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Performance and meat quality of beef steers fed corn-based or bread by-product-based diets¹

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ABSTRACT: A feeding trial was conducted with beef breed steers (120) to determine the effects of substituting bread by-product (BBY) for whole shelled corn on performance and meat quality. Chemical analysis of each diet ingredient and *in vitro* rates of digestion from gas production of BBY and corn were determined to provide accurate information for diet evaluations using the 1996 Beef NRC Model Level 2. Bread by-product contained 16% CP (75.6% degradable) and 75.1% non-structural carbohydrates (70% as starch, which had a digestion rate of 16%/h). The steers were given one estrogenic implant (Synovex-S) and started on the experiment at 15 mo of age and an average weight of 364 kg. The cattle were commercially slaughtered in three groups (40 steers at 101, 60 steers at 126, and 20 steers at 160 d on feed) weighing an average of 553 kg when

they reached a small degree of marbling. Carcasses were electrically stimulated to prevent cold shortening of muscles. Warner-Bratzler shear force values were measured in rib steaks at 5, 14, and 21 d after slaughter (n = 76). Rib steaks from 30 steers per treatment were evaluated for palatability traits. Use of BBY at 55% of the diet (substituted for 75% of the corn) significantly improved feed efficiency by 8.1%. There were no statistically significant differences between the two diets for effects on ADG, carcass characteristics, shear force values, or sensory panel ratings of tenderness, juiciness, flavor, or overall acceptability. After adjusting intestinal starch digestibility in Level 2 to 63% for the whole corn and 90% for the BBY, predicted ADG matched that observed. Apparent NE_g values for BBY and corn were 1.57 and 1.41 Mcal/kg, respectively.

Key Words: Beef Cattle, Feeds, Meat Quality, Net Energy

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Introduction

Bread by-product (**BBY**) consists of surplus and left-over materials collected from bakeries and other food-processing plants. A limitation in using large amounts of by-products in the diet, such as waste bread, is their wide variation in composition. Arosemena et al. (1995) found considerable differences in bakery waste composition from corresponding values previously reported in the literature (NRC, 1989), indicating substantial variation in the energy density of this by-product. Milton and Brandt (1994a) suggested an optimal inclusion

level of below 30% of the diet DM, and Huber (1981) recommended 10% in feedlot diets. However, little has been published regarding the effect of including a high level of this variable feedstuff in cattle diets on beef quality and feedlot performance.

Our objective for this study was to determine the effect of substituting BBY for corn in a high-energy finishing diet on feedlot performance and beef quality (tenderness, quality grade, and sensory panel evaluation). Tenderness is the most important beef palatability trait for consumer acceptance (Dikeman, 1987). Quality grade is important because it is used to determine carcass price.

Materials and Methods

Animals. This study was conducted in the slatted-floor confinement barn of the Cornell Animal Science Teaching and Research Center with Angus crossbred feeder steers (n = 120) assembled from known sires from northeastern beef herds. The steers were raised on forage-based diets until approximately 1 yr of age. They were started on the experiment May 29, 1997, at an average initial shrunk weight of 364 kg (range was 340 to 385 kg) at 15 mo of age. The steers were

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Table 1. Ingredient and nutrient composition of corn-based and bread by-product (BBy)-based diets

Item	Diet	
	Corn	BBy
Ingredient composition, % of DM		
Dry whole shelled corn	63.3	15.3
Bread by-product	—	55.2
Corn silage (40% grain)	18.1	18.4
Timothy hay	9.0	6.2
Soybean meal (49% CP)	7.2	2.5
Limestone	1.2	1.2
Mineral mix ^a	1.2	1.2
Vitamin premix ^b	.1	.1
Rumensin premix, g/kg feed ^c	.033	.033
Nutrient composition ^d		
CP, % of DM	12.7	12.7
DIP, % of CP ^e	63.0	72.0
Soluble protein, % of CP	20.0	17.0
Total NSC, % of DM ^f	60.0	65.0
NDF, % of DM	20.0	15.0
NE _m , Mcal/kg DM	2.08	2.25
NE _g , Mcal/kg DM	1.22	1.37
Ca, % of DM	.65	.59
P, % of DM	.39	.36

^aContained 98% NaCl, .4% Zn, .4% Fe, .3% Mn, .2% Cu, .02% Se, .007% I, and .007% Co.

^bContained 5,000 IU/kg of vitamin A, 2,000 IU/kg of vitamin D, and 100 IU/kg of vitamin E.

^cContained 132 g/kg of monensin (Elanco Animal Health, Indianapolis, IN).

^dNutrient composition values obtained from NRC (1996) model Level 2 to develop the experimental diets.

^eDIP = protein degradability.

^fNSC = nonstructural carbohydrate.

given one estrogenic implant (Synovex-S, Fort Dodge Animal Health, Overland Park, KS) at the start of the experiment.

Treatments, Chemical Composition, Rate of Digestion, and Diet Formulation. After an 18-d adjustment period on a diet containing 50% corn silage, 48% mature mixed hay, and 2% soybean meal, half of the steers were placed on a conventional high-energy (corn-based) finishing diet and half were fed the BBy-based diet. Table 1 shows the ingredient and nutrient composition of the diets. The feeding program was developed with the 1996 National Research Council Nutrient Requirements of Beef Cattle Model Level 1 (NRC, 1996). Because ingredient analyses for carbohydrate and protein fractions were available, diets were evaluated and reformulated using the 1996 Beef NRC Model Level 2. Borate-phosphate buffer was used to estimate soluble CP. Neutral detergent fiber was determined following the procedure of Van Soest et al. (1991). Nonstructural carbohydrates (NSC) was calculated as $NSC = (100 - (Ash + CP + EE + (NDF - (.01 \times NDFIP \times CP))))$, where NDFIP is neutral detergent insoluble protein and EE is ether extract.

Corn- and BBy-based diets were formulated to be isonitrogenous and to meet ruminal microbial N and peptide requirements for maximal microbial growth.

However, the diets were not rebalanced to be isocaloric, because we kept constant the replacement of 75% of the whole shelled corn and 65% of the soybean meal with BBy.

Twenty animals per treatment were individually fed, and the remaining 80 animals were fed in eight pens of 10 steers each (four pens per diet). Dry matter offered to and refused by individually fed and group-fed cattle were recorded daily.

In vitro rates of digestion from gas production of BBy were determined as described by Pell and Schofield (1993) for A (sugars and organic acids), B₁ (starch, pectins, and fructans), and B₂ (available cell wall) carbohydrate fractions for use in the 1996 Beef NRC Model Level 2. In addition, we were interested in evaluating possible variation in rates of digestion between loads of the BBy. Therefore, BBy from different loads from the same source (normal, moldy from storage, and containing ground bag plastic) were analyzed.

Marketing of Animals. When the manager estimated the animals to be near the optimum target body fat, they were visually condition-scored and ultrasonically scanned (Animal Ultrasound Services, Ithaca, NY) to predict backfat, degree of marbling, yield, and quality grade. The goal was to have 80% of the steers within our window of acceptability of 3 to 5% intramuscular fat in the longissimus muscle, which is associated with a marbling score of 5 to 6, as described by Perry and Fox (1997).

The cattle were slaughtered in three groups with equal numbers of both corn and BBy per group at Taylor Packing Co. (Wyalusing, PA), using electrical stimulation to prevent cold shortening of muscles (Hedrick et al., 1994). Groups 1 to 3 included 40, 60, and 20 steers at 101, 126, and 160 d on feed, respectively. Carcass measurements were taken by William Henning, Pennsylvania State University, and included marbling score, backfat thickness, and loin eye area at the 12th rib.

Meat Quality. We compared 1) tenderness, by Warner-Bratzler shear force evaluations; 2) palatability traits, including tenderness, juiciness, flavor intensity, and overall desirability by a sensory panel evaluation; and 3) chemical composition, by proximate analysis.

Within 24 to 48 h after slaughter, the whole primal rib was removed from the left side of each carcass, vacuum-packaged, held overnight, and transported to the Cornell Meat Laboratory. After the longissimus muscle was removed, five contiguous steaks of 2.54-cm thickness were removed from the 12th rib end. Steaks 1, 3, and 4 were vacuum-packaged and refrigerated at 0 to 4°C for shear force evaluation at 5, 14, and 21 d after slaughter. Steak 2 was stored the same way and was used for sensory evaluation by Wegmans Food Markets meat managers (Rochester, NY) and representatives from Taylor Packing Co. (Wyalusing, PA) 26 d after slaughter. Steak 5 was frozen for deter-

mination of chemical fat, protein, water, and ash content of the longissimus muscle.

Shear Force Evaluations. All the steaks used in the shear force evaluations were cooked in a gas-fired convection oven to a final internal temperature of 67°C. This was accomplished by monitoring the internal temperature during cooking. The steaks were cooled to room temperature for approximately 1 h before cores were removed for shear force evaluation. The shear force evaluation consisted of eight 1.27-cm cores taken parallel to the muscle fiber orientation from each steak. Each core was sheared once using a Warner-Bratzler blade attachment in an Instron Model 1122 Universal Testing Machine (Instron, Canton, MA), which measured the peak force required to cut the core in half perpendicular to the length of the core. The peak force generated was recorded for each core, and the mean of all the cores for a given steak was used for statistical analysis.

Sensory Panel Evaluation. Steaks from all 60 steers in the second slaughter group were used for the sensory evaluation. Thirty were from steers fed the BBy diet and 30 were from steers fed the corn diet. At the beginning of this evaluation, the Wegmans Food Markets meat managers and representatives from Taylor Packing Co. were given an explanation of the sensory evaluation data sheet then were divided into eight groups of eight panelists each. The objective was to evaluate eight steaks in each group so that the eight panelists in the group evaluated two pieces of each steak, one for the number of chews required before swallowing and the other for palatability characteristics. All steaks used in the sensory evaluation were cooked in groups of eight to the same final internal temperature (67°C) as in the shear force evaluation. This corresponds to a "medium" degree of doneness. Each block of eight panelists evaluated and scored each steak from eight different steers (four steers fed corn-based and four fed BBy-based diets). Each group of eight steaks was removed from the oven after reaching the target final temperature and each steak was cut into 1- × 1- × 2.5-cm pieces. Sixteen pieces were taken from each steak, and two pieces from each of the eight steaks were placed on a marked section of the plate for each panelist in the block. The panelists counted the number of chews required before swallowing the first piece of steak and scored the second piece of the same steak for tenderness, juiciness, flavor intensity, and overall desirability.

Chemical Analysis. Steak 5 was thawed and ground to a homogeneous consistency using a food processor (model DLC-10E, Cuisinart, Greenwich, CT). Subsamples were analyzed for nitrogen content with the Kjeldahl method (AOAC, 1990). Samples were dried in an oven at 70°C for 48 h for moisture content determination. Lipid percentage was determined by ether extraction of the dried samples following the procedures of AOAC (1990). The ash content was determined by dif-

ference after subtracting percentages of protein, fat, and moisture.

Statistical Analysis

Data obtained from this experiment were analyzed by analysis of variance using Proc GLM (SAS, 1988). Animal daily gain, carcass characteristics, and proximate analysis of longissimus muscle steaks were analyzed with one-way ANOVA for treatment main effect (corn vs bread by-product) for a completely randomized design with animal as the experimental unit. Dry matter intake and feed:gain ratios of individually fed and group-fed animals were pooled for analysis by using the WEIGHT statement of SAS (1988) to use weighted means in the analysis. The model for shear force analysis included treatment, time after slaughter, and the treatment × time after slaughter interaction. Mean separation was analyzed with Tukey's test. The model for the sensory evaluation included block, treatment, and the block × treatment interaction. Correlation and linear regression analysis (SAS, 1988) were conducted to determine the efficacy of the tenderness classification and to compare shear force values at 24 d postmortem with corresponding sensory panel tenderness evaluation.

Results and Discussion

Composition of Feed Ingredients. Table 2 shows the chemical composition of the BBy and other ingredients used in the diets. The BBy used in this study contained 16% CP (75.6% degradable), 3% NDF, 75.1% NSC (70% as starch), and 3.3% fat. Analysis of different BBy loads from the same source indicated that chemical composition was very consistent (data not shown). Table 2 compares chemical values determined in our study with the bakery waste composition data reported by the NRC (1996) and two studies at the University of California, Davis (Arosemena et al., 1995; DePeters et al., 1997). Nearly all composition values varied widely between these sources. The main reasons for these differences are origin or source of the by-product, specific products included, and processing currently used. These data indicate a complete chemical analysis is needed when using a by-product from a new source or when the by-product is inconsistent.

In Vitro Rate of Digestion. Gas production curves for whole BBy, whole BBy ethanol-insoluble residue (EIR, A fraction), EIR-NDF (B₁ fraction), and NDF (B₂ fraction) necessary to calculate the predicted digestion rates for the carbohydrate fractions were obtained. The data of these curves were then fit to an exponential model to obtain rate constants for these fractions required in the NRC (1996) computer Model Level 2. We obtained a rate of digestion of the BBy of 53, 16, and 5%/h for the A, B₁, and B₂ carbohydrate fractions, respectively (Table 2), with a whole DM rate of digestion of 20.7%/h.

Table 2. Chemical composition of diet ingredients^a and comparison of the chemical composition of the bread by-product (BBy) and bakery waste

Item	Corn silage	Dry whole shelled corn	Timothy hay	Soybean meal (49% CP)	BBy	Bakery waste NRC ^b	Bakery waste UCD ^c
Dry matter, % of DM	36.5	88.0	90.5	90.0	67.6	92.0	90.8
Crude protein, % of DM	6.8	10.1	11.9	55.1	16.0	5.4	12.3
DIP, % of DM ^d	78.0	45.0	69.0	65.0	75.6	48.2	ND ⁱ
Soluble protein, % of CP	51.0	11.0	42.0	20.0	11.0	11.0	ND
NDF, % of DM	42.0	9.0	65.8	7.7	3.0	18.0	11.9
ADF, % of DM	23.9	2.2	49.1	4.7	1.9	—	5.0
NDFIP, % of CP ^e	10.3	15.0	25.2	3.1	5.6	30.0	17.5
ADFIP, % of CP ^f	5.9	5.0	8.4	1.3	1.3	31.5	6.4
Crude fat, % of DM	3.3	4.3	1.5	3.0	3.3	4.7	8.5
NSC, % of DM ^g	45.4	76.5	15.1	27.3	75.1	68.5	66.2
Starch, % of NSC	100.0	90.0	6.0	90.0	69.9	100.0	ND
Lignin, % of NDF	8.1	2.2	12.6	3.0	20.0	5.6	14.3
Ash, % of DM	3.0	1.6	6.7	6.9	2.9	5.0	3.3
Ca, % of DM	.20	.01	.67	.27	.10	.20	.20
P, % of DM	.30	.30	.29	.69	.20	.20	.40
Degradation rates, %/h ^h							
A carbohydrate	275	150	250	300	53	350	—
B ₁ carbohydrate	30	10	30	45	16	50	—
B ₂ carbohydrate	4	5	3	6	5	9	7.1 ^j
Whole DM	—	—	—	—	20.7	—	14.2 ^j

^aWet chemistry composition provided by the Northeast DHIA Forage Laboratory, Ithaca, NY.

^bNRC (1996).

^cUCD = averages values from Arosemena et al. (1995) and DePeters et al. (1997), University of California, Davis.

^dDIP = degradable protein.

^eNDFIP = neutral detergent insoluble protein.

^fADFIP = acid detergent insoluble protein.

^gNSC = (100 - (Ash + CP + EE + (NDF - (.01 × NDFIP × CP))))), where NSC = nonstructural carbohydrate adjusted for NDFIP and EE = ether extract.

^hDegradation rate values for all feeds except BBy were obtained from NRC (1996) appendix Tables 6–8.

ⁱND = not determined.

^jDry matter in sacco digestion rate (DePeters et al., 1997).

DePeters et al. (1997) calculated in sacco digestion rates from three different sources of bakery waste for DM and NDF. They reported digestion rate averages of 14.2 and 7.1%/h for DM and NDF, respectively. We obtained a 46% higher rate of digestion for DM. Our higher DM rate is most likely due to the lower NDF (3.0 vs 13.6) and higher NSC (75.1 vs 65.34) content of our BBy, which therefore had more rapidly fermentable carbohydrates (starch and sugars).

Figure 1 shows the DM gas production of different loads of BBy, moldy BBy, BBy containing plastic, and corn. Differences in gas production among loads of BBy, moldy BBy, and BBy containing plastic were minimal.

Steer Performance and Carcass Characteristics. Steer performance and carcass characteristics are summarized in Table 3. There were no differences between the two diets in ADG and carcass characteristics ($P > .1$). Overall, 78% of the steers graded Choice. The only traits found in this study to be significantly affected by diet type were DM intake and feed:gain ratio ($P < .01$). The animals fed our BBy diet required 8.1% less DM/kg gain than the animals fed the corn diet. This result agrees with the study results of Milton and Brandt (1994a), who found a linear depression in DM intake without differences in ADG when corn was re-

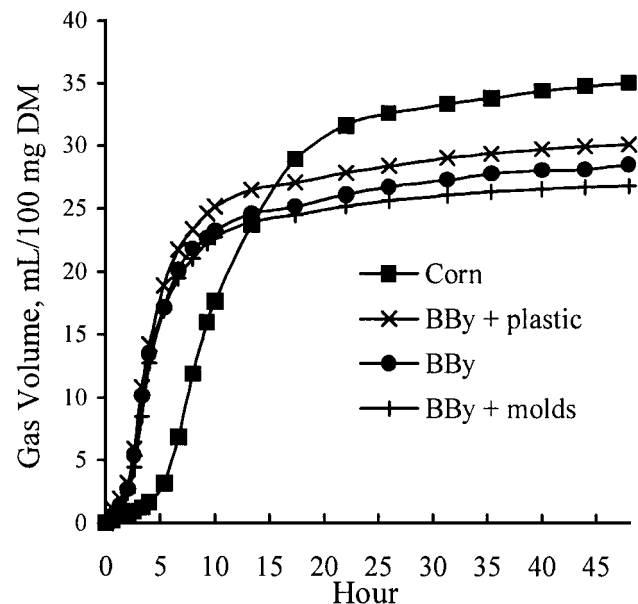


Figure 1. In vitro DM gas production of bread by-product (BBy), BBy containing plastic or molds, and whole shelled corn.

Table 3. Daily gain, dry matter intake, feed:gain ratio, and carcass characteristics of feedlot steers fed corn-based or bread by-product (BBy)-based diets (n = 120)

Variable	Diet		SEM	P-level
	Corn	BBy		
Daily gain, kg/d	1.59	1.54	.03	.24
DMI, kg/d ^a	11.39	10.17	.13	<.01
Feed:gain ratio ^a	7.22	6.64	.14	<.01
Dressing percentage	62.6	62.4	.27	.57
Quality grade ^b	4.92	4.82	.07	.33
Fat depth, cm	1.52	1.50	.04	.68
Yield grade	3.47	3.32	.07	.16

^aDMI and feed:gain ratios of individually fed and group-fed steers were analyzed combined by using the WEIGHT statement of SAS (1998) for test comparing weighted means.

^b4 = Select; 5.0 = Choice-; 6.0 = Choice 0; 7.0 = Choice+.

placed with dried bakery product (0, 15, and 30% replacement of corn).

Apparent Net Energy Value of Bread By-product and Corn. Apparent net energy gain (NE_g) values for the corn- and BBy-based diets were computed with the 1996 Beef NRC Model Level 2 as follows: 1) the animal, environment, management, feed composition, and ingredient DMI inputs from Tables 1 and 2 required by the model for the corn-based diet were entered; 2) the corn intestinal digestibility was adjusted until predicted and observed animal performance agreed, using the guidelines in NRC (1996) appendix table 10; and 3) this process was repeated for the BBy-based diet, using the above-determined values for intestinal digestibility of corn.

This methodology to obtain biological values relies on accurate model inputs (step 1) and an understanding of how to use the NRC (1996) Model Level 2. Without adjustment to intestinal digestibilities, the Model Level 2 overpredicted ADG by 86 g, or 5.4%, for the corn-fed steers and underpredicted ADG by 70 g, or 4.5%, for the BBy-fed steers. The model has a default value of 75% intestinal digestibility for all B₁ carbohydrate fractions (rumen escaped starch). However, the NRC (1996) appendix table 10 gives intestinal digestibilities for starch entering the intestines of 50 to 60% for whole corn, 80 to 90% for corn meal and whole high-moisture corn, and 92 to 97% for steam-flaked corn, based on Sniffen et al. (1992).

Predicted and observed animal performance agreed when the B₁ carbohydrate fraction intestinal digestibility was set at 63% for corn and 90% for BBy. The 63% value for corn agrees with the range of 50 to 60% for whole corn in the 1996 Beef NRC appendix table 10. The 90% value for BBy agrees with the range of 80 to 90% for corn meal in the same table. These results agree with a study by Milton and Brandt (1994b), who found that total tract starch digestibility increased (linearly, $P < .01$) when dried bakery product replaced 0, 15, 30, and 50% of corn.

Dietary NE_m and NE_g values obtained in this study by this method were 2.26 and 1.57 Mcal/kg of DM for BBy and 2.07 and 1.41 Mcal/kg of DM for whole shelled

corn, respectively. This result agrees with the results from Milton and Brandt (1994a), who suggested that dried bakery product has higher NE values than does corn.

In our study, BBy replaced 75% of the corn (DM basis) and was 55% of the diet DM, which exceeds any level reported in the literature. No digestive problems related to feeding BBy at this level were encountered in our study, despite the mold and/or ground plastic found in some loads. However, comparisons of results with other studies using bakery waste have to be made cautiously due to the high variability in composition.

Beef Quality Evaluation. Shear force values at 5 and 14 d were 4.88 and 4.15 kg and 4.74 and 3.53 kg for BBy and corn, respectively. None of the differences was statistically significant ($P > .1$). However, shear force was reduced 22% between 5 and 14 d ($P < .01$) and did not change significantly thereafter. There were no differences between diets at any of the slaughter times. Correlation analysis revealed that none of the carcass traits could account for over 1% of the variation in shear force at d 14 and 24 postmortem ($P > .1$).

Figure 2 shows the relationship between tenderness measured as shear force at d 5 or 14 postmortem. Following the procedure described by Shackelford et al. (1997), at d 5 postmortem the steaks are classified as tender if shear force values are less than 6 kg, but they are classified as probably tender after 14 d of aging if they are from 6 to 9 kg shear force. When measured at 14 d postmortem, steaks with shear force of less than 6 kg are classified as tender; if greater than 6 kg shear force, they are classified as tough. Eighty percent of the carcasses were tender at both 5 and 14 d. All that were tender at d 5 continued to be tender at d 14. Of the remaining 20% that were in the "probably tender" category at d 5, 67% changed to tender at d 14. Shear force at d 5 accounted for 45% of the variation in shear force at d 14 postmortem ($P < .1$). The R² when steaks were aged to d 24 was only increased to 48% (data not shown).

Table 4 shows the results of the sensory panel evaluation. None of the five palatability traits was statistically different between diet groups. We obtained a coef-

Table 4. Sensory panel evaluation comparing longissimus muscle steaks from steers fed diets containing bread by-product (BBy) or corn (n = 60)

Palatability traits ^a	Diet		SEM	P-level
	Corn	BBy		
No. of chews	16	16	.49	.49
Tenderness	5.33	5.39	.15	.78
Juiciness	5.05	5.33	.16	.23
Flavor intensity	5.18	5.03	.13	.40
Overall desirability	5.24	5.18	.15	.78

^a1 = extremely tough, dry, bland, or undesirable and 8 = extremely tender, juicy, intense, or desirable for tenderness, juiciness, flavor intensity, and overall desirability.

ficient of correlation of .50 for tenderness evaluated by shear force at 24 d postmortem and tenderness evaluated by sensory panel evaluation ($P < .1$).

Proximate analysis of the longissimus muscle (ribeye) for BBy- and corn-fed steers showed no differences between the two diets for effects on percentage of water, protein, fat, and ash ($P > .1$). Our results showed that we reached our goal of 3 to 5% intramuscular fat in 86% of the steers.

Correlations were small (not significant) between lipid percentage in the longissimus and shear force at d 5, 14, and 21 or with tenderness sensory evaluations. Percentage of lipid in the longissimus muscle accounted for 35% of the variation in quality grade, and lipid increased as quality grade increased.

One concern related to our objectives was how the meat quality of our BBy-fed cattle compared to a larger and more diverse population of cattle more representative of the U.S. cattle population. We compared our results with the results of a large study at the U.S. Meat Animal Research Center in Nebraska (MARC) as cited by Dikeman (1996). We assume that MARC cattle are representative of the U.S. cattle population,

which is diverse in breed type (NRC, 1996). The data included 1,160 steers from Angus and Hereford cows bred to 11 sire breeds. This comparison shows that a higher percentage of our cattle reached acceptable tenderness (shear force value ≤ 4.6 kg) than those in the summary of the MARC data (76.7 vs 21.2%). The animals in that study were fed high-energy diets for more than 100 d, they were young and managed optimally, and their carcasses were electrically stimulated. The results show that 16% of the steaks would be considered unacceptable in tenderness vs 3% in our study. The likely explanation for these differences is that our animals had less genetic variation and did not include breeds known to be less tender.

Implications

Bread by-product, consisting of rejected bread, can be substituted for up to 75% of whole shelled corn in a growing-finishing beef feedlot diet without reducing meat quality or feedlot performance.

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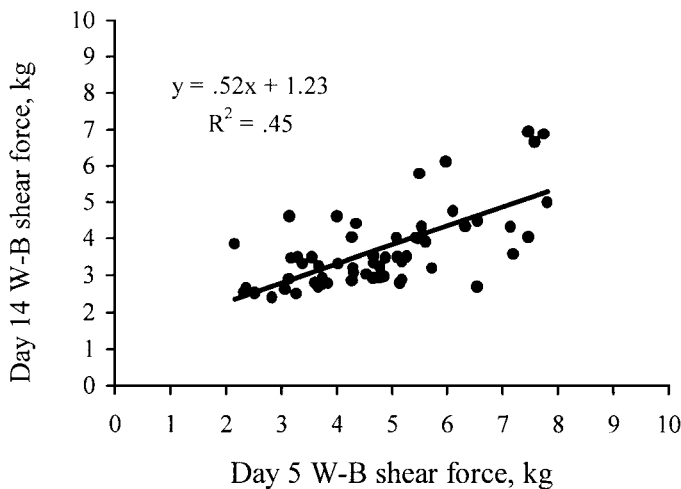


Figure 2. The relationship between tenderness measured as Warner-Bratzler (W-B) shear force at 5 vs 14 d postmortem (n = 60). The regression coefficients were different ($P < .01$) from zero.

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