	.24	-.01	.09	-.02	.04	-.23	-.03
398	.05	.15	.04	.10	-.15	.07	.19	.27	.17	.21	.04	.23	-.03	.08	-.04	.04	-.25	-.04
408	.03	.15	.02	.10	-.18	.05	.17	.26	.15	.21	.00	.22	-.05	.08	-.06	.03	-.27	-.05
418	.01	.14	.00	.09	-.20	.04	.15	.26	.13	.20	-.03	.21	-.07	.07	-.07	.03	-.29	-.06
428	-.01	.13	-.02	.09	-.23	.03	.12	.25	.11	.20	-.06	.20	-.08	.07	-.09	.02	-.31	-.08
438	-.03	.13	-.04	.08	-.25	.02	.10	.25	.09	.20	-.09	.19	-.10	.06	-.11	.02	-.32	-.09
448	-.05	.12	-.06	.08	-.27	.01	.08	.24	.07	.19	-.12	.18	-.12	.05	-.12	.01	-.34	-.10

Carcass prices were the 1971 averages from the USDA's Midwest-Iowa and Mississippi River Markets report. The Good grade averaged $48.06 to $48.07 for all weight ranges while the Choice grade sold at $51.93, $51.93, $51.75, and $51.09 for the 500-, 600-, 700-, and 800-pound categories respectively.

A retail price of $73.33 per 100 pounds was estimated for the Choice grade by subtracting the 1971 average live-to-retail spread from a weighted (by the distribution of carcasses in the various yield grades) retail price. Since no price series for Good grade beef is reported, a price was estimated by adjusting the $73.33 consistent with the Choice-Good price ratio at the live cattle level. The price estimated for the Good grade was thus estimated at $67.90.

Feed grain prices for 1971 were applied to the ration generated from a computerized least-cost ration program available at Oklahoma State University [14]. The ration produced energy for gain at 4.2 cents per megcal and energy for maintenance at 2.7 cents per megcal.

Computer programs were written to generate the needed net revenue functions. All cattle were "placed" on feed at 205 days of age and the revenue estimates printed out for 10-day intervals. Table 1 illustrates a representative set of results.

Perhaps the most important feature of the results shown in Table 1 is the dominant role played by the "price jump" as the cattle were allowed to grade Choice. For any particular group of cattle, this tends to force the replacement point toward the point at which the price shift is introduced and this generally holds for all three criteria.

For example, the Hereford (HH) group of cattle reached maximum ANR, for all three criteria, at 428 days. This is the point at which the program allowed the cattle to "make Choice." Live weights at 428 days averaged approximately 1000 pounds. The price for the Choice grade thus becomes a "shift parameter" at 428 days and the mathematical niceties of the accepted replacement criterion desert us. Since the ANR function is discontinuous at 428 days, the MNR function is also discontinuous at that point. However, examination of the revenue functions prior to 428 days proves interesting. There is indication replacement would have come sooner for all alternatives, and especially the lean-meat criterion, if the price change had not been allowed. Note the equality of MNR and ANR between 328 and 338 days for the lean-meat criterion.

A similar pattern emerges from the Jersey-Angus (JA) group. Since this group is comprised of cattle with lower mature weights, a priori expectations would suggest earlier replacement since the cattle would be expected to make Choice at an earlier age. The problems of discontinuity and the domineering influence of the price change persist. Replacement is suggested by all three criteria -- live, carcass and lean – at or around 378 days.

The Charolais-Hereford (CH) group provides an illustration of a situation in which some other factor overshadows the impact of the price premium for the Choice grade. The lean-meat criterion dictates replacement within the ten-day interval 338 to 348 days as the MNR function intersects the ANR function at its maximum. Both the live and carcass criteria indicate replacement later around the 418-day point.[3]

Further examination suggests reasons for the change in the CH group. At 348 days, the CH group was gaining an average of 2.4 pounds per day and exhibited a cumulative weight of muscle above 44 percent of cumulative live weight. By comparison, at the 348-day point, the JA group was gaining but 1.62 pounds per day and only 42 percent of live weight was muscle weight. At 348 days, then, the CH group was gaining relatively efficiently and producing muscle tissue instead of fat and bone. If replacement for the CH group were delayed until 418 days as suggested by both the live and the carcass criterion, daily gain is down to 2.03 pounds and the muscle-to-live-weight ratio down to less than 43 percent. If replacement were to be delayed to the 498-day point when the Choice price premium is realized, the corresponding figures are 1.6 pounds per day and lean-to-live ratio of slightly over 41 percent. For the CH group, the capacity to produce muscle efficiently at a relatively early age proved more important than the price premium associated with making Choice after a longer feeding period. The lean-meat criterion picks this up more readily than do the live and carcass criteria.

The discontinuity in the ANR functions introduced when the cattle are "allowed" to grade Choice makes comparison of the three alternative criteria difficult. As a rule, all three criteria are forced to call for replacement at the point in time when the Choice price is brought in. The one exception with the CH cattle raises the question of just how costly insistence on the Choice quality grade might be. To shed further light on this issue and to facilitate more direct comparisons of the three criteria, the various functions were estimated again using only one price.[4]

Table 2 exhibits the relevant net revenue functions and the replacement points. Upon examination of Table 2, two conclusions become obvious. First, the lean-meat criterion consistently replaces earlier than the other criteria. Second, the lighter groups of cattle (the HH group and the JA group in particular) will tend to be replaced earlier, using the same criterion, than the CH group. Without the influence of the price change at 75 percent of mature weight (when the Choice grade was allowed earlier) the issues of daily gain and muscle-fat production ratios become important. Considering the carcass criterion, replacement dates for the HH, JA and CH groups come relatively late at 68.31, 72.92 and 60.86 percent of mature weight respectively. Conversely, the lean-meat criterion would replace at 59.23, 65.44 and 53.52 percent respectively for the HH, JA and CH groups.

Examination of selected cost and revenue relationships at the different replacement points also proves revealing. Table 3 shows the MC per pound of muscle and the MNR per head per day for the CH group at the three alternative replacement points. The earlier replacement point dictated by the lean-meat criterion gives a lower MC per pound of muscle at competitive contributions to the net revenue streams.[5]

CONCLUSIONS AND IMPLICATIONS

The state of the arts is approaching the point at which replacement decisions based on projected yield of lean meat deserve consideration. Across all three groups of cattle analyzed, the lean-meat criterion dictated earlier replacement when only one set of selling prices was used. The marginal cost of a pound of lean (muscle) is lower with the earlier replacement and suggests possibilities for reducing the production costs of beef. Given current real-world conditions, adjustments toward earlier replacement will of course be constrained by limits on the available number of feeder cattle. In the future, however, and (1) allowing time for expansion of the nation's supply of feeder cattle, (2) increased efforts by packer-breakers to buy on the basis of yield of lean beef, and (3) increased

[3]The estimated average net revenue streams on both a live and carcass basis reach a maximum much later at 498 days, however. Only the lean-meat criterion meets the requirements of the Faris criterion which calls for equality of marginal net revenue and *maximum* expected average net revenue.

[4]The price used was the price for Choice cattle, Choice carcasses and the estimated retail price based on Choice cuts. Using only the Good grade price would permit essentially the same analysis but the published price series for the Good grade are more limited.

[5]For the other two groups of cattle, the MNR per head per day at the early replacement points dictated by the lean-meat criterion compare less favorably. However, this is due primarily to the lower profitability of the smaller cattle, especially the JA group which produce lean meat with less efficiency and at higher cost. Using liveweight and carcass criteria and the same live and carcass prices as for the other groups of cattle, any differences in the capacity of the smaller cattle to produce muscle are not reflected in the replacement decisions.

Table 3. COMPARISON OF MC PER POUND OF MUSCLE AND MNR PER HEAD PER DAY AT THREE ALTERNATIVE REPLACEMENT POINTS FOR THE CH GROUP OF CATTLE

Criterion	Days at Which Replace	MNR per Head per Day	MC/lb. of Muscle
Live	358	27¢	53¢
Carcass	378	21¢	60¢
Lean	328	27¢	46¢

awareness of the relationships between production of fat, muscle and bone during the growth process there may evolve pressures toward the earlier replacement suggested by the lean-meat criterion.

An even more powerful constraining influence, of course, is the price increment associated with the move from Good to Choice Quality grades. The cattle were allowed to grade Choice at 75 percent of maturity. With but one exception, this precipitated a maximum in ANR for all replacement criteria at the point the cattle were moved to Choice. Allowing the grade change in increments would have dampened the precipitous change in the ANR functions but the overall result would be the same – replacement will be delayed until a significant number of the cattle in each group would grade Choice.

Given the higher MC per pound of lean at the later replacement points, it would appear the current tendency to insist on feeding until cattle will grade Choice (usually the sale of cattle is on the basis of 75-80 percent of a pen grading Choice) deserves closer scrutiny. In a recent report, Dinkel and Dearborn [5] summarize the growing and voluminous body of literature which suggests differences in marbeling – the primary determinant as to whether most carcasses grade Choice – bears little or no relationship to acceptability as measured by laboratory tests or by taste panels. Combined with the effect on cost of production, the results summarized by Dinkel and Dearborn suggest the economic relevance of the Choice grade will in fact be subjected to closer scrutiny. If and when any adjustments occur, replacement in accordance with a lean-meat criterion will become even more important.

Continued refinement in replacement decision theory and the data required by that theory is needed. The applicability of this analysis is constrained by current levels of knowledge in the composition of beef carcasses and on how the composition changes over the feeding period. The available price series for retail cuts is difficult to adapt for research purposes and is nonexistent for any quality grade other than Choice. As a result of these and other shortcomings, the notion of replacement in accordance with a lean-meat criterion will likely be given consideration in its most general sense – that such a criterion will usually dictate earlier replacement with correspondingly lower marginal costs of producing lean meat. More sophisticated applications will await further research results and a period in which the number of feeder cattle is not a critically limited determinant of total supply.

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