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Use of individual feeding behavior patterns to classify beef steers into overall finishing performance and carcass characteristic categories

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Introduction

Shifts in the beef industry have resulted in an increased emphasis on quality-based marketing. Grid- or formula-based marketing requires producers to estimate the overall performance and carcass characteristics of cattle before slaughter. Pricing is often based on the producer's ability to correctly identify groups of animals that are most likely to produce the desired carcass qualities. Prediction equations allowing efficient identification of animals most likely to produce at the desired level would be useful to livestock producers who use formula-based pricing.

Recently developed technology (GrowSafe Systems, Inc., Airdrie, Alberta, Canada) allows for continuous collection of individual feeding behavior data. Whitley (2000) suggested that individual feeding behavior data collected with the GrowSafe system might be useful to classify cattle into performance and carcass outcome groups.

Our objective was to evaluate the possibility of using an individual animal's feeding behavior pattern early in the finishing period to classify cattle into overall performance or carcass outcome groups.

Experimental Procedures

Cattle. Three hundred seventy steers (mean initial BW = 339 kg) were used in a feeding behavior trial conducted at Cactus Research, Ltd. facility located within the Cactus Feedyard at Cactus, TX, approximately 113 km north of Amarillo, TX. The steers were obtained through commercial market channels in KS, OK, and TX, and were as similar as possible in breed type, age, body weight (BW), background, and implant status. The trial started on July 26, 1999. All cattle were processed during the first 3 d of the trial. At processing, each steer was identified with two uniquely numbered ear tags, individually weighed, implanted with Ralgro (Schering-Plough Animal Health), administered an IBR vaccine (Rhone Merieux), a seven-way clostridial bacterin-toxoid (Vision-7, Bayer Animal Health), a drench suspension that contained 1,000,000 IU of vitamin A and 200,000 IU of vitamin D, and treated for internal and external parasites (Dectomax, Pfizer Animal Health). Additionally, the cattle were each tagged with a passive transponder ear tag that allowed continuous monitoring of feeding behavior patterns using the GrowSafe system described in the next section.

Feeding Behavior System. The GrowSafe system records individual animal identification, location of the individual animal at the feed bunk, and time of day when the individual animal fed. This electronic monitoring system consisted of four main components: 1) individually numbered transponder ear tags; 2) a neoprene mat that contained an antenna to receive signals from the ear tags; 3) a reader panel; and 4) a desktop computer. The transponder ear tag was a passive transponder used for individual animal identification. The neoprene mat was located in the feed bunk of equipped pens on the far side of the bunk, facing the steers. Each neoprene mat housed an antenna that radiated a 134.2 kHz pulsating electromagnetic field through a series of cells evenly spaced along the mat (60 cells per mat). The rubber mat could read the passive transponders at a distance of up to 45.72 cm from any cell. The energy generated by the antenna was collected by the transponder and stored in a capacitor located within each transponder. A sufficient energy charge in the capacitor, such as that caused by an animal placing its head in the feed bunk directly across from the rubber mat, resulted in the transponder transmitting its information (identification number) back to the antenna. The reader panel on each mat differentiated several transponders at the same time and stored the data for approximately 1 min. Every 6.3 s, the desktop computer, housed in a weather-proof location and connected to the series of reader panels via a data cable, read and stored the data from each reader panel in the computer hard drive. The GrowSafe system used in this particular study was a combination of five neoprene mats within the bunks of four adjacent feedlot pens. For the purpose of this study, a feeding event (feeding bout) was defined as the presence of an animal at the feed bunk for ≥ 6.3 s. The feeding event was considered to have ended when the animal was absent from the bunk for ≥ 300 s.

Experimental Design. Individual steers were the experimental unit for collection and analysis of feeding behavior data. The five measurements used to define an individual steer's feeding behavior pattern were as follows:

1) **Head Down Duration (HDD)** – the number of times the animal was recorded by a mat reader multiplied by 6.3 s;

2) **In-to-Out Duration (ITOD)** – total duration of the feeding event from initial presence at the bunk to the final reading not broken by a ≥ 300-s absence;

3) **Feeding Frequency (FREQ)** – the number of visits to the feed bunk per day;

4) **Feeding Intensity 1 (INT1)** – the head-down duration divided by visits to the bunk (INT1 = HDD/FREQ);

5) **Feeding Intensity 2 (INT2)** – the head-down duration divided by the in-to-out duration (INT2 = HDD/ITOD).

Because of complications with the GrowSafe system, the data were divided into blocks of time during which the largest number of observations possible was available. The time periods were as follows:

- Comparison Period 1 (d 26 to 40);
- Comparison Period 2 (d 74 to 92);
- Comparison Period 3 (d 101 to 126);
- Comparison Period 4 (d 127 to 143).

Data were summarized for each collection period by averaging each animal's HDD, ITOD, FREQ, INT1, and INT2 for the period. Comparison Period 4 contained the most observations. Data for initial dietary transition periods (d 0 to 25) were excluded because of complete system failure. All data analyzed represented time periods after cattle were consuming the finishing diet (4.5 to 9% roughage; steam-flaked corn base).

Individual feeding behavior data within each comparison period were paired with corresponding performance and carcass measurement variables. Daily gain (ADG; Table 1) and hot carcass weight (HCW; Table 3) data were sorted based on individual ADG for the overall trial period or individual HCW and divided into four classification groups (quartiles; 25% per comparison group). Quality grade data (Table 5) were sorted into two classification groups of 1) Prime + Choice or 2) Select + Standard, and yield grade (YG) data (Table 7) were grouped into two classification groups of 1) YG 1 + YG 2 or 2) YG 3 + YG 4. Carcasses from the majority of steers represented in quality grade and YG classification groups were Choice or Select and YG 2 or 3. Of the 370 steers in the overall experiment, the carcasses of two steers graded Prime, and one graded Standard. Similarly, the carcasses of 83 steers were YG 1, and only one was YG 4. Finally, liver abscess data (Table 9) were divided into two classification groups of 1) cattle with liver abscesses and 2) cattle without liver abscesses at the time of slaughter.

Statistical Analyses. A linear discriminant function was defined for each classification group by a two-step process. First, feeding behavior data (HDD, ITOD, FREQ, INT1, and INT2) grouped by performance or carcass characteristic for each comparison period were analyzed using the STEPDISC (stepwise discriminant analysis) procedure of SAS (SAS Inst. Inc., Cary, NC) to determine which variables might be useful for classification of steers into the various gain or carcass categories. Potential variables entered into the linear discriminant function when they were significant at $P < 0.10$. This step yielded the variables that contributed to the linear discriminant function significantly. Differences between or among classification groups for the selected variables were verified using the GLM procedure of SAS. Finally, feeding behavior variables defined by the STEPDISC procedure grouped by performance or carcass characteristic for each comparison period were analyzed using the DISCRIM procedures of SAS. Classification accuracy was defined as the percentage of animals classified correctly into their respective classification group based on the linear discriminant function.

Results and Discussion

Commercial feedlot pens typically contain from 50 to 200 animals. The animals are handled as little as possible because additional stress and movement are assumed to hinder overall performance. Hence, sorting these large pens of cattle late in the feeding period into outcome groups for marketing might not be cost-effective. However, if a large portion of animals could be identified and classified into uniform groups based on expected overall daily gain or carcass quality at a convenient time (e.g., reimplant), the added cost of sorting might be small compared with higher prices received in a value-based market. These statements led to two assumptions that we used in the interpretation and discussion of these results: 1) to be applicable to the beef cattle industry, classification of overall performance or carcass characteristics using

feeding behavior pattern must be accurate; and 2) classification must be possible before cattle are reimplanted to eliminate excessive handling of the cattle. As a result of these assumptions, a value of 90% classification accuracy was arbitrarily chosen as an acceptable level, and emphasis was placed on the practical value of linear discriminant functions defined for Comparison Period 1 (d 26 to 40).

In general, preliminary analyses indicated that classification accuracy was relatively low, ranging from 1.4 to 60% of animals classified into the correct group for linear discriminant functions constructed by using feeding behavior variables only. For this reason, linear discriminant functions were defined for each comparison group and comparison period by including initial BW as a potential function variable. Initial BW was chosen as a possible means of improving classification accuracy because it would typically be known for most industry settings. However, as will be noted in the subsequent discussion, addition of initial BW to the potential variables only slightly improved accuracy of the linear discriminant functions.

Descriptive statistics for ADG quartiles are shown in Table 1, and results of discriminant analysis using individual feeding behavior patterns and initial BW to classify steers into ADG quartiles are presented in Table 2. In Comparison Period 1, ITOD could be used to classify the lowest 25% of animals defined by ADG with an accuracy of 60%; however, the function only identified 1.43% of the highest gaining animals. Accuracy of the linear discriminant function for the other three comparison periods averaged 34.9, 27.4, 19.8, and 36.4% for the lowest to highest ADG quartiles, respectively (Table 2).

Descriptive statistics for HCW quartiles are shown in Table 3, and results of discriminant analysis using individual feeding behavior patterns and initial BW to classify steers into HCW quartiles are shown in Table 4. In Comparison Period 1, the linear discriminant function based on initial BW correctly classified 62.9, 23.2, 29.0, and 62.9% of steers into the lightest to heaviest HCW quartiles, respectively. Classification accuracy of the linear discriminant function for the other three comparison periods averaged 60.9, 39.2, 31.2, and 68.3% for the lightest to heaviest HCW quartiles, respectively. The highest accuracies were for the heaviest 25% of carcasses, with 62.9, 68.1, 65.7, and 71.0% correctly classified by the linear discriminant function for Comparison Periods 1, 2, 3, and 4, respectively. In contrast to Comparison Period 1, the linear discriminant functions for Comparison Periods 2, 3, and 4 included feeding behavior variables in addition to initial BW.

Descriptive statistics for quality and yield grade categories are shown in Tables 5 and 7, respectively. Results of discriminant analyses to classify steers into USDA quality and yield grade categories are shown in Tables 6 and 8, respectively. Quality grade categories were correctly classified 63.5 and 58.3% of the time for Select + Standard and Prime + Choice classification groups, respectively. Linear discriminant functions for the other three comparison periods were, on average, slightly less accurate, resulting in average classification accuracies of 60.1 and 57.9% for these two classification groups, respectively. Yield grade categories were less accurately classified by a linear discriminant function for the first comparison period (62.1 and 55.7% for YG 1 + YG 2 and YG 3 + YG 4 classification groups, respectively) compared with the other three comparison

periods, which averaged 64.4 and 61.9% correct classification for YG 1 + YG 2 and YG 3 + YG 4 classification groups, respectively.

Descriptive statistics for liver score categories are shown in Table 9. Classification into liver abscess categories (Table 10) for Comparison Period 1 was 68.2 and 56.5% accurate for the no abscess and abscesses present at slaughter classification groups, respectively. This linear discriminant function was based on FREQ only. Similar values were noted for Comparison Period 3; however, no significant variables were detected for Comparison Period 2 and 4, so linear discriminant functions were not calculated.

Based on assumptions discussed earlier (e.g., 90% classification accuracy), the results of this study indicate that use of an individual animal's feeding behavior is not adequate to classify steers into overall ADG or carcass characteristic groups. Addition of initial BW as a potential variable only slightly improved the classification accuracy. The classification equations (linear discriminant functions) ranged in accuracy from 1 to 70%, indicating highly variable classification ability. Nonetheless, the fact that up to 60 to 70% classification accuracy could be achieved using data with numerous gaps caused by equipment failure suggests that classifying cattle into outcome groups based on feeding behavior measurements merits further study.

Although the results presented herein suggest limited classification capability for individual feeding behavior measurements, certain trends were evident. Steers with the lowest ADG had higher ($P < 0.10$) head-down intensity (INT2) for Comparison Periods 2, 3, and 4 compared with steers with the highest ADG. These results were consistent with those of Whitley (2000). Steers with the lowest ADG spent less ($P < 0.10$) total time (ITOD) at the feed bunk and had lower ($P < 0.10$) initial BW than steers with the highest ADG (Table 1). There was no difference ($P > 0.10$) in FREQ for high- or low-gaining quartiles (Table 1). Steers with the lightest HCW consistently had lower ($P < 0.10$) initial BW and higher ($P < 0.10$) feeding intensity (INT2) than steers with the highest HCW (Table 3). Steers with carcasses grading Choice or Prime (Table 5) or having a YG 3 or 4 (Table 7) had higher ($P < 0.10$) initial BW and spent more total time (ITOD, $P < 0.10$) at the feed bunk than steers with carcasses grading Select or Standard or having a YG 1 or 2. Also, steers without liver abscesses at slaughter had a lower ($P < 0.10$) feeding frequency (FREQ) than steers with liver abscesses for Comparison Periods 1 and 3 (Table 9); however, in contrast with the results of Whitley (2000), our findings indicated no differences ($P > 0.10$) in feeding intensity (INT1 or INT2) for liver abscess classification groups.

Summary and Conclusions

Results of the present study were hindered by limited data for the period of time before reimplant. Based on these preliminary findings, we were unable, with high accuracy, to classify feedlot cattle into overall performance and carcass characteristic outcome groups using the feeding behavior measurements that we evaluated. Further analysis of feeding behavior patterns, including patterns not considered in our study, in conjunction with other readily available measurements, might improve classification accuracy early in the finishing period.

Literature Cited

Whitley, E. M. 2000. The performance and feeding behavior of steers in a finishing program. Ph.D. Dissertation, Texas A&M Univ., College Station, TX.

Acknowledgements

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Table 1. Means and standard deviations for individual feeding behavior variables and initial body weight based on daily gain quartiles.

Item	Classification group mean[a]				Classification group std. dev.[a]			
	Lowest ADG	Third highest ADG	Second highest ADG	Highest ADG	Lowest ADG	Third highest ADG	Second highest ADG	Highest ADG
Comparison Period 1[b]								
No. of steers	70	69	69	70	-	-	-	-
Overall ADG, kg	1.31	1.59	1.75	1.97	0.18	0.05	0.05	0.11
Initial BW, kg[c]	335.9[d]	336.2[d]	340.1[de]	344.5[e]	30.20	28.84	26.06	28.24
HDD[c]	49.40	53.92	52.23	52.50	15.64	21.12	19.12	19.87
ITOD[c]	111.40[d]	122.13[e]	119.59[e]	120.62[e]	25.20	29.80	24.86	27.15
FREQ[c]	9.46	9.35	9.55	9.40	2.20	1.83	1.92	2.11
INT1[c]	5.66	6.29	5.90	6.23	1.96	2.95	2.46	2.94
INT2[c]	0.44	0.43	0.43	0.43	0.10	0.11	0.10	0.11
Comparison Period 2[b]								
No. of steers	69	68	68	69	-	-	-	-
Overall ADG, kg	1.31	1.57	1.73	1.98	0.17	0.05	0.05	0.12
Initial BW, kg	333.1[d]	333.0[d]	339.0[de]	344.7[e]	27.51	28.05	27.98	29.62
HDD	48.45	50.67	52.30	49.68	18.50	19.34	20.43	18.76
ITOD	106.19[d]	111.56[de]	113.95[de]	116.80[e]	27.86	26.73	26.86	30.35
FREQ	8.27	8.20	7.91	8.24	1.72	1.86	1.79	1.56
INT1	6.50	7.07	7.35	6.61	2.94	3.51	3.30	2.87
INT2	0.45[d]	0.45[de]	0.45[de]	0.42[e]	0.11	0.12	0.11	0.10

Table 1 (continued). Means and standard deviations for individual feeding behavior variables and initial body weight based on daily gain quartiles

Item	Classification group mean[a]				Classification group std. dev.[a]			
	Lowest ADG	Third highest ADG	Second highest ADG	Highest ADG	Lowest ADG	Third highest ADG	Second highest ADG	Highest ADG
Comparison Period 3[b]								
No. of steers	70	69	69	70	-	-	-	-
Overall ADG, kg	1.31	1.59	1.75	1.97	0.18	0.05	0.05	0.11
Initial BW, kg	335.9[d]	336.2[d]	340.1[de]	344.5[e]	30.20	28.84	26.06	28.24
HDD[c]	43.25	42.58	40.52	42.55	17.83	18.39	16.31	19.12
ITOD[c]	96.06[d]	103.65[e]	102.13[de]	104.25[e]	25.61	28.42	20.55	27.37
FREQ[c]	8.26	7.89	8.09	8.03	1.76	1.55	1.73	1.73
INT1[c]	5.83	6.08	5.53	5.98	2.70	3.25	2.48	3.22
INT2[c]	0.44[d]	0.40[e]	0.39[e]	0.40[e]	0.12	0.11	0.12	0.11
Comparison Period 4[b]								
No. of steers	93	92	92	93	-	-	-	-
Overall ADG, kg	1.31	1.59	1.76	2.00	0.18	0.05	0.05	0.11
Initial BW, kg	334.4[d]	336.9[d]	339.3[de]	345.1[e]	29.50	29.13	27.17	29.87
HDD	45.95	46.06	43.71	44.29	18.24	18.63	16.42	17.93
ITOD	99.79[d]	104.80[de]	102.23[de]	106.13[e]	25.21	27.67	21.41	27.46
FREQ	7.87	7.72	7.87	7.90	1.81	1.56	1.64	1.76
INT1	6.41	6.59	6.09	6.25	2.84	3.09	2.65	2.97
INT2	0.45[d]	0.43[de]	0.42[e]	0.41[e]	0.11	0.11	0.12	0.10

[a]Classification group = quartiles (25% per group); ADG = average daily gain.

[b]Comparison Period 1 = d 26 to 40; Comparison Period 2 = d 74 to 92; Comparison Period 3 = d 101 to 126; Comparison Period 4 = d 127 to 143.

[c]BW = body weight; HDD = head-down duration, min; ITOD = in-to-out duration, min; FREQ = frequency of visits, visits per day; INT1 = head-down duration/frequency of visits; INT2 = head-down duration/in-to-out duration.

[d,e]Means with different superscripts differ, $P < 0.10$.

Table 2. Results of discriminant analysis using individual feeding behavior patterns and initial body weight to classify finishing beef steers into daily gain categories

Item	Classification group[a]			
	Lowest ADG	Third highest ADG	Second highest ADG	Highest ADG
Comparison Period 1[b]				
Constant	-8.624	-10.367	-9.940	-10.113
ITOD[c]	0.155	0.170	0.166	0.168
Accuracy[d]	60.00	44.93	5.80	1.43
Comparison Period 2[b]				
Constant	-69.242	-69.218	-71.733	-74.176
IBW[c]	0.416	0.416	0.423	0.430
Accuracy	5.80	48.53	7.35	52.17
Comparison Period 3[b]				
Constant	-8.651	-6.604	-6.408	-6.442
INT1[c]	-0.963	-0.632	-0.723	-0.631
INT2[c]	52.074	42.520	43.363	42.102
Accuracy	51.43	21.74	39.13	12.86
Comparison Period 4[b]				
Constant	-9.570	-8.383	-8.203	-7.490
INT1	-0.960	-0.770	-0.856	-0.722
INT2	55.854	50.386	51.239	47.539
Accuracy	47.31	11.96	13.04	44.09

[a]Classification group = quartiles (25% per group); ADG = average daily gain.

[b]Comparison Period 1 = d 26 to 40; Comparison Period 2 = d 74 to 92; Comparison Period 3 = d 101 to 126; Comparison Period 4 = d 127 to 143.

[c]Potential variables that entered into the linear discriminant function with a significance level for entry of $P < 0.10$ were: IBW = initial BW, kg; HDD = head-down duration, min; ITOD = in-to-out duration, min; FREQ = frequency of visits, visits per day; INT1 = head-down duration/frequency of visits; and INT2 = head-down duration/in-to-out duration.

[d]Accuracy is the percentage of animals classified into the correct classification group based on the linear discriminant function.

Table 3. Means and standard deviations for individual feeding behavior variables and initial body weight based on hot carcass weight quartiles

Item	Classification group mean[a]				Classification group std. dev.[a]			
	Lightest HCW	Third heaviest HCW	Second heaviest HCW	Heaviest HCW	Lightest HCW	Third heaviest HCW	Second heaviest HCW	Heaviest HCW
Comparison Period 1[b]								
No. of steers	70	69	69	70	-	-	-	-
Hot carcass wt, kg	328.0	358.6	380.2	407.5	19.24	6.04	5.60	16.63
Initial BW, kg[c]	318.5[d]	330.0[e]	344.6[f]	363.7[g]	25.81	20.95	21.03	23.57
HDD[c]	53.14	51.14	59.91	49.84	16.29	18.82	23.17	17.21
ITOD[c]	114.73[d]	116.31[de]	123.55[e]	119.12[de]	25.81	25.97	31.26	24.25
FREQ[c]	9.28	9.60	9.39	9.49	2.16	1.77	2.08	2.06
INT1[c]	6.27	5.76	6.25	5.79	2.28	2.38	3.07	2.64
INT2[c]	0.46[d]	0.43[e]	0.42[e]	0.41[e]	0.09	0.11	0.12	0.09
Comparison Period 2[b]								
No. of steers	69	68	68	69	-	-	-	-
Hot carcass wt, kg	326.7	355.4	378.1	408.6	15.66	6.24	6.50	18.22
Initial BW, kg	315.6[d]	330.1[e]	341.1[f]	363.0[g]	26.83	19.58	21.49	22.56
HDD	52.26	47.83	47.83	53.08	19.11	19.25	20.21	18.04
ITOD	107.87[d]	108.20[d]	111.05[d]	121.28[e]	26.88	26.97	28.98	28.05
FREQ	8.09	8.01	8.23	8.29	1.74	1.72	1.80	1.67
INT1	7.23	6.72	6.45	7.11	3.24	3.38	3.01	3.03
INT2	0.48[d]	0.44[e]	0.42[e]	0.43[e]	0.11	0.11	0.11	0.10

Table 3 (continued). Means and standard deviations for individual feeding behavior variables and initial body weight based on hot carcass weight quartiles

Item	Classification group mean[a]				Classification group std. dev.[a]			
	Lightest HCW	Third heaviest HCW	Second heaviest HCW	Heaviest HCW	Lightest HCW	Third heaviest HCW	Second heaviest HCW	Heaviest HCW
Comparison Period 3[b]								
No. of steers	70	69	69	70	-	-	-	-
Hot carcass wt, kg	328.0	358.6	380.2	407.5	19.24	6.04	5.60	16.63
Initial BW, kg	318.5[d]	330.0[e]	344.6[f]	363.7[g]	25.81	20.95	21.03	23.57
HDD[c]	45.57[d]	38.91[e]	45.15[d]	39.29[e]	17.67	16.91	19.69	16.35
ITOD[c]	98.03[d]	96.10[d]	108.71[e]	103.22[de]	24.68	25.66	26.51	24.76
FREQ[c]	8.00	8.23	7.84	8.20	1.70	1.58	1.77	1.72
INT1[c]	6.37[d]	5.26[e]	6.38[d]	5.41[e]	2.89	2.65	3.10	2.92
INT2[c]	0.46[d]	0.39[e]	0.40[e]	0.37[e]	0.11	0.11	0.12	0.10
Comparison Period 4[b]								
No. of steers	93	92	92	93	-	-	-	-
Hot carcass wt, kg	327.7	358.9	380.7	410.5	19.02	6.23	6.03	17.37
Initial BW, kg	315.9[d]	331.6[e]	343.2[f]	365.1[g]	25.48	21.16	21.20	23.71
HDD	48.11[d]	42.72[e]	45.91[de]	43.24[e]	17.93	16.48	19.22	17.14
ITOD	99.83[d]	101.25[de]	107.08[e]	104.81[de]	23.44	24.81	28.71	24.85
FREQ	7.58[d]	7.99[e]	7.93[de]	7.85[de]	1.68	1.64	1.82	1.61
INT1	6.97[d]	5.90[e]	6.35[de]	6.12[e]	2.92	2.71	2.85	2.98
INT2	0.48[d]	0.41[e]	0.42[e]	0.41[e]	0.11	0.11	0.11	0.10

[a]Classification group = quartiles (25% per group); HCW = hot carcass weight.

[b]Comparison Period 1 = d 26 to 40; Comparison Period 2 = d 74 to 92; Comparison Period 3 = d 101 to 126; Comparison Period 4 = d 127 to 143.

[c]BW = body weight; HDD = head-down duration, min; ITOD = in-to-out duration, min; FREQ = frequency of visits, visits per day; INT1 = head-down duration/frequency of visits; INT2 = head-down duration/in-to-out duration.

[d,e,f,g]Means with different superscripts differ, $P < 0.10$.

Table 4. Results of discriminant analysis using individual feeding behavior patterns and initial body weight to classify finishing beef steers into hot carcass weight categories

Item	Classification group[a]			
	Lightest HCW	Third heaviest HCW	Second heaviest HCW	Heaviest HCW
Comparison Period 1[b]				
Constant	-96.334	-103.441	-112.814	-125.632
IBW[c]	0.605	0.627	0.655	0.691
Accuracy[d]	62.86	23.19	28.99	62.86
Comparison Period 2[b]				
Constant	-110.973	-118.331	-125.281	-141.568
IBW	0.611	0.638	0.659	0.701
ITOD[c]	0.089	0.091	0.095	0.107
INT2[c]	40.555	36.843	35.878	36.426
Accuracy	62.32	33.82	30.88	68.12
Comparison Period 3[b]				
Constant	-112.210	-116.603	-126.493	-138.450
IBW	0.630	0.650	0.679	0.714
INT1[c]	-0.537	-0.481	-0.176	-0.269
INT2	59.896	54.391	49.728	49.990
Accuracy	60.00	47.83	33.33	65.71
Comparison Period 4[b]				
Constant	-109.316	-116.053	-123.445	-137.962
IBW	0.615	0.643	0.665	0.707
HDD[c]	-0.209	-0.192	-0.174	-0.187
INT2	72.095	64.999	63.441	64.237
Accuracy	60.22	35.87	29.35	70.97

[a]Classification group = quartiles (25% per group); HCW = hot carcass weight.

[b]Comparison Period 1 = d 26 to 40; Comparison Period 2 = d 74 to 92; Comparison Period 3 = d 101 to 126; Comparison Period 4 = d 127 to 143.

[c]Potential variables that entered into the linear discriminant function with a significance level for entry of $P < 0.10$ were: IBW = initial BW, kg; HDD = head-down duration, min; ITOD = in-to-out duration, min; FREQ = frequency of visits, visits per day; INT1 = head-down duration/frequency of visits; and INT2 = head-down duration/in-to-out duration.

[d]Accuracy is the percentage of animals classified into the correct classification group based on the linear discriminant function.

Table 5. Means and standard deviations for individual feeding behavior variables and initial body weight based on USDA quality grade groups

Item	Classification group mean[a]		Classification group std. dev.[a]	
	Select + Standard	Prime + Choice	Select + Standard	Prime + Choice
Comparison Period 1[b]				
No. of steers	115 (41.4)[d]	163 (58.6)[d]	-	-
Initial BW, kg[c]	335.2[e]	342.0[f]	28.31	28.29
HDD[c]	51.36	52.46	19.34	18.81
ITOD[c]	114.81[e]	120.97[f]	25.99	27.49
FREQ[c]	9.65	9.29	2.24	1.83
INT1[c]	5.90	6.10	2.67	2.57
INT2[c]	0.44	0.43	0.11	0.10
Comparison Period 2[b]				
No. of steers	114 (41.6)[d]	160 (58.4)[d]	-	-
Initial BW, kg	332.6[e]	340.9[f]	27.12	29.14
HDD	49.35	50.92	20.39	18.37
ITOD	107.59[e]	115.35[f]	28.30	27.63
FREQ	8.30	8.06	1.96	1.54
INT1	6.70	7.01	3.26	3.10
INT2	0.45	0.44	0.12	0.10
Comparison Period 3[b]				
No. of steers	115 (41.4)[d]	163 (58.6)[d]	-	-
Initial BW, kg	335.2[e]	342.0[f]	28.31	28.29
HDD	41.27	42.91	18.64	17.34
ITOD	96.69[e]	104.91[f]	25.56	25.40
FREQ	8.15	8.01	1.71	1.68
INT1	5.65	6.00	2.92	2.93
INT2	0.41	0.40	0.13	0.11

Table 5 (continued). Means and standard deviations for individual feeding behavior and initial weight variables based on USDA quality grade groups

Item	Classification group mean[a]		Classification group std. dev.[a]	
	Select + Standard	Prime + Choice	Select + Standard	Prime + Choice
Comparison Period 4[b]				
No. of steers	149 (40.3)[d]	221 (59.7)[d]	-	-
Initial BW, kg	334.1[e]	342.2[f]	28.37	29.19
HDD[c]	44.26	45.50	18.16	17.55
ITOD[c]	98.97[e]	106.11[f]	24.62	25.86
FREQ[c]	7.82	7.85	1.74	1.66
INT1[c]	6.25	6.39	2.99	2.82
INT2[c]	0.44	0.42	0.12	0.11

[a]USDA quality grades were combined (Prime + Choice or Select + Standard) to form the classification groups.

[b]Comparison Period 1 = d 26 to 40; Comparison Period 2 = d 74 to 92; Comparison Period 3 = d 101 to 126; Comparison Period 4 = d 127 to 143.

[c]BW = body weight; HDD = head-down duration, min; ITOD = in-to-out duration, min; FREQ = frequency of visits, visits per day; INT1 = head-down duration/frequency of visits; INT2 = head-down duration/in-to-out duration.

[d]Percentage of total observations.

[e,f]Means with different superscripts differ, $P < 0.10$.

Table 6. Results of discriminant analysis using individual feeding behavior patterns and initial body weight to classify finishing beef steers into USDA quality grade categories

	Classification group[a]	
Item	Select + Standard	Prime + Choice
Comparison Period 1[b]		
Constant	-107.369	-108.566
IBW[c]	0.459	0.465
FREQ[c]	5.472	5.189
ITOD[c]	-0.150	-0.125
INT1[c]	4.301	4.083
Accuracy[d]	63.48	58.28
Comparison Period 2[b]		
Constant	-91.288	-93.271
IBW	0.409	0.419
FREQ	5.233	4.929
ITOD	-0.161	-0.138
INT1	3.023	2.862
Accuracy	57.02	60.63
Comparison Period 3[b]		
Constant	-82.972	-85.804
IBW	0.421	0.428
HDD[c]	0.256	0.234
FREQ	2.132	2.001
ITOD	-0.032	-0.007
Accuracy	64.35	55.21

Table 6 (continued). Results of discriminant analysis using individual feeding behavior patterns and initial body weight to classify finishing beef steers into USDA quality grade categories

	Classification group[a]	
Item	Select + Standard	Prime + Choice
Comparison Period 4[b]		
Constant	-77.654	-81.057
IBW[c]	0.397	0.405
HDD[c]	0.201	0.178
FREQ[c]	2.204	2.091
ITOD[c]	-0.035	-0.010
Accuracy[d]	59.06	57.92

[a]USDA quality grades were combined (Prime + Choice or Select + Standard) to form the classification groups.

[b]Comparison Period 1 = d 26 to 40; Comparison Period 2 = d 74 to 92; Comparison Period 3 = d 101 to 126; Comparison Period 4 = d 127 to 143.

[c]Potential variables that entered into the linear discriminant function with a significance level for entry of $P < 0.10$ were: IBW = initial BW, kg; HDD = head-down duration, min; ITOD = in-to-out duration, min; FREQ = frequency of visits, visits per day; INT1 = head-down duration/frequency of visits; and INT2 = head-down duration/in-to-out duration.

[d]Accuracy is the percentage of animals classified into the correct classification group based on the linear discriminant function.

Table 7. Means and standard deviations for individual feeding behavior variables and initial body weight based on USDA yield grade groups

Item	Classification group mean[a]		Classification group std. dev.[a]	
	YG 1 + YG 2	YG 3 + YG 4	YG 1 + YG 2	YG 3 + YG 4
Comparison Period 1[b]				
No. of steers	190 (68.3)[d]	88 (31.7)[d]	-	-
Initial BW, kg[c]	337.3[e]	343.2[f]	28.96	27.04
HDD[c]	51.27	53.60	18.93	19.17
ITOD[c]	116.14[e]	123.34[f]	27.25	25.93
FREQ[c]	9.49	9.32	2.05	1.95
INT1[c]	5.91	6.25	2.64	2.54
INT2[c]	0.43	0.43	0.11	0.10
Comparison Period 2[b]				
No. of steers	196 (71.5)[d]	78 (28.5)[d]	-	-
Initial BW, kg	334.5[e]	344.9[f]	28.79	26.74
HDD	49.56	52.04	18.16	21.67
ITOD	108.98[e]	120.00[f]	26.53	30.53
FREQ	8.17	8.13	1.77	1.63
INT1	6.81	7.07	3.10	3.35
INT2	0.45	0.43	0.11	0.12
Comparison Period 3[b]				
No. of steers	190 (68.3)[d]	88 (31.7)[d]	-	-
Initial BW, kg	337.3[e]	343.2[f]	28.96	27.04
HDD	41.62	43.56	17.45	18.80
ITOD	98.18[e]	108.71[f]	25.16	25.64
FREQ	8.08	8.05	1.74	1.59
INT1	5.78	6.02	2.91	2.96
INT2	0.41	0.39	0.12	0.12

Table 7 (continued). Means and standard deviations for individual feeding behavior and initial weight variables based on USDA yield grade groups

Item	Classification group mean[a]		Classification group std. dev.[a]	
	YG 1 + YG 2	YG 3 + YG 4	YG 1 + YG 2	YG 3 + YG 4
Comparison Period 4[b]				
No. of steers	253 (68.4)[d]	117 (31.6)[d]	-	-
Initial BW, kg	335.9[e]	345.6[f]	29.10	28.08
HDD[c]	44.19	46.75	17.51	18.33
ITOD[c]	100.16[e]	109.88[f]	25.04	25.57
FREQ[c]	7.77	7.99	1.65	1.78
INT1[c]	6.27	6.48	2.88	2.91
INT2[c]	0.43	0.42	0.11	0.11

[a]USDA yield grades (YG) were combined (YG 1 + YG 2 or YG 3 + YG 4) to form the classification groups.

[b]Comparison Period 1 = d 26 to 40; Comparison Period 2 = d 74 to 92; Comparison Period 3 = d 101 to 126; Comparison Period 4 = d 127 to 143.

[c]BW = body weight; HDD = head-down duration, min; ITOD = in-to-out duration, min; FREQ = frequency of visits, visits per day; INT1 = head-down duration/frequency of visits; INT2 = head-down duration/in-to-out duration.

[d]Percentage of total observations.

[e,f]Means with different superscripts differ, $P < 0.10$.

Table 8. Results of discriminant analysis using individual feeding behavior patterns and initial body weight to classify finishing beef steers into USDA yield grade categories

	Classification group[a]	
Item	YG 1 + YG 2	YG 3 + YG 4
Comparison Period 1[b]		
Constant	-80.790	-84.535
IBW[c]	0.421	0.429
ITOD[c]	0.167	0.177
Accuracy[d]	62.11	55.68
Comparison Period 2[b]		
Constant	-85.392	-89.563
IBW	0.432	0.442
ITOD	0.056	0.071
INT2[c]	45.186	42.750
Accuracy	64.80	64.10
Comparison Period 3[b]		
Constant	-8.058	-10.160
HDD[c]	-0.091	-0.120
ITOD	0.203	0.235
Accuracy	63.16	62.50
Comparison Period 4[b]		
Constant	-73.641	-78.718
IBW	0.403	0.413
HDD	0.088	0.071
ITOD	0.079	0.103
Accuracy	65.22	58.97

[a]USDA yield grades (YG) were combined (YG 1 + YG 2 or YG 3 + YG 4) to form the classification groups.

[b]Comparison Period 1 = d 26 to 40; Comparison Period 2 = d 74 to 92; Comparison Period 3 = d 101 to 126; Comparison Period 4 = d 127 to 143.

[c]Potential variables that entered into the linear discriminant function with a significance level for entry of $P < 0.10$ were: IBW = initial BW, kg; HDD = head-down duration, min; ITOD = in-to-out duration, min; FREQ = frequency of visits, visits per day; INT1 = head-down duration/frequency of visits; and INT2 = head-down duration/in-to-out duration.

[d]Accuracy is the percentage of animals classified into the correct classification group based on the linear discriminant function.

Table 9. Means and standard deviations for individual feeding behavior variables and initial body weight based on liver abscess groups

Item	Classification group mean[a]		Classification group std. dev.[a]	
	No abscesses	Abscesses	No abscesses	Abscesses
Comparison Period 1[b]				
No. of steers	255 (91.7)[d]	23 (8.3)[d]	-	-
Initial BW, kg[c]	338.8	343.8	28.22	31.13
HDD[c]	52.06	51.36	19.05	18.89
ITOD[c]	117.96	123.48	26.47	32.56
FREQ[c]	9.34[e]	10.51[f]	1.93	2.60
INT1[c]	6.07	5.44	2.62	2.50
INT2[c]	0.43	0.42	0.10	0.11
Comparison Period 2[b]				
No. of steers	246 (89.8)[d]	28 (10.2)[d]	-	-
Initial BW, kg	336.7	344.1	28.39	29.74
HDD	50.48	48.41	19.29	18.78
ITOD	111.88	114.17	27.13	36.16
FREQ	8.12	8.48	1.72	1.82
INT1	6.94	6.34	3.20	2.80
INT2	0.45	0.42	0.11	0.10
Comparison Period 3[b]				
No. of steers	255 (91.7)[d]	23 (8.3)[d]	-	-
Initial BW, kg	338.8	343.8	28.22	31.13
HDD	42.55	38.75	18.10	15.08
ITOD	101.65	100.01	25.58	28.05
FREQ	8.00[e]	8.79[f]	1.64	2.06
INT1	5.93	5.02	2.95	2.58
INT2	0.41	0.38	0.12	0.11

Table 9 (continued). Means and standard deviations for individual feeding behavior and initial weight variables based on liver abscess groups

Item	Classification group mean[a]		Classification group std. dev.[a]	
	No abscesses	Abscesses	No abscesses	Abscesses
Comparison Period 4[b]				
No. of steers	337 (91.1)[d]	33 (8.9)[d]	-	-
Initial BW, kg	338.5	343.8	29.12	28.94
HDD[c]	45.10	44.01	17.89	16.90
ITOD[c]	102.95	106.20	25.49	26.67
FREQ[c]	7.82	8.05	1.69	1.73
INT1[c]	6.35	6.15	2.87	3.10
INT2[c]	0.43	0.41	0.11	0.11

[a]No abscesses present at slaughter or one or more abscesses detected at slaughter.

[b]Comparison Period 1 = d 26 to 40; Comparison Period 2 = d 74 to 92; Comparison Period 3 = d 101 to 126; Comparison Period 4 = d 127 to 143.

[c]BW = body weight; HDD = head-down duration, min; ITOD = in-to-out duration, min; FREQ = frequency of visits, visits per day; INT1 = head-down duration/frequency of visits; INT2 = head-down duration/in-to-out duration.

[d]Percentage of total observations.

[e,f]Means with different superscripts differ, $P < 0.10$.

Table 10. Results of discriminant analysis using individual feeding behavior patterns and initial body weight to classify finishing beef steers into liver abscess categories

	Classification group[a]	
Item	No abscesses	Abscesses
Comparison Period 1[b]		
Constant	-11.013	-13.955
FREQ[c]	2.358	2.654
Accuracy[d]	68.24	56.52
Comparison Period 2[b]		
Constant	-	-
NS[e]	-	-
Accuracy	-	-
Comparison Period 3[b]		
Constant	-11.343	-13.665
FREQ	2.834	3.111
Accuracy	62.35	52.17
Comparison Period 4[b]		
Constant	-	-
NS	-	-
Accuracy	-	-

[a]No abscesses present at slaughter or one or more abscesses detected at slaughter.

[b]Comparison Period 1 = d 26 to 40; Comparison Period 2 = d 74 to 92; Comparison Period 3 = d 101 to 126; Comparison Period 4 = d 127 to 143.

[c]Potential variables that entered into the linear discriminant function with a significance level for entry of $P < 0.10$ were: IBW = initial BW, kg; HDD = head-down duration, min; ITOD = in-to-out duration, min; FREQ = frequency of visits, visits per day; INT1 = head-down duration/frequency of visits; and INT2 = head-down duration/in-to-out duration.

[d]Accuracy is the percentage of animals classified into the correct classification group based on the linear discriminant function.

[e]NS = no variables entered into the linear discriminant function, $P > 0.10$.