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Ruminant Nutrition

Intake of corn stover botanical parts by growing and finishing beef steers

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ABSTRACT

Single-pass corn stover harvest is a method whereby combine harvester tailings consisting of cob, stalk, leaf, husk, and tassel fractions are collected and baled without coming into contact with soil. The objective was to feed beef steers diets that included a roughage component consisting of harvested corn residue in chopped form from conventional corn stover bales (**CST**) or single-pass bales (**SPB**) to assess intake selectivity of corn stover fractions and estimate net energy values of these corn stovers. Whole plant corn silage served as the control roughage in the control diet (**CSIL**). Steers (n = 90, 5 pens per treatment) were fed during Grow (84 d) and Finish (66 d) trials. Steers sorted through corn stover during both trials and consumed 52.5% of corn stover offered and 40% of cob offered. Intake of SPB cob was 2.6-fold and 3.3-fold greater than CST cob intake ($P < 0.01$) in Grow and Finish trials, respectively, indicating that when more cob was available, cattle consumed more. During the Grow trial, stover intake tended ($P = 0.07$) to be lower for SPB and diet dry matter intake (**DMI**) was less ($P \leq 0.05$) for SPB, which may be due to the elevated cob intake by SPB steers. Across treatments, stover DMI was similar in the Grow (1.10 kg per steer per d) and Finish (1.11 kg per steer per d) trials. The proportion (65%) of Fines (<8 mm) consumed from the Grow diet (40% neutral detergent fiber, **aNDF**) was greater than the Finish diet (25% aNDF; 18% to 31%) and gleaning of concentrate feeds from orts seemed to be more extensive in the Grow diet. Steers consuming Finish diets containing SPB and CST had DMI that were 17% and 18%, respectively, greater ($P \leq 0.05$) than CSIL, an indication of compensatory intake. The physical effectiveness factors for stovers fed in the Grow and Finish diets were 0.85 and 0.95, respectively. Estimates for net energy maintenance and net energy gain (**NEg**), respectively, using National Research Council methods from 2001 were as follows for consumed stovers: SPB (1.09 and 0.54 Mcal/kg) and CST (0.98 and 0.44 Mcal/kg) in the Grow trial, and SPB (0.96 and 0.42 Mcal/kg) and CST (0.95 and 0.40 Mcal/kg) in the Finish trial. Although SPB and CST differ in botanical fraction composition and net intakes of botanical fractions, their energetic contributions to steer performance were very similar. Steers fed the Finish diet (1.25 Mcal performance-adjusted NEg per kg) selected stover botanical components to achieve a diet composition of 25% aNDF.

Key words: cob, fiber, maize, net energy, physical effectiveness

INTRODUCTION

Corn stover is the plant biomass available after the harvest of grain from mature corn plants. It can be an important crop to support cattle operations in intensive corn-producing regions of the United States. During 2017 to 2021, an annual average of 35.7 million ha of corn were planted in the United States (USDA-FSA, 2022) producing 365 million tons of corn grain (USDA-NASS, 2022). Every year an equal weight of non-grain corn plant material (Shinners and Binversie, 2007) is left to decompose in fields, be grazed by livestock, be baled for livestock production, or be baled for bioenergy production. The traditional process to mechanically bale corn stover consists of corn residue shredding with a flail shredder, drying at ambient conditions, raking into a windrow, and collection into bale packages (Shinners and Binversie, 2007). Corn grain harvest and corn stover baling have been two separate field procedures. It was reasoned that the simultaneous harvest of corn grain and corn stover would increase the efficiency of field operations (Shinners et al., 2003). Keene et al. (2013) evaluated a large-round baler that could be towed by a combine harvester to accomplish corn grain and stover harvest in a single pass.

There are several feed quality advantages associated with corn stover collected into single-pass bales (**SPB**). Stover collection rates can be mechanically adjusted, that is, an ear-snapper corn head on a combine will collect less stalk than a whole-plant corn head (Keene et al., 2013). When considering corn stover as a cattle feed source, less stalk is advantageous because the stalk has lower digestibility when compared with other botanical parts of the corn plant (Petzel et al., 2019). Updike et al. (2015) concluded that harvested SPB improved forage quality when compared with conventional corn stover harvested bales fed to growing steers due to the reduction in harvested corn stalk. Also, the stover in SPB never touches the soil surface unlike conventional corn stover bales (**CST**). This eliminates soil contamination of the corn residue (Shinners et al., 2012).

Corn residue has long been harvested as an alternative feed for beef cattle (Klopfenstein et al., 1987; Shinners and Binversie, 2007). However, research characterizing the ruminant animal nutritional value of corn stover and its differing harvest methods is limited. Experiments have considered corn residue in cattle grazing (Stalker et al., 2015; Watson et al., 2015; Lehman et al., 2021), beef cattle finishing diets (Gentry et al., 2016), and bio-energy production systems (Johnson et al., 2010).

Differential selection and consumption of corn plant parts by cattle have been appreciated (Klopfenstein et al., 1987)

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and quantitation of cattle preferences has focused on the selection that occurs during grazing (Petzel et al., 2018). In the grazing circumstance following corn grain harvest, weaned beef calves initially gleaned corn residue fields for residual grain and husks (Fernandez-Rivera and Klopfenstein, 1989a) and leaf plus husk fractions accounted for the majority of residue that disappeared, followed in rank by cob, and then stalk (Fernandez-Rivera and Klopfenstein, 1989b). Dairy (Methu et al., 2001) and beef cows exhibited similar preferences, preferring to avoid cob and stalk (Stalker et al., 2015). The bottom two-thirds of the stalk had the lowest in vitro dry matter (**DM**) digestibility of all botanical fractions (Watson et al., 2015). When fed to growing feedlot steers, SPB husklage was found to be refused at 5% to 8% of daily feed offering and refusals were visually assessed to consist of primarily cob (Updike et al., 2015).

Harvested corn stover is heterogeneous in botanical components nutritional composition, and particle size. It is challenging to blend uniformly into total mixed rations. Grinding of stover is the common approach used to improve its blendability into diets fed to feedlot cattle (Gentry et al., 2016; Jennings et al., 2020). Despite the material handling challenges of corn stover, its physical and nutritional heterogeneity may offer an opportunity for its inclusion as a roughage source in high-concentrate diets fed to feedlot cattle (Galyean and Defoor, 2003). Furthermore, we recognized the presumed differences in botanical fraction and fiber composition between CST and SPB to be an opportunity to characterize these two types of stover as potential roughage sources in feedlot cattle diets.

The objectives of these trials were to feed harvested corn residue in the form of CST or SPB as a proportion of diet forage to beef steers. Steers were fed during their growing and finishing phases for the purpose of assessing the consumption of corn plant botanical fractions and calculating net energy values for the stovers. The estimation of net energy values for corn stover is very challenging because cattle do not uniformly consume all fractions of the stover offered to them. Further, it was hypothesized that the relative absence of the corn stalk trunk in SPB would result in better cattle growth rates for SPB compared with CST. Since both SPB and CST contain botanical fractions that cattle avoid, whole-plant corn silage (**WPCS**) was chosen as the positive control treatment. WPCS was chosen since it comprises all corn botanical fractions of interest, though with less physiological maturity than stover, and is readily consumed by growing and finishing cattle without avoidance of any botanical fractions. A diet (CSIL) containing WPCS allows for the determination of the dry matter intake (**DMI**) potential of feedlot cattle. Lastly, it was hypothesized that the contextual high and low fiber compositions of growing and finishing diets, respectively, would influence the selection of corn botanical fractions by feedlot steers.

MATERIALS AND METHODS

All procedures involving cattle were approved by the University of Wisconsin, Madison, College of Agricultural and Life Sciences Animal Care and Use Committee (protocol A005870).

Corn Silage and Stover Harvest

Corn plant variability among WPCS and harvested corn stovers was controlled by sourcing all roughages within a 3 km radius from the University of Wisconsin-Madison Arlington Agricultural Research Station (AARS) located near Arlington, WI (43°20′N latitude, 89°22′W longitude, 320 m elevation). Whole corn plants were chopped (Claas Jaguar 940, Claas KGaA mbH, Harsewinkel, Germany) at a target residual stalk height of 25.4 cm from the soil surface. The chopper was calibrated to a 1.905 cm length of cut with a 2.5 mm kernel processor setting. Multiple commercial corn varieties were harvested for silage, from numerous fields for the purpose of filling concrete stave silos (4.9 × 16.8 m) at the research farm. Corn chopping occurred during September 28 to October 4, 2017 and corn silage feeding to these research cattle occurred during January 9 through July 10, 2018. The targeted physiological maturity and DM content of the WPCS were 25% milk line and 40% DM, respectively (UWE, 1994). There was no addition of silage inoculant.

Two methods were used for corn stover harvest. All CST bales were made by multiple field operations including corn residue shredding, raking, and round baling. Stover was packaged with round balers and net wrapped. Several fields were used for CST harvest to achieve similar stover moisture content at the time of baling. Bales were purchased from a local farmer in 2017 due to wet harvest conditions at the time of AARS stover baling. SPB were produced by researchers from the University of Wisconsin-Madison Biological Systems Engineering Department using harvest methods as described in Keene et al. (2013). The combine harvester was equipped with a 12-row ear-snapper header equipped with knives on six rows that increased the inclusion of the upper portion of the stalk (Walters et al., 2020). CST bales and SPB were stored on a concrete floor inside a pole barn.

Experimental Designs

The Grow trial was designed as a randomized complete block design. There were three dietary treatments (Table 1) in which 20% of the DM formula was provided from one of three corn plant fiber sources. In the control CSIL diet, fiber was provided as WPCS. Additional dietary treatments were corn plant fiber provided as CST or SPB. There were 5 replications per treatment and pen was the experimental unit. For the Grow trial, there were 15 pens with 6 steers per pen and the trial duration was 84 d. A preliminary experiment was conducted to determine the dietary inclusion rate of stover which enabled diet mixing and accurate quantitation of stover orts. To attain this objective, the maximum stover inclusion was determined to be 20% of the Grow diet DM formulas (Table 1).

A Finish trial was conducted immediately after the Grow trial concluded and utilized the same animals and pens as in the Grow trial. The experimental design for the Finish trial was the same as that used in the Grow trial, except that the DM formulas of the three dietary treatments (Table 1) consisted of 15% of corn roughage from each of the three corn plant fiber sources. Assignments of pens and animals to treatment were the same for the Finish trial as the Grow trial.

Animals

In 2017, 90 black British × Continental steers were selected from a preceding grazing research trial at the AARS. Steers were vaccinated at the beginning of the prior research trial with Bovi-Sheld Gold 5 (Zoetis Inc., Kalamazoo, MI) and Vision-7 (Intervet Schering-Plough, Somerville, NJ), and were also confirmed to not be persistently infected with bovine viral diarrhea virus, palpated to confirm castration, and dewormed.

Table 1. Diet dry matter formulas for Grow and Finish trials

	Grow			Finish		
Ingredient, % of DM	**CSIL**[1]	**CST**[2]	**SPB**[3]	**CSIL**	**CST**	**SPB**
Corn silage	72	52	52	20	5	5
Conventional stover	-	20	-	-	15	-
Single-pass bale	-	-	20	-	-	15
Corn, high-moisture	-	-	-	46.5	46.5	46.5
Dry distillers' grain	25.4	25.4	25.4	30.7	30.7	30.7
Urea	-	-	-	0.5	0.5	0.5
Calcium sulfate	0.264	0.264	0.264	-	-	-
Limestone	1.36	1.36	1.36	1.59	1.59	1.59
KCl	0.430	0.430	0.430	-	-	-
Vitamin A[4]	0.035	0.035	0.035	0.035	0.035	0.035
Vitamin D[5]	0.013	0.013	0.013	0.013	0.013	0.013
Vitamin E[6]	0.143	0.143	0.143	0.095	0.095	0.095
Rumensin[7]	-	-	-	0.25	0.25	0.25
Tylan[8]	-	-	-	0.038	0.038	0.038
Salt, iodized	0.20	0.20	0.20	0.20	0.20	0.20
Trace minerals[9]	0.05	0.05	0.05	0.05	0.05	0.05
Corn, cracked	0.109	0.109	0.109	-	-	-

[1] Corn silage treatment.
[2] Conventional corn stover treatment.
[3] Single-pass bale corn stover treatment.
[4] Vitamin A premix (6,600,000 IU per kg as-is) was added to achieve 2,420 IU per kg diet DM.
[5] Vitamin D premix (2,200,000 IU per kg as-is) was added to achieve 308 IU per kg diet DM.
[6] Vitamin E premix (44,000 IU per kg as-is) was added to achieve 44 IU per kg diet DM.
[7] 26.0 g monensin/909 kg DM; Rumensin, Elanco Animal Health, Greenfield, IN.
[8] 8.0 g tylosin/909 kg DM; Tylan, Elanco Animal Health, Greenfield, IN.
[9] Trace mineral premix contained (mg/kg) of the following: Ca, 230,000; Fe, 10,000; Mn, 40,000; Zn, 60,000; Co, 200; Cu, 6,000; Iodine, 1,000; Se, 200.

Steers were dewormed after the grazing trial was completed with Dectomax and Cydectin (Zoetis Inc., Kalamazoo, MI). All pens were under a roof in a pole barn and bedded with sawdust to discourage bedding consumption. All cattle were adapted to a WPCS-based, totally mixed diet. On day 0, steers were weighed individually prior to feeding and stratified by day 0 weights into initial weight blocks. Steers were randomly allocated by stratum within the block to 6 steers per pen (42.9 m^2) for 15 pens. Diet treatments were randomly assigned within the block and commenced on day 1. Two consecutive pre-feeding morning weights were taken for each steer for average initial (days 0 and 1) and final unshrunk weights. All steers received a Revalor-S (Merck Animal Health, Merck & Co., Inc.) implant on day 0 of the Finish trial. The trial concluded for weight blocks of steers when most steers were visually evaluated to possess 1.3 cm of backfat at the 12th rib. Steers were hauled 290 km to Tyson Fresh Meats, Joslin, IL and then they were harvested. Ribeye camera data for carcasses were collected after 48 h of chilling. The Finish trial durations were 47, 69, and 83 d for heaviest to lightest blocks (5 blocks total).

Feed Management

Conventional CST and SPB were processed through a bale chopper (Teagle 8080, Teagle Machinery Ltd, Three Burrows, Truro, UK) prior to feeding to cattle. The cutting knives on the bale chopper were set to the maximum extent to ensure stover particle reduction. One or two bales per treatment were chopped at a time into respective piles. The chopped bale piles were stored inside a pole barn on the concrete floor and used for feeding until the stored inventory was fed. Once the chopped bale pile was fed, one or two more bales were chopped. Cattle in the study were fed once a day by fence line bunks at 0800 hours. Diets (Table 1) were mixed and fed using a feed mixing cart (Rissler 1050, I H Rissler Manufacturing, Mohnton, PA). The CSIL diet was a homogeneous mixture when fed. The CST and SPB diets were likewise mixed, but these diets were not homogeneous due to particle size differences (WPCS vs. chopped stover). To avoid a systematic error, the sequence of pen feeding for all diets was adjusted daily such that the first pen fed on day 1 was the last pen fed on day 2, then again the first pen fed on day 3, and so on.

Feed DMI of CST and SPB pens were managed to match the daily DMI by CSIL pens within a block of pens. The daily pen allotment of CSIL diet was managed so that a negligible ration remained after 24 h. Daily adjustments in the amount of CST and SPB diets offered were based on knowing the stover DM weight offered the previous day and ort DM weight so that pen DMI could be estimated relative to pen DMI for the corresponding CSIL block. Substantial orts occurred for CST and SPB treatments. Refusals were weighed and removed from the bunk before each daily feeding.

There was a 28-d transition period between the Grow and Finish trials during which diets were adjusted every 5 or 6 d to simultaneously increase high moisture corn inclusion and reduce corn roughage inclusion. The Finish trial began when the final diet adjustment was made and cattle were weighed on days 0 and 1. The corn grain component of the Finish diet

Table 2. Nutritional composition of major ingredients[1] used in Grow and Finish trial diets[2]

	Grow			Finish			
Item	Corn silage	DDG[3]	Supplement	Corn silage	DDG	Supplement	Corn, high moisture
Dry matter, %	43.6	91.3	93.2	41.2	92.1	92.2	77.3
Component	%, DM basis						
CP[4]	8.5	29.3	20.8	7.2	28.0	38.3	7.8
ADICP[5]	0.5	4.2	1.5	0.6	4.5	1.4	0.1
Available CP	8.0	25.0	19.3	6.5	23.5	36.9	7.7
ADICP, % of CP	6.1	14.4	7.1	8.6	15.9	3.9	1.7
aNDF[6]	35.4	33.7	24.7	40.4	33.6	26.1	6.7
ADF[7]	20.5	12.0	9.9	23.6	12.6	11.0	3.4
Lignin	3.8	4.0	6.9	1.6	4.3	3.5	ND[8]
Ether extract	3.1	8.5	6.1	2.3	7.7	4.6	3.4
Starch	38.3	4.1	9.6	36.1	2.9	2.1	72.7
NFC[9]	49.6	27.1	27.8	46.3	29.1	5.9	80.8
Calcium	0.18	0.09	5.79	0.19	0.07	10.2	0.02
Phosphorus	0.25	1.04	0.74	0.24	1.05	0.68	0.25
Magnesium	0.15	0.36	0.35	0.15	0.36	0.43	0.08
Potassium	0.80	1.38	1.06	0.75	1.47	1.18	0.31
Sulfur	0.08	0.46	0.45	0.06	0.45	0.49	0.07
Ash	4.31	6.39	24.4	4.70	6.78	31.2	1.61
Net energy (NE)	Mcal/kg DM						
NE maintenance	1.71	1.92	1.20	1.86	1.86	0.97	2.48
NE gain	1.09	1.28	0.64	1.22	1.22	0.42	1.75

[1] Ingredients were sampled weekly and four consecutive samples were composited. The mean of three composite samples is shown here.
[2] Rock River Laboratory of Watertown, WI conducted the nutritional analyses.
[3] Distillers dried grains.
[4] Crude protein.
[5] Acid detergent-insoluble crude protein.
[6] Neutral detergent fiber with addition of sulfite and heat-stable amylase.
[7] Acid detergent fiber.
[8] Not detectable.
[9] Non-fiber carbohydrate.

(Table 1) was harvested at 23% moisture and blown into a sealed storage silo by means of an impeller blower. Doing so resulted in the fracturing of most whole kernels and anaerobic fermentation followed.

Sampling

Weekly samples were taken for diet ingredients (Table 2), mixed CSIL diet, chopped stover bales, and refusals. Ingredient and CSIL diet samples were collected at the time of feeding and frozen (−14 °C) for future analysis. One bale per treatment was chopped per week on average. A new bale was chopped when the previously chopped bale had been fed. Chopped bale samples were collected during bale chopping using a 38 L bucket to collect chopped material from the bale chopper chute at three time points during the chopping of a bale. The bucket was then quickly inverted and dumped onto a clean mat. Approximately 25% (0.5 kg) of the original collected sample was kept for future analysis. Pen refusal was sampled once a week. The sample was acquired by shoveling the refusal to one side of the bunk, mixing the refusal until uniformly distributed, and collecting a 0.5 kg grab sample. Chopped bale samples and pen refusal samples were immediately analyzed for DM content by forced air oven at 55 °C for 48 h. Dried samples were stored for future nutritional analyses and hand separation of botanical fractions. Four consecutive weekly samples of each type of sample were composited and these samples were sent to a commercial laboratory (Rock River Laboratory, Watertown, WI) for nutrient analyses using wet chemistry methods.

Stover and Refusal Fraction Separation

Chopped bale samples and pen refusal samples were hand separated into the following four botanical fractions: cob, stalk, leaf and husk (**LH**), and Fines. A Penn State Particle Separator (PSPS, The Pennsylvania State University, PA) was used to separate the Fines from the rest of the sample. Fines were any portion of stover or ingredient that passed through an 8 mm sieve. The 8 mm sieve was chosen because the 4 mm sieve retained a substantial mass of undistinguishable particles that were not amenable to hand separation. The residue remaining above the 8 mm sieve was then hand-sorted into botanical fractions. The cob fraction was any particle resembling a corn cob. The stalk was classified as any portion of the stem including brace root, rind, pith, and node. The LH fraction remained after the separation of the cob and stalk fractions and was characterized as the leaf, husk, tassel, and any undistinguishable particles. Each fraction was weighed and its proportion was calculated to be the quotient of its weight and total dry (55 °C) stover sample weight.

Net Energy Calculations

Performance adjusted net energy of maintenance and gain (**paNEm** and **paNEg**; Owens and Hicks, 2019) were calculated using equations listed in Supplementary Table S1. Briefly, empty body fat (**EBF**) and empty body weight were calculated as described in Guiroy et al. (2001). Adjusted final shrunk body weight was based on 28% EBF. Equivalent shrunk body weight, based on the standard reference weight of 478 kg, was used to calculate NEg required. NEm and NEg required were then used in the quadratic formula approach as described by Zinn et al. (2003) to calculate paNEm and paNEg.

Analytical Methods

Ingredient analyses were conducted by Rock River Laboratory (Watertown, WI). All samples were dried and ground to pass a 1 mm screen (Udy Cyclone, Udy Corporation, Fort Collins, CO). The neutral detergent fiber was determined using method 6 (Ankom Technologies, 2017a), which includes the addition of sulfite and heat-stable amylase but not an ashing step. Acid detergent fiber (**ADF**) was determined using method 5 (Ankom Technologies, 2017b). Acid detergent lignin was determined in ADF residue samples after sulfuric acid digestion (method 9, Ankom Technologies, 2020). The methods for crude protein (**CP**; AOAC 990.03), ether extract (AOCS Am5-04; rapid determination of oil/fat utilizing high-temperature solvent extraction; AOCS, 2017), starch (Hall, 2009), ash (AOAC 942.05), and minerals (Modified AOAC 968.08) are reported at https://docs.google.com/spreadsheets/d/1Mmf7v-wT5GDbho1kbO2PzEPUxut0IzgtRO6XU-Ed-JE/edit?usp=sharing. Acid detergent-insoluble CP (**ADICP**) was determined by doing a Dumas combustion (AOAC 990.03; AOAC, 2003) of ADF residues, followed by nitrogen determination, and then multiplying nitrogen times 6.25. Available CP is CP less acid detergent-insoluble CP. Nonfiber carbohydrate was calculated using the method of Lanzas et al. (2007). The results were used with NRC (2001) equations to estimate NEm and NEg. Diet NEm and NEg values estimated on the basis of cattle performance or ingredient composition were compared.

Statistical Methods

Animal performance and nutritional characteristics of feed refusal data were analyzed using the MIXED procedure of SAS (SAS 9.4, SAS Inst. Inc., Cary, NC) with treatment as the fixed effect, weight block as a random effect, and pen as the experimental unit. The model for nutritional characteristics of feed included diet treatment and botanical fraction as fixed effects, sampling month was a random effect, and pen as the experimental unit. When the *F*-statistic was significant ($P \leq 0.05$), the LSMEANS statement with the PDIFF option was used to separate treatment means ($P \leq 0.05$). Tendencies were reported for *P*-values ($0.10 \geq P > 0.05$).

RESULTS AND DISCUSSION

Grow Trial

Table 3. Nutritional composition[1] of corn silage diets fed in Grow and Finish trials

Nutrient, % DM basis	Grow[2]	Finish[2]
CP[3]	14.3	16.2
ADICP	0.57	1.24
Available CP	13.7	14.9
aNDF	32.5	21.1
ADF	16.9	9.84
Lignin	4.71	1.65
Ether Extract	4.75	4.76
Starch	31.0	38.8
NFC	43.3	53.8
Calcium	0.65	0.75
Phosphorus	0.47	0.52
Magnesium	0.21	0.21
Potassium	0.95	0.89
Sulfur	0.20	0.23
Ash	6.34	6.01
Net energy (NE)	Mcal/kg DM	
NE maintenance	1.71	2.07
NE gain	1.09	1.40

[1] Rock River Laboratory of Watertown, WI conducted the nutritional analyses.

[2] Diet was sampled weekly and four consecutive samples were composited. The mean of 3 composite samples is shown here.

[3] See Table 2 footnotes for definition of this and subsequent abbreviations.

The control CSIL diet composition for the Grow trial is presented in Table 3. Diets were formulated to meet the nutrient recommendations (NASEM, 2016) for 400 kg beef steers consuming a diet with 1.70 Mcal NEm per kg and 1.10 Mcal NEg per kg DM. The CP, available CP, and mineral concentrations shown exceeded NASEM (2016) recommendations. Therefore, the availability of dietary net energy was presumed to be the growth-limiting factor.

The ration offered to CST and SPB pens in the Grow trial was intended to ensure daily DMI equal to CSIL pens. This objective was achieved for the CST treatment but not for the SPB treatment ($P = 0.05$; Table 4). The DMI for the SPB diet was 96% of CSIL. This strategy was employed to create a situation in which CST and SPB steers had similar daily satiety compared with the CSIL steers, and then to determine stover fraction selection preferences in that context. Daily diet sorting was consistent by CST and SPB pens resulting in only small adjustments in DMI offered after the first 5 d of feeding the stover diets (data not shown).

Nutrient intakes (Table 4) were based upon net consumption of the respective diet, after accounting for orts. Daily consumption of available CP, lignin, ether extract, starch, NFC, calcium, phosphorus, magnesium, potassium, and sulfur was greatest for cattle fed the CSIL diet. Net intakes of ADICP, amylase-included neutral detergent fiber (**aNDF**), ADF, and ash were greatest for steers fed the CST diet ($P \leq 0.0001$). Although DMI by SPB pens was less than CST pens, consumption of available CP, lignin, ether extract, starch, and NFC were not different between CST and SPB ($P > 0.05$). The quotient of aNDF intake and DMI intake indicates that the consumed CSIL, CST, and SPB diets contained 32.4%, 40.9%, and 40.2% aNDF, respectively. Similarly, the NFC concentrations in the consumed diets were 43.3%, 36.8%, and 37.3% NFC for CSIL, CST, and SPB diets, respectively.

The distributions of stover dry weight among corn plant botanical fractions for CST stover and SPB stover prior to feeding are shown in Table 5. Stover DM percentages for CST and SPB were 84.8 and 85.1, respectively (SEM = 0.6;

Table 4. Grow trial nutrient intakes

Item	Corn silage	Conventional corn stover	Single-pass bale	SEM	*P*-value
Diet DMI[1], kg per steer per d	9.97^{a}	9.82^{a}	9.63^{b}	0.08	0.009
Component, DM[2] basis, kg per steer per d					
CP[3]	1.42^{a}	1.32^{b}	1.31^{b}	0.01	<0.001
ADICP	0.06^{c}	0.14^{a}	0.13^{b}	0.001	<0.001
Available CP	1.36^{a}	1.18^{b}	1.19^{b}	0.01	<0.001
aNDF	3.23^{c}	4.02^{a}	3.87^{b}	0.06	<0.001
Corn silage	2.48	1.76	1.73	-	-
Stover	-	1.09	0.95	-	-
ADF	1.69^{c}	2.22^{a}	2.07^{b}	0.03	<0.001
Lignin	0.47^{a}	0.42^{b}	0.41^{b}	0.01	0.001
Ether extract	0.47^{a}	0.41^{b}	0.40^{b}	0.002	<0.001
Starch	3.09^{a}	2.26^{b}	2.29^{b}	0.03	<0.001
NFC	4.31^{a}	3.62^{b}	3.59^{b}	0.03	<0.001
Calcium	0.065^{a}	0.064^{b}	0.062^{c}	0.0003	<0.001
Phosphorus	0.047^{a}	0.042^{c}	0.043^{b}	0.0003	<0.001
Magnesium	0.021^{a}	0.019^{b}	0.019^{b}	0.0002	<0.001
Potassium	0.095^{a}	0.093^{a}	0.091^{b}	0.0009	<0.001
Sulfur	0.020^{a}	0.018^{b}	0.018^{b}	0.0001	<0.001
Ash	0.63^{b}	0.67^{a}	0.63^{b}	0.005	0.001

[1] Dry matter intake.
[2] Dry matter.
[3] See Table 2 footnotes for definition of this and subsequent abbreviations.
[a,b,c] Means in a row without common superscripts differ at $P \le 0.05$.

Table 5. Fractional dry weight distribution of stover botanical components for stovers fed in the Grow trial

	Conventional stover		Single-pass bale		Net intake	
Fraction	Pre-feeding[1]	Net Intake[2]	Pre-feeding	Net Intake	SEM	*P*-value
Cob	0.16	0.12^{b}	0.45	0.37^{a}	0.02	<0.001
Stalk	0.24	0.26^{a}	0.11	0.09^{b}	0.02	0.001
LH[3]	0.44	0.45	0.32	0.38	0.025	0.055
Fines	0.15	0.17	0.12	0.17	0.02	0.79

[1] Pre-feeding values were determined by hand separation of fractions from chopped bale samples. Treatment values shown are averaged from all bales used during trial period (n = 14 for CST and n = 15 for SPB). It was not possible to conduct a statistical comparison of botanical fraction composition between stover offered and fraction net intake because the same stover, bale after bale, was offered to pens within treatment, whereas stover refusal samples were collected by pen over time.
[2] Within botanical fraction, the total stover weight fed was multiplied by the respective fractional weight of the pre-fed stover to determine weight of botanical component fed (F). The total stover orts weight of a pen was multiplied by the respective fractional component weight of the stover refused by the respective pen to determine the weight of botanical fraction refused (R). A net intake (NI) weight for each botanical component for each pen was determined as follows: NI = F – R. For each botanical component, its NI weight was expressed as a fraction of total stover NI by the pen and these values are presented in this table.
[3] Fraction consisting of leaf and husk.
[a,b] Within botanical fraction, means with different superscripts are different $P \le 0.05$.

P = 0.62). Pre-feeding corn plant fractions could not be statistically analyzed due to the method for sequentially feeding stover bales to all pens within a stover treatment. The cob fraction was clearly amplified in SPB stover resulting in dilution of the LH fraction. The stalk fraction was diminished in SPB stover compared with CST stover due to the method of stover harvest.

This botanical fraction composition of CST is consistent with the results of field collections (Shinners and Binversie, 2007; Stalker et al., 2015; Watson et al., 2015) with regard to the cob fraction (0.15), similar to Shinners and Binversie (2007) with regard to the stalk fraction (0.29), and similar to Watson et al. (2015) and Stalker et al. (2015) with regard to the LH fraction (0.45). Environmental as well as corn varietal factors could influence the leaf:stalk ratio. Fernandez-Rivera et al. (1989b) reported that irrigated corn as compared with dryland corn had a lower leaf plus husk to stalk ratio.

All ingredients in the CSIL diet were consumed, with no recurring orts, while orts for the CST and SPB diets were voluminous and composed of the four stover fractions. Daily steer net stover and stover fraction DMI for the Grow trial are shown in Table 6. Total stover intake is the sum of intakes of the four fractions. Total stover intake tended

Table 6. Stover botanical fraction intakes during the Grow trial

Item, kg DM[1] per steer per d	Conventional stover	Single-pass bale	SEM	*P*-value
Total intake	1.19	1.00	0.08	0.07
Cob offered	0.35^b	0.98^a	0.01	<0.001
Cob refused	0.21^b	0.61^a	0.02	<0.001
Cob intake	0.14^b	0.37^a	0.03	0.001
Stalk offered	0.53^a	0.23^b	0.01	<0.001
Stalk refused	0.22^a	0.15^b	0.01	<0.001
Stalk intake	0.30^a	0.09^b	0.01	<0.001
LH[2] offered	0.96^a	0.69^b	0.01	<0.001
LH refused	0.42	0.31	0.06	0.13
LH intake	0.54	0.38	0.06	0.05
Fines offered	0.32^a	0.26^b	0.001	<0.001
Fines refused	0.12	0.10	0.03	0.56
Fines intake	0.21	0.17	0.03	0.22
Intake/offered				
Total	0.55	0.46	0.04	0.06
Cob	0.40	0.38	0.04	0.65
Stalk	0.58^a	0.37^b	0.02	0.001
LH	0.56	0.55	0.06	0.87
Fines	0.65	0.64	0.09	0.91

[1] Dry matter.
[2] Fraction consisting of leaf and husk.
[a,b] Means in a row without common superscripts differ at $P \le 0.05$.

to be greater for CST than SPB ($P = 0.07$). Consistent with fractional differences in bale composition (Table 5), SPB had more cob net intake ($P = 0.001$), less stalk net intake ($P < 0.0001$) and less LH intake ($P < 0.06$). Consumption of cob was 138 vs. 369 g DM per head daily for CST and SPB steers, respectively. We speculate that this 2.6-fold greater cob intake suppressed DMI of the SPB diet and that this effect was not due to the nutrient or fiber intake characteristics of the SPB diet, but instead due to a biophysical effect of the ingested cobs.

The proportion of total stover offered that was consumed tended to also be greater for CST than SPB ($P = 0.06$; Table 6). Since at least 35% of each stover fraction offered was ort, fractional consumption is an indication of stover botanical fraction selection preference by steers. If consumption of non-stover ingredients would have been restricted for CST and SPB diets, it is reasonable to expect that stover consumption would have been greater. Pens of CST cattle consumed 40% of the cob fraction, similar to SPB pens ($P = 0.65$), but consumed a larger proportion (58%) of the stalk fraction than SPB pens. Both CST and SPB cattle consumed 56% and 64% of LH and Fines offered, respectively ($P > 0.85$).

It is remarkable that 40% of the cobs offered were consumed whereas cattle grazing corn residue prefer to avoid the cob fraction (Watson et al., 2015). Further, while the LH fraction would have been more digestible than the cob and stalk fractions (Watson et al., 2015; Petzel et al., 2019), SPB cattle consumed 380 vs. 540 g LH DM per steer per d by CST cattle ($P = 0.05$).

To assess the extent of stover fraction selection by the steers, the net intake of each botanical component was expressed as a fraction of total stover intake and compared with the fractional weight distribution that existed in the stover pre-feeding (Table 5). Cattle consumed a larger proportion of stover as cob ($P < 0.05$) and less as stalk ($P < 0.05$) when stover was offered as SPB rather than CST. These differences are consistent with the fractional distribution of botanical components offered. Likewise, LH tended to be a greater proportion of stover intake for CST than SPB ($P < 0.06$), which is also consistent with the prevalence of LH in CST.

Recent cattle grazing research found that the masses of cob and stem remaining in corn fields were similar before and after cattle grazing, but leaf and husk were significantly reduced (Stalker et al., 2015). Cattle grazing corn residue avoid consumption of corn cobs and prefer to consume leaf and husk fractions. We hypothesized that the fraction of stover consumed as cob would be less than the fraction of cob present in pre-fed stover, and vice versa for the LH fraction. The results generally supported this hypothesis. In the Grow trial (Table 5), the cob fraction was 12% and 37% of CST and SPB stovers consumed, respectively, and less than cob proportions in CST (16%) and SPB (45%) prior to feeding. The LH fraction was 45% and 38% of CST and SPB stovers consumed, respectively, compared with LH proportions in CST (44%) and SPB (32%) prior to feeding. Yet while these indications of preference were evident, a more overarching summary is that these confined steers consumed stover fractions in proportions that were similar to those offered to them within the respective stovers.

This summary contrasts with the much more extensive consumption of husk by cows at high stocking density grazing corn residue. Stalker et al. (2015) reported that when cows were grazing corn residue at 2.5 animal unit month (**AUM**) per ha, the mass of leaf and husk fractions was reduced by 42% and 57%, respectively. When grazing

Table 7. Nutritional composition by fraction of stover offered[1] in the Grow trial

	Conventional stover				Single-pass bale				SEM				*P*-value			
Item, % DM basis	**Cob**	**Stalk**	**LH[2]**	**Fines**	**Cob**	**Stalk**	**LH**	**Fines**	**Cob**	**Stalk**	**LH**	**Fines**	**Cob**	**Stalk**	**LH**	**Fines**
CP[3]	1.8^{b}	3.8	3.6	5.6^{b}	3.4^{a}	5.4	4.5	6.8^{a}	0.27	0.50	0.20	0.13	0.03	0.09	0.051	0.01
Available CP	1.2^{b}	3.0	3.0^{b}	4.5^{b}	2.8^{a}	4.6	4.1^{a}	6.2^{a}	0.34	0.52	0.19	0.29	0.047	0.09	0.03	0.04
aNDF	87.8	79.4	79.9	75.5	86.2	81.5	81.9	75.5	0.6	1.1	1.9	1.2	0.12	0.20	0.40	0.96
ADF	47.9	54.6	49.5	48.2	45.9	52.3	50.3	44.4	0.6	0.6	0.5	2.0	0.08	0.06	0.26	0.20
Lignin	4.5	5.8	6.0	7.2	4.9	7.5	5.3	7.4	0.29	0.91	0.21	0.24	0.38	0.20	0.07	0.66
Starch	0.6^{b}	0.8	1.1	1.3^{b}	1.5^{a}	0.6	0.5	3.9^{a}	0.18	0.21	0.52	0.39	0.04	0.42	0.35	0.02
NFC	10.1	12.0^{a}	11.3	11.5	9.2	7.4^{b}	10.2	12.9	0.6	1.0	1.4	2.5	0.24	0.04	0.53	0.60

[1] Values are based on hand fractionation of composite chopped stover bale samples collected during the Grow trial. Samples were composited over 4 wk and analyzed. Results are based on three composite samples.
[2] Fraction consisting of leaf and husk.
[3] See Table 2 footnotes for definition of this and subsequent abbreviations.
[a,b] Within fraction, means in a rows without common superscripts differ at $P \leq 0.05$.

Table 8. Nutritional composition by fraction of stover refused[1] in the Grow trial

	Conventional stover				Single-pass bale				SEM				*P*-value			
Item, % DM basis	**Cob**	**Stalk**	**LH[2]**	**Fines**	**Cob**	**Stalk**	**LH**	**Fines**	**Cob**	**Stalk**	**LH**	**Fines**	**Cob**	**Stalk**	**LH**	**Fines**
CP[3]	2.4^{b}	4.4^{b}	6.3	10.2	2.9^{a}	6.2^{a}	6.8	10.9	0.15	0.18	0.32	0.34	0.02	<0.01	0.17	0.11
Available CP	1.4^{b}	2.9^{b}	4.9	9.2	1.8^{a}	4.7^{a}	5.5	9.8	0.14	0.23	0.33	0.33	0.02	<0.01	0.14	0.11
aNDF	81.6	74.8	60.9	38.9	82.4	77.3	61.1	41.9	0.6	1.5	1.2	2.5	0.25	0.19	0.92	0.31
ADF	42.6^{b}	46.8	34.2	20.1	44.2^{a}	45.2	34.2	21.6	0.3	0.9	1.0	1.4	<0.01	0.16	0.99	0.37
Lignin	7.5	9.3	5.9	4.0	6.1	9.1	5.6	4.4	0.8	1.1	0.8	0.6	0.14	0.86	0.72	0.51
Starch	2.0	3.1	8.2	27.2	1.8	3.2	8.5	25.6	0.18	0.19	0.82	1.72	0.35	0.85	0.72	0.40
NFC	15.8	17.1^{a}	27.4	41.5	14.9	12.6^{b}	27.7	39.3	0.4	1.4	0.8	2.2	0.08	0.03	0.71	0.38

[1] Values are based on refusal samples collected weekly per pen, hand-fractionated, then composited over 4 wk and analyzed. Results are based on three composite samples.
[2] Fraction consisting of leaf and husk.
[3] See Table 2 footnotes for definition of this and subsequent abbreviations.
[a,b] Within fraction, means in a rows without common superscripts differ at $P \leq 0.05$.

cows were stocked at 5.0 AUM per ha, leaf and husk were reduced by 47% and 82%, respectively. Earlier research also concluded that growing beef calves grazing corn residue fields primarily consumed leaf and husk (Fernandez-Rivera and Klopfenstein, 1989a; Gutierrez-Ornelas and Klopfenstein, 1991).

Tables 7 and 8 display the nutritional composition of Grow trial stover fractions at the time stover was offered and refused, respectively. The dominant analytical fraction in all stover botanical fractions was aNDF and all offered fractions contained at least 4.5% lignin and less than 4% starch. The lignin contents of the cob fractions of CST and SPB were 4.5% and 4.9%, respectively, and not different ($P = 0.38$). These lignin concentrations were lower than those reported by Pointner et al. (2014) for 10 varieties of Austrian corn (11.9%, DM basis). There was more available CP and starch in SPB cob and Fines when compared with CST ($P < 0.05$; Table 7). Stalk from CST had more NFC than SPB stalk ($P < 0.05$; Table 7). There were no differences between CST and SPB fractions with regard to aNDF and ADF, which is expected since the stover harvest method should have no bearing on the fiber content of corn plant stover.

Sorting by the cattle was hypothesized to have no effect on the nutritional composition of the fractions, therefore nutritional differences between CST and SPB should be similar in offered (Table 7) and refused fractions (Table 8). This hypothesis was supported by the aNDF results, especially for the cob and stalk fractions ($P \geq 0.12$; Tables 7 and 8). These two botanical fractions are most easily recognizable for hand-sorting and are not determined by difference as is the case for the LH fraction. Stalk NFC values for CST were similarly greater than SPB stalk in offered and ort samples ($P < 0.05$). Effects of stover treatment on CP content of cob and stalk fractions were similar between offered and ort samples. However, refused cob in Table 8 had higher ADF ($P = 0.007$) for SPB when compared with CST, whereas there was no difference between stovers as offered cob ($P > 0.07$; Table 7). In general, the hypothesis was supported. Sorting during stover consumption did not alter the fiber composition of the cob and stalk fractions.

We reasoned that the Fines fraction may reflect the nutritional composition of the distiller's dried grain (DDG) if the steers were not quantitatively selecting the DDG particles from the Fines fraction. Note that the CP content of Fines was slightly elevated for both CST (5.6% vs. 10.2% CP) and SPB (6.8% vs. 10.9% CP) stovers between offered (Table 7) and ort (Table 8) samples, respectively. The Fines fraction included any small particles (<8 mm) from DDG that escaped gleaning by the steers. Assuming that the increase in CP in ort Fines was due to DDG, this was equivalent to 1.9% and 1.2% of respective CST and SPB total ort DM. The same kind of scrutiny was applied to the increase in starch content of ort LH and Fines fractions. If the additional starch is assumed to be present from corn particles that escaped gleaning by the steers, this corn DM accounted for 8.5% and 5.3% of respective CST and SPB total ort DM. These calculations are consistent with the visual observation of orts which suggested that the steers gleaned diet ingredients more extensively from SPB than CST.

Cattle fed the CSIL diet had greater daily gains than cattle fed the SPB and CST diets ($P < 0.05$; Table 9). These results are consistent with greater consumption of ether extract and NFC and less consumption of aNDF and ADF by CSIL steers, despite greater consumption of lignin (Table 4). CSIL cattle were more efficient than CST cattle, but CST cattle were similar to SPB cattle in gain efficiency (Table 9).

Finish Trial

The control CSIL diet composition for the Finish trial is presented in Table 3. Diets were formulated to meet the nutrient recommendations (NASEM, 2016) for 530 kg beef steers consuming a diet with 2.10 Mcal NEm per kg and 1.45 Mcal NEg per kg DM. The CP, available CP, and mineral concentrations shown exceeded NASEM (2016) recommendations.

In the Finish trial, DMI was greater for treatments CST and SPB than CSIL ($P < 0.05$; Table 10). As in the Grow trial, the original intent was to match the DMI of CST and SPB diets with the CSIL diet, but the DMI of CST and SPB pens exceeded the DMI of CSIL. Consequently, the daily consideration in determining the amount of CST and SPB diet to offer was that the orts be gleaned of corn and DDG to a similar degree as observed in the Grow trial, by means of subjective visual assessment.

The distributions of stover dry weight among corn plant botanical fractions for CST stover and SPB stover prior to feeding are shown in Table 11. Stover DM percentages for CST and SPB were 91.7 and 82.9, respectively, and different (SEM = 1.3; $P = <0.01$). Similar to the Grow trial pre-feeding fractions (Table 5), the dominant fractions in CST were stalk and LH, while cob and LH were the major fractions in SPB.

Stover and stover fraction daily DMI by steers in the Finish trial are shown in Table 12. Again, all ingredients in the CSIL diet were consumed, with no consistent ort (data not shown). In contrast, approximately 45% of stover offered was refused daily by steers that received the CST and SPB treatments. Total stover intake between CST and SPB treatments was not different ($P = 0.97$). For the SPB treatment, more cob was offered, refused, and consumed ($P < 0.01$). Cob consumption was 122 vs. 398 g per head daily for CST and SPB

Table 9. Steer weights, growth rates, diet dry matter intakes, and gain efficiencies in Grow trial

	Corn silage	Conventional stover	Single-pass bale	SEM	*P*-value
Initial, kg per steer	$402^{a,b}$	398^{b}	404^{a}	1.9	0.03
Final, kg per steer	509^{a}	489^{b}	500^{a}	4.0	<0.01
DMI, kg per steer per d	9.97^{a}	9.82^{a}	9.63^{b}	0.08	<0.01
Gain, kg per steer per d	1.27^{a}	1.08^{b}	1.14^{b}	0.05	0.02
Gain/DMI	0.128^{a}	0.111^{b}	$0.119^{a,b}$	0.005	0.04

^{a,b}Means in a row without common superscripts differ at $P \leq 0.05$.

Table 10. Finish trial daily nutrient intakes

	Corn silage	Conventional corn stover	Single-pass bale	SEM	*P*-value
Diet DMI[1], kg per steer per d	10.8^{b}	12.7^{a}	12.6^{a}	0.3	<0.001
Component, DM basis, kg per steer per d					
CP	1.69^{b}	1.94^{a}	1.91^{a}	0.07	0.015
ADICP	0.129^{b}	0.188^{a}	0.189^{a}	0.006	<0.001
Available CP	1.56^{b}	1.75^{a}	1.72^{a}	0.06	0.04
aNDF	2.19^{b}	3.21^{a}	3.21^{a}	0.12	<0.001
Corn silage	0.75	0.22	0.22	-	-
Stover	-	1.05	1.09	-	-
ADF	1.03^{b}	1.65^{a}	1.58^{a}	0.06	<0.001
Lignin	0.172^{b}	0.292^{a}	0.29^{a}	0.01	<0.001
Ether extract	0.497	0.545	0.544	0.02	0.08
Starch	4.05^{b}	4.88^{a}	4.83^{a}	0.17	0.002
NFC	5.62^{b}	6.58^{a}	6.49^{a}	0.24	0.006
Calcium	0.078^{b}	0.117^{a}	0.119^{a}	0.004	<0.001
Phosphorus	0.054^{b}	0.060^{a}	0.060^{a}	0.002	0.04
Magnesium	0.022	0.024	0.024	0.0009	0.09
Potassium	0.09	0.103	0.098	0.004	0.11
Sulfur	0.024	0.026	0.026	0.0009	0.06
Ash	0.63^{b}	0.77^{a}	0.74^{a}	0.03	0.001

[1] See Table 4 footnotes for definition of this and subsequent abbreviations.
^{a,b}Means in a row without common superscripts differ at $P \leq 0.05$.

treatments. For the CST treatment, more stalk was offered, refused, and consumed ($P < 0.01$). Consumption of the LH and Fines fractions were not different between treatments ($P > 0.78$). Intake of each of the stover botanical fractions, as a proportion of the weight of fraction offered in the diet, was not affected ($P \geq 0.29$) by CST or SPB treatment. At least 29% (e.g., SPB LH) of each stover fraction remained in the ort. Again, this method of feeding the stovers allowed steers to express their preference for consuming the cob, stalk, and LH fractions.

Table 11 displays the fractional distribution of total stover intake for CST and SPB treatments. Steers fed SPB tended ($P = 0.06$) to eat more stover as cob, and ate less stover as stalk ($P < 0.01$). For both CST and SPB, the proportion of net stover intake as cob was less than the proportion of cob in stover prefeeding. Note that the SEM for these cob LSmeans was much larger in the Finish trial (SEM = 0.12) than in the Grow trial (SEM = 0.02; Table 5). For both CST and SPB, the proportion of net stover intake as LH was greater than the proportion of LH in stover pre-feeding. The LSmeans for LH fractional consumption is similar between the Grow (Table 5) and Finish trials, ranging from 0.38 to 0.45. In contrast, the fractional consumption of Fines was not affected by stover treatment within the trial ($P \geq 0.79$) but was less in the Finish (average = 0.055; Table 11) than in the Grow (average = 0.17; Table 5) trial.

Cattle feeders have appreciated for a long time that cattle prefer finishing diets having a relatively coarse texture. Steers in the Grow trial consumed 210 and 170 g Fines per steer per d for CST and SPB treatments, respectively, which were 65% and 64% of Fines offered; however, steers in the Finish trial consumed only 50 and 80 g Fines per steer per d for CST and SPB treatments, respectively, which were 18% and 31% of Fines offered. Dykier et al. (2020) found that beef steers with the most desirable residual feed intake consumed proportionately more of a finishing diet fraction that was retained on the 19 mm sieve than was consumed by steers with a less desirable residual feed intake. The relative abundance of ort Fines observed here when feedlot steers were fed a high-concentrate vs. a high-roughage diet is consistent with this long-held notion.

We hypothesized that SPB cob intake would be greater in the Finish trial than in the Grow trial because the Finish trial diet was lower in aNDF concentration (25.5% aNDF vs. 40.2% aNDF in Grow diet), and possibly due to increased ingestive chewing or rumination induced by corn cobs and ruminal benefits therefrom. While consumption of cob DM from SPB stover was 369 g/d in the Grow trial (Table 6) vs. 398 g/d in the Finish trial (Table 12), these intakes equated to only 3.8% and 3.2% of DMI for the respective trials.

The nutritional composition of Finish trial stover fractions offered and refused are displayed in Tables 13 and 14, respectively. The principal analytical fraction in all stover botanical fractions was aNDF and all offered fractions contained at least 5.8% lignin and less than 3.2% starch. The offered stalk fraction of SPB had more CP and more lignin ($P < 0.01$) than CST stalk (Table 13). The aNDF, ADF, and NFC compositions of CST and SPB stovers were not different ($P \geq 0.08$).

The aNDF and ADF concentrations of refused cob and stalk fractions were not different due to stover treatment ($P \geq 0.12$; Table 14) and were very similar to the respective values in the offered stovers (Table 13). Similar to the Grow trial, the refused Fines fraction was enriched in CP and both Fines and LH fractions were enriched in starch (Table 14) compared with the composition of these fractions when they were offered (Table 13). Assuming that the increase in CP in refused Fines was due to DDG, this was equivalent to 9.4% and 5.2% of respective CST and SPB total ort DM. The same kind of evaluation was applied to the increase in

Table 11. Fractional dry weight distribution of stover botanical components for stovers fed in the Finish trial

	Conventional stover		Single-pass bale		Net intake	
Fraction	Pre-feeding[1]	Net intake[2]	Pre-feeding	Net intake	SEM	*P*-value
Cob	0.17	0.11	0.43	0.36	0.12	0.06
Stalk	0.31	0.40[a]	0.09	0.12[b]	0.05	<0.01
LH[3]	0.38	0.45	0.34	0.44	0.02	0.85
Fines	0.14	0.04	0.13	0.07	0.14	0.89

[1] Pre-feeding values were determined by hand separation of fractions from chopped bale samples. Treatment values shown are averaged from all bales used during trial period ($n = 10$ for CST, and $n = 13$ for SPB).

[2] Within botanical fraction, the total stover weight fed was multiplied by the respective fractional weight of the pre-fed stover to determine weight of botanical component fed (F). The total stover orts weight of a pen was multiplied by the respective fractional component weight of the stover refused by the respective pen to determine the weight of botanical fraction refused (R). A net intake (NI) weight for each botanical component for each pen was determined as follows: NI = F – R. For each botanical component, its NI weight was expressed as a fraction of total stover NI by the pen and these values are presented in this table.

[3] Fraction consisting of leaf and husk.

[a,b] Within botanical fraction, means with different superscripts are different $P \le 0.05$.

Table 12. Stover botanical fraction intakes during the Finish trial

Item, kg DM[1] per steer per d	Conventional stover	Single-pass bale	SEM	*P*-value
Total intake	1.09	1.12	0.22	0.97
Cob offered	0.36[b]	0.88[a]	0.01	<0.001
Cob refused	0.23[b]	0.48[a]	0.05	0.009
Cob net intake	0.12[b]	0.40[a]	0.05	0.006
Stalk offered	0.64[a]	0.19[b]	0.01	<0.001
Stalk refused	0.20[a]	0.05[b]	0.02	0.004
Stalk intake	0.44[a]	0.13[b]	0.01	<0.001
LH[2] offered	0.78[a]	0.69[b]	0.02	<0.001
LH refused	0.30	0.20	0.08	0.45
LH intake	0.49	0.50	0.07	0.96
Fines offered	0.28[a]	0.27[b]	0.01	0.03
Fines refused	0.23	0.19	0.08	0.71
Fines intake	0.05	0.08	0.08	0.78
Intake/offered				
Total	0.54	0.55	0.11	0.93
Cob	0.35	0.45	0.08	0.29
Stalk	0.69	0.71	0.03	0.71
LH	0.63	0.71	0.10	0.60
Fines	0.18	0.31	0.28	0.75

[1] Dry matter.

[2] Fraction consisting of leaf and husk.

[a,b] Means in a row without common superscripts differ at $P \le 0.05$.

starch content of refused LH and Fines fractions. If the additional starch was assumed to be present from corn particles that escaped sorting by the steers, this corn DM accounted for 24.5% and 14.7% of respective CST and SPB total ort DM.

It appears that steers fed the Grow diet were more extensive in consuming the available concentrate feeds from the stover context than were steers fed the Finish diet. Stover orts have few alternatives other than to be discarded. In that option and based on the Grow trial results, 10% and 6% of orts DM discarded could be valuable concentrate feeds. For the Finish trial, 33% and 20% of orts DM discarded could be concentrate feeds.

Due to the difference in DMI, nutrient intakes for CSIL were lower ($P < 0.05$) than CST and SPB for all diet components analyzed, except ether extract, magnesium, potassium, and sulfur (Table 10). Since DMI was not different between SPB and CST pens, there were no differences ($P > 0.05$) between stover treatments for any nutritive component. Intakes of CP, Ca, and P exceeded the recommendations of NASEM (2016). The quotients of aNDF intake and DMI indicated that the aNDF concentrations in the consumed diets were 20.3%, 25.3%, and 25.5% for CSIL, CST, and SPB treatments. Since the stover orts were substantial, this indicates that steers fed a high-concentrate Finish diet (Tables 1 and 10) chose to consume CST and SPB diets that were 25% aNDF. Dykier et al. (2020) noted that beef steers fed a finishing diet (1.36 Mcal NEg and 20.8% aNDF) ad libitum selected a diet that contained 22.6% aNDF. Considering corn silage and corn

Table 13 Nutritional composition by fraction of stover offered[1] in the Finish trial

	Conventional stover				Single-pass bale				SEM				*P*-value			
Item, % DM basis	Cob	Stalk	LH[2]	Fines	Cob	Stalk	LH	Fines	Cob	Stalk	LH	Fines	Cob	Stalk	LH	Fines
CP[3]	2.4	3.4^{b}	3.8	5.7	1.8	4.6^{a}	3.9	6.1	0.6	0.02	0.2	0.4	0.45	0.01	0.86	0.43
Available CP	1.7	2.6^{b}	3.5	5.2	1.2	3.7^{a}	2.8	4.9	0.5	0.04	0.6	0.2	0.49	0.02	0.50	ND[4]
aNDF	87.6	78.7	78.9	73.4	87.9	83.1	83.1	77.0	2.8	1.6	0.6	1.1	0.95	0.22	0.08	ND
ADF	46.5	56.9	49.8	47.0	47.2	57.7	50.1	46.2	1.0	1.6	0.2	0.02	0.60	0.75	0.42	ND
Lignin	6.9	8.9^{b}	5.8	6.6^{b}	6.4	13.5^{a}	6.4	8.4^{a}	0.3	0.05	1.5	0.02	0.38	<0.01	0.77	<0.01
Starch	0.3	0.9	0.2	1.0	0.2	0.1	0.4	3.1	0.1	0.3	0.4	0.3	0.26	0.22	0.72	0.10
NFC	9.5	13.4	12.3	14.5	9.1	9.5	10.8	16.5	2.9	0.6	0.8	0.8	0.93	0.09	0.31	ND

[1] Values are based on hand fractionation of composite chopped stover bale samples collected during the Finish trial. Samples were composited over 4 wk and analyzed. Results are based on three composite samples.
[2] Fraction consisting of leaf and husk.
[3] See Table 2 footnotes for definition of this and subsequent abbreviations.
[4] Not determined due to insufficient sample replicates.
[a,b] Within fraction, means in a rows without common superscripts differ at $P \le 0.05$.

Table 14. Nutritional composition by fraction of stover refused[1] in the Finish trial

	Conventional stover				Single-pass bale				SEM				*P*-value			
Item, % DM basis	Cob	Stalk	LH[2]	Fines	Cob	Stalk	LH	Fines	Cob	Stalk	LH	Fines	Cob	Stalk	LH	Fines
CP[3]	3.5	5.2^{b}	7.5^{a}	16.6^{a}	3.7	6.6^{a}	6.8^{b}	13.5^{b}	0.3	0.4	0.2	0.8	0.47	0.02	0.04	0.02
Available CP	2.8	4.4^{b}	7.0^{a}	15.9^{a}	3.1	5.8^{a}	6.4^{b}	12.9^{b}	0.3	0.4	0.2	0.8	0.46	0.02	0.04	0.02
aNDF	86.0	80.7	44.1^{b}	35.8	87.3	80.5	60.0^{a}	37.5	0.7	1.0	3.4	2.7	0.16	0.83	<0.001	0.56
ADF	44.0	55.6	26.5^{b}	15.2	45.4	53.5	35.2^{a}	17.7	0.7	1.1	1.9	2.3	0.13	0.12	0.01	0.32
Lignin	5.3	8.8	3.6	3.1	7.0	10.5	4.3	3.6	0.9	1.1	0.6	0.5	0.14	0.20	0.27	0.40
Starch	1.9	1.2	35.7^{a}	27.6^{b}	1.8	1.8	21.3^{b}	32.9^{a}	0.3	0.4	3.2	1.8	0.96	0.26	0.01	0.04
NFC	9.0^{a}	9.9	42.4^{a}	36.8	7.6^{b}	9.2	28.7^{b}	41.3	0.4	1.1	3.5	2.0	0.03	0.57	0.02	0.09

[1] Values are based on refusal samples collected weekly per pen, hand-fractionated, then composited over 4 wk and analyzed. Results are based on three composite samples.
[2] Fraction consisting of leaf and husk.
[3] See Table 2 footnotes for definition of this and subsequent abbreviations.
[a,b] Within fraction, means in a rows without common superscripts differ at $P \le 0.05$.

Table 15. Steer weights, growth rates, diet dry matter intakes, and measures of gain efficiency in Finish trial

	Corn silage	Conventional stover	Single-pass bale	SEM	*P*-value
Initial, kg per steer	547^{a}	531^{b}	543^{a,b}	5.58	0.05
Final, kg per steer	660	651	661	7.46	0.37
DMI, kg per steer per d	10.8^{b}	12.7^{a}	12.6^{a}	0.31	<0.01
Gain, kg per steer per d	1.69	1.79	1.78	0.06	0.12
Gain/DMI	0.155^{a}	0.141^{b}	0.142^{b}	0.004	0.02

^{a,b}Means in a row without common superscripts differ at $P \leq 0.05$.

Table 16. Carcass characteristics for pens of steers harvested at the conclusion of Finish trial[1]

Item, individual steer basis	Corn silage	Conventional stover	Single-pass bale	SEM	*P*-value
Hot carcass, kg	402^{a}	391^{b}	397^{a,b}	5.0	0.10
Ribeye area, cm^2	84.6	85.5	87.5	1.9	0.30
Marbling score[2]	583	553	557	32.4	0.60
Backfat, cm	1.63^{a}	1.39^{b}	1.39^{b}	0.09	<0.01
KPH[3], %	2.01^{a}	1.88^{b}	1.95^{a,b}	0.56	0.08
Empty body fat[4], %	33.1^{a}	31.5^{b}	31.4^{b}	0.62	0.01
AFBW[5], kg	548	559	567	9.42	0.24

[1] Carcass characteristics were measured by carcass camera grading system of Tyson Fresh Meats, Joslin, IL.
[2] 500–599 = modest degree of marbling.
[3] Kidney, pelvic, and heart fat; calculated percent of hot carcass weight.
[4] Empty body fat calculated by method described in Guiroy et al. (2001).
[5] Adjusted final shrunk body weight to 28% empty body fat.
^{a,b}Means in a row without common superscripts differ at $P \leq 0.05$.

stover to be the roughage sources in these diets (Table 10), the sum of aNDF contributed by one (CSIL) or both (CST or SPB) of these roughage sources expressed as the quotient of diet DMI indicates that the roughage aNDF concentrations were 6.9%, 10.0%, and 10.4% of consumed CSIL, CST, and SPB diets, respectively.

Steer weights, growth rates, and gain efficiencies are shown in Table 15. Since CST steers were the lightest at the conclusion of the Grow trial (Table 9), they had the lightest initial, unshrunk body weights ($P < 0.05$) for the Finish trial (Table 15). At the conclusion of the Finish trial, there was no treatment effect on final unshrunk body weight ($P = 0.37$) or growth rate ($P = 0.12$). However, the CSIL treatment had better gain efficiency than CST and SPB because DMI was less for CSIL.

Carcass characteristics are displayed in Table 16. There was no effect of treatment on hot carcass weight, ribeye area, or marbling score ($P \geq 0.10$). Steers fed the CSIL treatment had the greatest backfat thickness and highest EBF percentage ($P < 0.05$). There was no difference between CST and SPB in carcass fatness. Following adjustment of final shrunk body weights to 28% EBF, there was no difference among treatments for this variable ($P = 0.24$). Thus, the biological type of steer was not different among treatments.

Table 17 reports the physically effective aNDF based on aNDF present in stover particles retained on the 8 mm sieve (peNDF$_{>8}$ using the nomenclature of Zebeli et al., 2012). The aNDF concentration in each hand-separated fraction of each stover (results repurposed from offered stover in Table 7) was weighted by the proportion of each stover fraction that was consumed (Table 5). The peNDF$_{>8}$ concentrations in CST and SPB were 67.1% and 69.5%, respectively. Goulart et al. (2020) have succinctly distinguished between the physical effectiveness factor (**pef**) and the effectiveness factor. In the present experiments, we have characterized the pef of two chopped stovers using sieving and aNDF methods. The pef for CST and SPB in the Grow trial were 0.84 and 0.85, respectively. To clarify, this means that 84% of the total aNDF consumed in the form of CST fractions was contained in particles that were retained by the 8 mm sieve.

Net energy values for CST and SPB stovers (Table 17) were estimated based on compositional analysis of the four stover fractions, calculations that used the approach of the dairy cattle NRC (2001), and the proportional net intake of each of the stover fractions in the Grow trial. The estimates for CST were 0.98 Mcal NEm per kg and 0.44 Mcal NEg per kg, and for SPB they were 1.09 Mcal NEm per kg and 0.54 Mcal NEg per kg. The values indicate CST to be less energy-dense than SPB, and CST values are less than the values reported by NASEM (2016) for cornstalks which are 1.06 Mcal NEm per kg and 0.51 Mcal NEg per kg. When the fractional proportions of pre-fed stover (Table 5) were applied to the compositional results, respective NEm and NEg values were essentially unchanged, that is, 1.00 and 0.45 Mcal/kg for CST and 1.09 and 0.54 Mcal/kg for SPB.

Estimates of net energy values and peNDF$_{>8}$ based on corn stover consumed in the Finish trial are shown in Table 18. Using the same methods as for Grow trial stovers, calculations yielded estimates (Table 18) of 0.95 and 0.96 Mcal NEm per kg for CST and SPB, respectively, and 0.40 and 0.42 Mcal NEg per kg for CST and SPB, respectively. The peNDF$_{>8}$ values for CST and SPB fed in the context of a high concentrate diet were 76.6% and 78.2%, respectively. The pef for CST and SPB consumed in the Finish trial were 0.96 and

Table 17. Estimation of physically effective neutral detergent fiber[1] (peNDF$_{>8}$) and net energy values[2] for conventional and single-pass bale corn stover fractions according to the proportions at which stover fractions were consumed during the Grow trial

	Conventional stover					Single-pass bale				
Fraction	Net intake	aNDF	peNDF$_{>8}$	NEm	NEg	Net intake	aNDF	peNDF$_{>8}$	NEm	NEg
	DM basis	%		Mcal/kg		DM basis	%		Mcal/kg	
Cob	0.12	87.8	10.5	1.21	0.64	0.37	86.2	31.9	1.18	0.62
Stalk	0.26	79.4	20.6	1.03	0.48	0.08	81.5	6.5	0.82	0.29
LH[3]	0.45	79.9	36.0	0.99	0.44	0.38	81.9	31.1	1.11	0.56
Fines	0.17	75.5	-	0.79	0.25	0.17	75.5	-	0.99	0.44
Total[4]	1.00	-	67.1	0.98	0.44	1.00	-	69.5	1.09	0.54

[1] Physically effective neutral detergent fiber (peNDF$_{>8}$; Zebeli et al., 2012) is the percent aNDF of chopped stover particles retained on the 8 mm sieve. The value for each stover fraction was calculated as the product of fractional net intake of the fraction (Table 5) and the aNDF concentration of the respective fraction upon offer (Table 7), for example, for CST cob, 0.12 * 87.8 = 10.5%. The aNDF content of Fines was not included in this calculation because Fines DM passed through the 8 mm sieve.

[2] Net energy for maintenance (NEm) and net energy for gain (NEg) values were calculated (NRC, 2001) for each of the individual stover fractions based upon compositional analysis.

[3] Fraction consisting of leaf and husk.

[4] NEm and NEg values in this row are the cumulative contribution of all fractions weighted by the respective proportion of stover consumed as each stover fraction. Respective NEm and NEg values of pre-fed stover (Table 5) are 1.00 and 0.45 Mcal/kg for conventional stover, and 1.09 and 0.54 Mcal/kg for single-pass bale.

Table 18. Estimation of physically effective neutral detergent fiber[1] (peNDF$_{>8}$) and net energy values[2] for conventional and single-pass bale corn stover fractions according to the proportions at which stover fractions were consumed during the Finish trial

	Conventional stover					Single-pass bale				
Fraction	Net intake	aNDF	peNDF$_{>8}$	NEm	NEg	Net intake	aNDF	peNDF$_{>8}$	NEm	NEg
	DM basis	%		Mcal/kg		DM basis	%		Mcal/kg	
Cob	0.11	87.6	9.6	1.03	0.48	0.36	87.9	31.6	1.06	0.51
Stalk	0.40	78.7	31.5	0.82	0.28	0.12	83.1	10.0	0.53	0.04
LH[3]	0.45	78.9	35.5	1.04	0.49	0.44	83.1	36.6	1.01	0.46
Fines	0.04	73.4	-	0.98	0.43	0.07	77.0	-	0.99	0.44
Total[4]	1.00	-	76.6	0.95	0.40	0.99	-	78.2	0.96	0.42

[1] Physically effective neutral detergent fiber (peNDF$_{>8}$; Zebeli et al., 2012) is the percent aNDF of chopped stover particles retained on the 8 mm sieve. The value for each stover fraction was calculated as the product of fractional net intake of the fraction (Table 11) and the aNDF concentration of the respective fraction upon offer (Table 13), for example, for CST cob, 0.11 * 87.6 = 9.6%. The aNDF content of Fines was not included in this calculation because Fines DM passed through the 8 mm sieve.

[2] Net energy for maintenance (NEm) and net energy for gain (NEg) values were calculated (NRC, 2001) for each of the individual stover fractions based upon compositional analysis.

[3] Fraction consisting of leaf and husk.

[4] NEm and NEg values in this row are the cumulative contribution of all fractions weighted by the respective proportion of stover consumed as each stover fraction. Respective NEm and NEg values of pre-fed stover are 0.96 and 0.42 Mcal/kg for CST, and 0.99 and 0.44 Mcal/kg for SPB.

0.94, respectively. Note that proportion of stover consumed as Fines in the Finish trial (0.04 and 0.07 for CST and SPB, respectively) was much less than for the Grow trial (0.17 and 0.17 for CST and SPB, respectively). Consequently, the aNDF from Fines was a much smaller contribution to total aNDF consumed.

After the steers were transitioned to the Finish trial, DMI for CST and SPB were greater than for CSIL (Table 15). We offer two interpretations for the observation that DMI of CST and SPB were greater than CSIL in the Finish trial but not in the Grow trial (Table 9). Perhaps corn stover, regardless of whether its composition is that of CST or SPB, is a source of fiber which is more physically effective for enhancement of ruminant animal function (Armentano and Pereira, 1997; Mertens, 1997) and, more specifically, feedlot cattle performance (Galyean and Defoor, 2003). The model of Zebeli et al. (2012) is helpful for broadly categorizing diets having a widely varying concentrations of peNDF$_{>8}$, though admittedly the context for this model is the high-producing dairy cow. In their model, DMI is maximized at a dietary peNDF$_{>8}$ concentration greater than 18%, while the risk of acidosis accelerates at a dietary peNDF$_{>8}$ concentration less than 14.9%. If it is assumed that WPCS aNDF is 93% peNDF$_{>8}$ (Mertens, 1997), then the peNDF$_{>8}$ concentration of CSIL (Table 4) was 23.1%. Similarly, the peNDF$_{>8}$ concentrations of the CST and SPB diets were 26.0% and 25.1%. Thus, DMI for all diets fed in the Grow trial could be considered, according to the Zebeli et al. (2012) model, to have been limited by the physical fill capacity of the cattle. For the Finish trial, pef of 0.93, 0.96, and 0.94 for WPCS, CST, and SPB, respectively, were applied to the aNDF intakes (Table 10) and the resulting peNDF$_{>8}$ concentrations were 7.0%, 12.3%, and 12.8% for CSIL, CST, and SPB diets, respectively. All diets in the Finish trial could be considered to be high-concentrate diets according to the model of Zebeli et al. (2012). Because the CST and SPB diets had elevated peNDF$_{>8}$ concentrations, these treatments would be expected to and did have elevated DMI according to the physically effective fiber hypothesis.

Galyean and Defoor (2003) advocated dietary percentage NDF from roughage sources as an explanatory variable for DMI, expressed as a percentage of trial average shrunk body weight. When Finish trial DMI results were expressed as a percentage of trial average shrunk body weight, the results for CSIL, CST, and SPB were 1.86%, 2.24%, and 2.18%, respectively. The increased percentages for CST and SPB are consistent with the prediction of Galyean and Defoor (2003), though their prediction equation (in view of the erratum https://doi.org/10.2527/2006.8441038x) estimated DMI as a percentage of body weight to be 104% and 105% of CSIL for CST and SPB, respectively. The actual values calculated from the DMI results (Table 15) are 120% and 117% of CSIL for CST and SPB, respectively.

The magnitude of the stover effect on Finish trial DMI leads to the second interpretation, which is that this increase in DMI is a carryover effect from consumption of the elevated aNDF diets in the Grow trial. Experimentation to evaluate the physically effective fiber hypothesis has heretofore not involved sequential administration of high-roughage followed by low-roughage diets to feedlot cattle as was done here. Also, the Grow trial involved feeding the CST and SPB diets to steers during 400 to 500 kg body weight, which is a relatively heavy body weight range in which to feed a high-roughage diet. Sainz et al. (1995) fed ad libitum a growing phase diet having 58% aNDF to beef steers and then switched them to a high-concentrate diet with 16% aNDF and noted that DMI was 30% greater for refed steers compared with steers that received the high-concentrate diet continuously through growing and finishing phases.

The methods of Tylutki et al. (1994), NRC (2000), Guiroy et al. (2001), and Zinn et al. (2003) were used to calculate paNEm and paNEg values for the treatment diets administered in the Grow and Finish trials (Table 19). The equations for these calculations are shown in Supplementary Table S1. These estimates were compared to diet NEm and NEg values determined for the CSIL diet (Table 3) and calculated (NRC, 2001) for CST and SPB diets from diet ingredient composition (Table 2) plus the stover fraction analyses (Table 17). These are two independent methods for estimating diet NEm and NEg values. Relative to the CSIL diet, CST diet, and SPB diet net energy values were ranked the same by the performance-based and ingredient composition-based approaches. This was true for both the Grow and Finish trial results.

Net energy values (Table 19) calculated from ingredient composition data were based on wet chemical analyses of ingredient samples collected within these trials, rather than reference values. This approach was apparently beneficial to the alignment of resulting net energy values with performance-adjusted net energy values (Table 19). To explain, the determined NEm and NEg values for corn silage (Table 2) were 1.71 and 1.09 Mcal/kg, respectively, while the NASEM (2016)

Table 19. Treatment diet net energy values calculated from animal performance[1] or diet ingredient analyses[2] for Grow and Finish trials

		paNEm[1]	paNEg[1]	NEm[2]	NEg[2]
Treatment diet	**Trial**	**Mcal/kg DM**			
Corn silage	Grow	1.83	1.19	1.71	1.10
	Finish	2.14	1.47	2.07	1.40
Conventional corn stover	Grow	1.66	1.05	1.57	0.96
	Finish	1.89	1.25	1.94	1.28
Single-pass bale	Grow	1.73	1.11	1.59	0.98
	Finish	1.90	1.26	1.94	1.28

[1] Performance-adjusted NEm and NEg values (Owens and Hicks, 2019) were calculated as described in Zinn et al. (2003).

[2] Diet NEm and NEg values were calculated from individual feed ingredients following analyses by Rock River Laboratory, Watertown, WI. Ingredient NEm and NEg values were based on composition analyses and then calculated using the method described in NRC (2001).

reference values are 1.56 and 0.96. The determined NEm and NEg values for DDG (Table 2) were 1.92 and 1.28 Mcal/kg, respectively, while the NASEM (2016) reference values are 2.21 and 1.52. Lastly, the determined NEm and NEg values for high-moisture corn (Table 2) were 2.48 and 1.75 Mcal/kg, respectively, while the NASEM (2016) reference values are 2.25 and 1.56.

For the Grow trial, performance-based net energy values were greater than respective ingredient composition-based net energy values (Table 19). Across CSIL, CST, and SPB diets fed in the Grow trial, paNEm values were 107% of NEm values, and paNEg values were 110% of NEg values. There was a better agreement between performance-based and ingredient composition-based net energy values for the Finish trial (Table 19). Across CSIL, CST, and SPB diets, paNEm values were 99% of NEm values and paNEg values were 99% of NEg values.

Since the strategy for the development of performance-adjusted net energy values emphasized testing and validation using feedlot pen closeout data (Owens and Hicks, 2019), it seems reasonable that close agreement existed between performance-adjusted net energy values and net energy values based on diet composition for the Finish trial. Since the composition of weight gain for steers in the Grow trial was leaner than that of steers in the Finish trial and since such low-adipose composition of gain was not the focus of the data-driven development of performance-adjusted net energy values, it also seems reasonable that performance-adjusted net energy values in the Grow trial were larger than net energy values based on ingredient composition.

CONCLUSIONS

Confined steers consumed stover fractions in proportions that were similar to those offered to them within the respective stovers, although there was evidence for some avoidance of cob and preference for the LH fraction. Cob DM consumption from SPB stover was 369 g/d in the Grow trial and 398 g/d in the Finish trial, which was 3.8% and 3.2% of DMI for the respective trials. Consumption of Fines was less in the context of the Finish diet (1.28 Mcal NEg per kg DM) than the Grow diet (0.97 Mcal NEg per kg DM), affirming the importance of coarse feed particle size in finishing diets. There was no difference in net energy values between CST and SPB stovers as an ingredient in the Finish diet. Steers fed the Finish diet selected stover botanical components to achieve a diet composition of 25% aNDF. The pef of conventional corn stover that was baled and chopped was 0.96 of its aNDF concentration when fed in the Finish diet. While corn stover could be an inexpensive source of roughage in growing phase diets and peNDF in finishing diets, the inclusion of stover should be optimized so that there would be minimal orts. Feed refusal constitutes a vector by which concentrate feeds could be wasted. The agreement between performance-adjusted and ingredient composition-based net energy values was close for Finish trial diets but less so for the Grow trial diets.

Supplementary Data

Supplementary data are available at *Translational Animal Science* online.

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Conflict of interest statement

The authors have no relationships or activities that have influenced the current work.

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