WEIGHT LOSS OF FED STEERS DURING MARKETING

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Feeding and marketing practices are related to weight loss of fed steers during marketing. Liveweight and carcass weight losses are higher if feed and water are withheld from steers before slaughter. Packers have incentive to require this practice because the liveweight-cost reduction exceeds the value of the lost weight.

Key words: cattle marketing, shrink.

Weight loss of fed steers during marketing adds to marketing costs. Explanations of variation in weight loss, however, have been incomplete. Previous studies have shown that liveweight loss, or shrink, increases at a decreasing rate with time elapsed during marketing and with shipping distance (Abbenhaus and Penny; Brotherton and Tippets; Henning and Thomas). But these studies also have shown that these two factors explain only part of the variation in liveweight shrink. Carcass weight loss is even less well understood.

This paper reports quantitative estimates of the impacts some factors associated with feeding and marketing practices have on percentage liveweight shrink and on hot carcass weights of fed steers. The results are used to develop guidelines for feeding and marketing decisions and to suggest that a cost-increasing condition of sale is sometimes negotiated on liveweight sales. The results pertain only to fed steers marketed directly from feedlots to packing plants.[1] Weight losses of heifers, of cattle not shipped directly to packing plants, or of carcasses during chilling (i.e., "cooler shrink") were not examined.

MODEL, DATA, AND METHODS OF ANALYSIS

The explanatory factors for percentage liveweight shrink and hot carcass weights considered were weather conditions during the feeding and marketing periods, amount of shelter provided in the feedlot, average daily rate of gain achieved near the end of the feeding period, feedlot weight on the marketing date, shipping distance, a condition of sale requiring that feed and water not be provided during the period immediately before slaughter, and quality and yield grades of carcasses.

Previous studies suggest the nature of the impacts of some of these explanatory factors on weight losses. Percentage liveweight shrink is expected to be less when temperature and other weather conditions are moderate (Brotherton and Tippets; Harston 1959a), when steers are shipped short distances (Abbenhaus and Penny; Henning and Thomas), and when feed and water are provided during the period immediately before slaughter (Harston 1959b). Hot carcass weights have been found unaffected when feed is withheld from cattle for up to forty-eight hours before slaughter (Carr, Allen, and Phar; Kirton, Patterson, and Duganzich). The effect of withholding both feed and water, however, has not been examined, but is expected to reduce hot carcass weights.

Neither amount of shelter provided nor rate of gain have been considered in earlier studies. The amount of shelter may affect weight loss because it affects exercise habits and cleanliness, but the nature of the effect is not clear from a priori analysis. Weight loss is expected to be greater for steers gaining more rapidly before marketing. The impacts on weight losses of feedlot weight, of degree of fatness of the carcass (quality grade), or of ratio of fat to lean in the carcass (yield grade) have been examined, but not well established (Abbenhaus and Penny; Brotherton and Tippets; Henning and Thomas).

Some other factors that are likely to affect weight loss, notably time elapsed during marketing (Brotherton and Tippets; Henning and Thomas) and loading and hauling methods, were

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[1] Shipments from feedlots to packing plants and to other direct outlets (i.e., outlets other than terminal and auction markets) account for most of fed cattle marketings. In 1972, packers procured 81.1% of heifers and steers through direct outlets (U.S. Department of Agriculture).

not explicitly considered in this study. Variation in time elapsed during marketing, however, was closely associated with variations in distance shipped and the condition of sale (i.e., whether feed and water were withheld before slaughter). Loading and hauling methods were not varied.

Data for the analysis were obtained from an experiment conducted at the Iowa State University Allee Experimental Farm near Newell, Iowa during which 585 steers were subjected to different feeding and marketing treatments.

The experiment covered two feeding periods and included three shelter treatments. The 304 steers fed during the first feeding period were marketed in the week of October 1, 1972, after approximately 165 days on feed. The remaining 281 steers were fed during the second feeding period and were marketed in the week of May 27, 1973, after approximately 180 days on feed. Each group was fed in one of sixteen feedlots on the farm. Seven of the feedlots were unsheltered; five were partly sheltered; and four were in a confinement building.[2]

The experiment also included three shipping-distance treatments, and two condition-of-sale (no feed-water and control) treatments. At the end of each feeding period, twelve truckloads of steers were shipped over a three-day period. Steers in each load were taken from each feedlot just before shipment. No more than two steers fed in the same lot were shipped in the same load. One third each of the loads were shipped 40 miles, 80 miles, and 120 miles.[3] The loads shipped each distance were paired, and steers in loads in a pair were slaughtered at the same time. Steers in one (no feed-water) load of each pair were penned at the plant without feed and water for twelve hours before slaughter. Steers in the other (control) load of each pair were shipped from the feedlot twelve hours later, and steers in both the no feed-water and control loads of each pair were slaughtered as soon as the control load arrived at the plant.

Additional detail about the shipment schedule and marketing treatments is presented in table 1. Loads 1–12 were from the first feeding period, and loads 13–24 were from the second. Loads on the same line were slaughtered at the same time. The no feed-water treatment was applied to each odd-numbered load, and the control treatment was applied to each even-numbered load. The first line, for example, shows that load 1 left the farm on Tuesday at 6:00 P.M., and that the twenty-five steers in the load were hauled 120 miles and penned for twelve hours at the plant

[2] The rations fed and the feeding procedures were the same for the different lots and periods except that grain sorghum replaced corn in rations fed some lots, and some lots were fed from self-feeders instead of bunks.

[3] The same size of truck and the same loading and hauling methods were used for each load.

Table 1. Shipment Schedule, Marketing Treatments, and Number of Steers for Each Load

Paired Loads[a] for Each Feeding Period	Shipment Time: No Feed-water	Shipment Time: Control	40 Miles: No Feed-water	40 Miles: Control	80 Miles: No Feed-water	80 Miles: Control	120 Miles: No Feed-water	120 Miles: Control
Loads shipped week beginning Oct. 1, 1972:								
1, 2	Tues., 6:00 P.M.	Wed., 6:00 A.M.					25	26
3, 4	Tues., 6:00 P.M.	Wed., 6:00 A.M.			26	25		
5, 6	Wed., 6:00 A.M.	Wed., 6:00 P.M.	26	26				
7, 8	Wed., 6:00 P.M.	Thurs., 6:00 A.M.					25	25
9, 10	Wed., 6:00 P.M.	Thurs., 6:00 A.M.			25	25		
11, 12	Thurs., 6:00 A.M.	Thurs., 6:00 P.M.	25	25				
Loads shipped week beginning May 27, 1973:								
13, 14	Tues., 6:00 P.M.	Wed., 6:00 A.M.					24	24
15, 16	Tues., 6:00 P.M.	Wed., 6:00 A.M.			24	24		
17, 18	Tues., 6:00 P.M.	Wed., 6:00 A.M.	24	24				
19, 20	Wed., 6:00 P.M.	Thurs., 6:00 A.M.					24	22
21, 22	Wed., 6:00 P.M.	Thurs., 6:00 A.M.			24	24		
23, 24	Wed., 6:00 P.M.	Thurs., 6:00 A.M.	23	22				

[a] Paired loads on the same line were slaughtered at the same time. The no feed-water treatment was applied to each odd-numbered load, and the control treatment was applied to each even-numbered load.

without feed and water before slaughter. The line also shows that the twenty-six steers in load 2, the control load paired with load 1, were shipped 120 miles, but left the feedlot twelve hours later so they could be slaughtered immediately on arrival at the plant at the same time that steers in load 1 were slaughtered.

Feeding and marketing treatments, average daily rate of gain during a twenty-eight day period near the end of the feeding period, liveweight at the feedlot before loading, liveweight at the plant before slaughter, hot carcass weight, and the quality and yield grades of the carcass were recorded for each steer. Grading was done by USDA graders.

These data and regression procedures were used to estimate two equations. Dependent and independent variables are defined in table 2. The independent variables initially included in the equation explaining percentage liveweight shrink, Y_1, were $X_1 - X_{10}$ and all two-way interactions involving $X_1 - X_6$. These independent variables plus two-way interactions between X_8 and $X_1 - X_6$ were initially included in the equation explaining hot carcass weight, Y_2.[4]

Table 2. Definitions of Dependent and Independent Variables

Symbol	Definition
Y_1	$= (1 - PW/X_8)$ (100) $=$ percentage liveweight shrink, where $PW =$ liveweight at the slaughter plant.
Y_2	$=$ hot carcass weight.
X_0	$=$ intercept.
X_1	$=$ 1 if fed during first feeding period, -1 otherwise.
X_2	$=$ 1 if fed in unsheltered lot, -1 if fed in confinement building, 0 otherwise.
X_3	$=$ 1 if fed in partly sheltered lot, -1 if fed in confinement building, 0 otherwise.
X_4	$=$ 1 if shipped 40 miles, -1 if shipped 120 miles, 0 otherwise.
X_5	$=$ 1 if shipped 80 miles, -1 if shipped 120 miles, 0 otherwise.
X_6	$=$ 1 if no feed and water before slaughter, -1 otherwise.
X_7	$=$ average daily rate of gain during 28 days near the end of the feeding period.
X_8	$=$ liveweight at the feedlot.
X_9	$=$ quality grade score, ranging from 0 for carcasses grading low Standard to 12 for carcasses grading high Prime.
X_{10}	$=$ yield grade score, ranging from 1.0 for high yielding carcasses to 5.9 for low yielding carcasses.

The statistical model initially specified for both the liveweight-shrink and hot-carcass-weight equations was, in standard matrix notation,

$$Y = XB + U,$$

where the element of the vector of random errors U that corresponds to the jth steer in the ith load, u_{ij}, is given by

$$u_{ij} = v_i + e_{ij},$$

and where v_i is the random effect associated with the ith load, and where e_{ij} is the random effect associated with the jth steer in the ith load. The random errors, v_i and e_{ij}, were assumed to be independently distributed with zero means and variances σ_v^2 and σ_e^2, respectively, where $\sigma_v^2 \geqslant 0$ and $\sigma_e^2 > 0$. This model is of the onefold, nested-error type discussed by Fuller and Battese, where the nests correspond to loads. The covariance structure of the random errors u_{ij} in this model is expressed by

$$\begin{aligned} E(u_{ij}u_{i'j'}) &= \sigma_v^2 + \sigma_e^2, \text{ if } i = i', \ j = j' \\ &= \sigma_v^2 \qquad\quad , \text{ if } i = i', \ j \neq j' \\ &= 0 \qquad\qquad , \text{ if } i \neq i', \ j \neq j'. \end{aligned}$$

An estimation method was selected for each equation. The selection procedure applied to each equation involved two steps. First, the variance components, σ_v^2 and σ_e^2, were estimated by using the "fitting of constants" method.[5] Then, the null hypothesis that $\sigma_v^2 = 0$ was tested. The null hypothesis was rejected for the liveweight-shrink equation, so the estimation method for the onefold, nested-error model that Fuller and Battese suggest was used. Their method involves using the estimates of the variance components to calculate a transformation matrix, premultiplying the original model by the transformation matrix, and then applying ordinary least squares to the transformed model to obtain the generalized least squares estimates. The null hypothesis that $\sigma_v^2 = 0$ was accepted for the hot-carcass-weight equation, so ordinary least squares was applied to the original dependent and independent variables.

The final estimated equations were arrived

[4] Hot carcass weight rather than percentage hot-carcass-weight shrink was used as the dependent variable in this equation because observations on hot carcass weight at the feedlot were not available.

[5] For discussions of the fitting-of-constants method, see Henderson; Searle.

at by deleting from each equation treatments and covariates not significant at the 10% level.[6]

RESULTS

The coefficient estimates and test statistics for the final liveweight-shrink equation are presented in table 3, and those for the final hot-carcass-weight equation are presented in table 4. Percentage liveweight shrink was significantly affected by feeding-period, shelter, shipping-distance and condition-of-sale treatments, by two-way interactions between these treatments, and by feedlot weight. In contrast to percentage liveweight shrink, hot carcass weight was not significantly affected by shipping distance or by two-way interactions, and it was significantly affected by rate of gain and by yield grade.

The negative coefficients of X_1 in tables 3 and 4 indicate that preslaughter liveweights were higher, but that hot carcass weights were lower per pound of liveweight at the feedlot for steers marketed at the end of the first feeding period than for steers marketed at the end of the second feeding period. The higher preslaughter liveweights per pound of feedlot weight (i.e., the lower percentage liveweight shrink) for first-period steers may have been attributable to weather conditions. Weather was cool and wet when the first-period steers were marketed. The second-period steers, on the other hand, were marketed during warm, dry weather. Percentage liveweight shrink was less in cool, wet weather than in warm, dry weather. A major cause of the lower hot carcass weights per pound of feedlot weight for the first-period steers may have been differences in weather conditions during the feeding periods.

The coefficients of the shelter classification variables in the two equations are perhaps surprising. The more shelter provided, the lower is the percentage liveweight shrink, i.e., percentage shrink is highest for no shelter (coefficient of X_2 in table 3), second highest for partial shelter (coefficient of X_3), and lowest for cattle fed in confinement (negative sum of coefficients of X_2 and X_3). Hot carcass weight also increases with the amount of shelter (coefficients of X_2 and X_3 in table 4).

The results concerning the impact of shipping distance on percentage liveweight shrink sup-

[6] There was a problem in testing shelter and distance treatments and interactions in the liveweight-shrink equation. To calculate the required F-ratios, reduced models had to be estimated. This required prior estimation of the variance components for the reduced models. Such estimates, however, were different from those for the full model. And when different estimates were used to transform the full and reduced models, the transformed variables in the full and reduced models were different, and the sums of squares used to calculate the F-ratios were not comparable. Therefore, variance components were estimated for the full and all reduced models, a "representative" estimate of each variance component was selected from these estimates, and the same representative estimate of each variance component was used in transforming both the full and reduced models that had to be estimated for each F-test.

Table 3. Liveweight-shrink Equation: Coefficient Estimates and Test Statistics

Variable	F-Ratio	Coefficient Estimate[a]	t-Ratio
Feeding period			
X_1		—0.321	2.987[b]
Shelter	36.34[b]		
X_2		0.273	
X_3		—0.116	
Shipping distance	6.40[b]		
X_4		—0.521	
X_5		0.185	
Condition of sale			
X_6		1.064	9.903[b]
Interactions	2.78[b]		
$X_1 \cdot X_2$		—0.219	
$X_1 \cdot X_3$		0.658	
$X_1 \cdot X_4$		—0.260	
$X_1 \cdot X_5$		—0.064	
$X_1 \cdot X_6$		0.075	
$X_2 \cdot X_4$		0.076	
$X_2 \cdot X_5$		—0.080	
$X_2 \cdot X_6$		0.084	
$X_3 \cdot X_4$		—0.061	
$X_3 \cdot X_5$		0.096	
$X_3 \cdot X_6$		0.161	
$X_4 \cdot X_6$		—0.024	
$X_5 \cdot X_6$		0.203	
Feedlot weight			
X_8		0.002	2.483[b]

Note: The R^2 for the regression of the transformed dependent variable on the transformed independent variables was 0.59.

[a] An example will illustrate the interpretation of these coefficients. Suppose steers weighing 1100 pounds at a feedlot with unsheltered facilities are marketed in the fall, shipped 120 miles, and provided no feed and water before slaughter. The values for the independent variables in the left column are $X_1 = 1$, $X_2 = 0$, $X_3 = 1$, $X_4 = -1$, $X_5 = -1$, $X_6 = 1$, $X_1 \cdot X_2 = 0$, $X_1 \cdot X_3 = 1, \ldots, X_8 = 1100$. The estimated percentage liveweight shrink, then, is the sum of the coefficients of X_1, X_3, X_6, $X_1 \cdot X_3$, $X_1 \cdot X_6$, $X_3 \cdot X_6$, and $X_5 \cdot X_6$, plus 1100 times the coefficient of X_8, which equals 3.571%.

[b] $P < 0.01$.

Table 4. Hot-Carcass-Weight-Shrink Equation: Coefficient Estimates and Test Statistics

Variable	F-Ratio	Coefficient Estimates	t-Ratio
Intercept			
X_0		−41.638	−4.424[a]
Feeding period			
X_1		− 2.923	−3.646[a]
Shelter	19.17[a]		
X_2		− 5.062	
X_3		− 1.919	
Condition of sale			
X_6		− 3.881	4.920[a]
Rate of gain			
X_7		− 2.312	−3.075[a]
Yield grade			
X_{10}		7.777	6.488[a]

Note: $R^2 = 0.91$.
[a] $P < 0.01$.

port findings of earlier studies (Abbenhaus and Penny; Henning and Thomas). Shrink increases, but at a decreasing rate as distance increases. Hot carcass weights, however, were not affected by distance shipped.

Withholding feed and water from steers for twelve hours before slaughter had a sharp impact on both percentage liveweight shrink and hot carcass weight. Steers provided no feed and water before slaughter lost an average of 2.128% more liveweight than control steers. The difference was even greater for steers marketed at the end of the first feeding period, fed in unsheltered lots, and shipped short distances. Hot carcass weights of steers provided no feed and water were 7.762 pounds lower than those of control steers. This result and the results of two earlier studies (Carr, Allen, and Phar; Kirton, Patterson, and Duganzich) suggest that withholding feed but providing water to steers before slaughter does not reduce hot carcass weight, but that withholding both feed and water from steers does reduce hot carcass weight.

The coefficients of feedlot weight in the two equations have different meanings. In the liveweight-shrink equation, the positive coefficient indicates that heavier cattle not only lost more liveweight, but also lost a larger percentage of liveweight during marketing than did lighter cattle. In the hot-carcass-weight equation, the coefficient of feedlot weight multiplied by 100 is an average hot-carcass-weight-to-feedlot-weight dressing percentage (63.1%). Two-way interactions between feedlot weight and the classification variables were not significant in the hot-carcass-weight equation. This indicates that the quantitative impacts on hot carcass weight of different feeding-period, shelter, and condition-of-sale treatments were the same for steers with different feedlot weights.

Average rate of gain and yield grade affected hot carcass weight but not percentage liveweight shrink, and quality grade affected neither dependent variable. Hot carcasses of steers gaining more rapidly just before marketing weighed less per pound of feedlot weight than did hot carcasses of steers gaining more slowly. Also, the positive coefficient for yield grade indicates that steers producing higher yielding carcasses (lower yield-grade score) produced smaller carcasses per pound of feedlot weight.

APPLICATIONS

Livestock marketing specialists might use these results to provide cattle feeders with guidelines for selecting feeding practices. For example, feeders investing in feedlot facilities might wish to take into account the impact of shelter on weight losses. The results might also be used to provide feeders and buyers with guidelines for making outlet and pricing decisions. For example, a liveweight bid at outlet k (LB_k) will return more net revenue to a feeder than a carcass weight bid at outlet m (CB_m) if

$$[(1 - \widehat{LS}_k)/(100)X_8]/\widehat{CW}_m > CB_m/LB_k,$$

where $\widehat{LS}_k$ = predicted percentage liveweight shrink at outlet k from the coefficients in table 3, and $\widehat{CW}_m$ = predicted hot carcass weight at outlet m from the coefficients in table 4.[7] A buyer could use guidelines developed from this expression to determine, for example, what carcass weight (liveweight) bid is needed to meet or exceed a competitor's liveweight (carcass weight) bid.

A condition of sale requiring withholding feed and water from steers before slaughter is sometimes negotiated on liveweight sales. The analysis suggests (a) that although this condition of sale increases weight losses and therefore mar-

[7] Other expressions can be used to develop guidelines for comparing two liveweight bids, or two carcass-weight bids. A feeder's net revenue from a liveweight sale at outlet k will be higher than his net revenue from a liveweight sale at outlet m if $(1 - \widehat{LS}_k)/(1 - \widehat{LS}_m) > LB_m/LB_k$. A carcass-weight sale at outlet k will return more net revenue than a carcass-weight sale at outlet m if $\widehat{CW}_k/\widehat{CW}_m > CB_m/CB_k$.

keting costs, it reduces revenue to the packer from the carcass and by-products less than it reduces the cost to the packer of the live animal; (*b*) that because of this, a packer can afford to offer a premium to induce feeders to accept this condition of sale; but (*c*) that the largest premium a packer can offer is less than a feeder would accept provided the feeder was aware of the impact that this condition of sale has on the live-pay weight and, therefore, on his revenue.

Withholding feed and water from steers before slaughter on liveweight sales reduces the packer's revenue by reducing the weight and value of both the carcass[8] and offal[9] components of the live animal. But the cost to the packer of the live animal also is reduced because of the liveweight loss. It is to the packer's advantage, then, to require this condition of sale if the reduction in cost is greater than the reduction in revenue, i.e., if

$$(1)\quad (LP)(PLL)(LW) > (CL)(CP) + (OP)(PLL)(LW),$$

where CW = hot carcass weight in cwt. of steers if feed and water are not withheld, CP = hot carcass value per cwt., LW = live-pay weight in cwt. of steers if feed and water are not withheld, OP = offal value per cwt. of liveweight, LP = liveweight price per cwt., CL = loss of hot carcass weight in cwt. caused by withholding feed and water from steers before slaughter, and PLL = proportion of liveweight lost when feed and water are withheld from steers before slaughter.

The inequality in equation (1) may be rewritten as

$$(2)\quad (LP - OP)/CP > CL/(PLL)(LW).$$

The value of the ratio on the left of the inequality in equation (2) depends on the liveweight, offal, and hot-carcass-weight prices, but can be expected to be only slightly less than the hot-carcass-weight-to-liveweight dressing ratio or approximately 0.6. The term on the right of the inequality in equation (2) is the ratio of the hot-carcass-weight loss to the liveweight loss from holding steers off feed and water. Estimates of PLL and CL can be obtained from tables 3 and 4. With these estimates, the value of the term on the right is less than 0.40 for liveweights greater than 900 pounds. Thus, the inequality in equation (2) can be expected to hold.

Because withholding feed and water from steers before slaughter increases net value to the packer, he can offer a premium if the feeder agrees to this condition of sale. The maximum premium per cwt. of liveweight ($PRMB$) a packer can offer is

$$(3)\quad [(LP - OP)(PLL) - (CP)(CL)(LW)]/(1 - PLL).$$

The premium in equation (3) will be positive if the inequality in equation (2) holds. If the packer is required to pay a smaller premium than this, the condition of sale reduces his live animal cost more than it reduces the value of the carcass and offal he receives.

On the other hand, if a feeder is aware of the impact that this condition of sale has on liveweight shrink, he should not be indifferent about a liveweight bid requiring it and an equal bid that does not require it. Rather, the smallest premium per cwt. of liveweight ($PRMF$) that he should be willing to accept in return for agreeing to withhold feed and water from steers before slaughter is

$$(4)\quad PRMF = [(LP)(PLL) - (FC)/(LW)]/(1 - PLL),$$

where FC is the feeding cost per head avoided by providing no feed for twelve hours before slaughter.

A comparison of equations (3) and (4) suggests that the largest premium a buyer can offer is less than the smallest premium a feeder should be willing to accept to withhold feed and water from steers before slaughter, that is, $PRMF > PRMB$ because it would be expected that $(CL)(CP) + (OP)(PLL)(LW) > FC$. That this condition of sale is sometimes agreed to on liveweight sales indicates that its impacts on weight losses are not well understood by feeders or packers or both.

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[8] The value to the packer will be reduced if the weight of the chilled carcass is reduced, and the weight of the chilled carcass will be reduced unless hot carcasses from steers provided no feed and water before slaughter shrink less in chilling than hot carcasses from steers not receiving this treatment. But some evidence indicates this does not happen; Carr, Allen, and Phar found that hot carcasses from cattle provided no feed before slaughter shrink more in chilling.

[9] Results of one study (Kirton, Patterson, and Duganzich) show that providing no feed to steers before slaughter reduces weights of stomachs, intestines, and lungs.

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