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Finishing diets with Sweet Bran and wet distillers grains with solubles alone or in combination improve performance and carcass characteristics of feedlot steers

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ABSTRACT

Objective: This study evaluated the effects of Sweet Bran (SB) and wet distillers grains with solubles (WDGS) in the diet alone or in combination on performance and carcass characteristics of finishing beef cattle.

Materials and Methods: For this study, steers (n = 455; 373 ± 15.5 kg) were stratified by BW and previous antimicrobial treatment to 48 pens in a randomized complete block design (12 blocks, 4 pens per block) using pen as the experimental unit. Within block, pens of steers transitioned over 20 d to 1 of 4 dietary treatments based on steam-flaked corn, containing no corn-milling products (CON), 20% WDGS (WDGS20), 20% SB (SB20), or 20% SB and 10% WDGS (COMBO).

Results and Discussion: Final BW and overall (d 0 to final) DMI and ADG were greater ($P < 0.01$) for WDGS20, SB20, and COMBO than for CON, but overall G:F ($P = 0.48$) was not different. Hot carcass weight was greatest ($P = 0.04$) for SB20 and WDGS20, intermediate for COMBO, and least for CON. Dressing percentage, marbling score, QG, 12th-rib fat, LM area, and KPH did not differ ($P \geq 0.21$). Yield grade tended ($P = 0.09$) to be greater for WDGS20 and SB20 than CON. No difference ($P \geq 0.32$) was observed between treatments for QG. Liver scores were not different ($P = 0.47$) among treatments. Empty body fat did not differ ($P = 0.25$), but empty BW was greater ($P = 0.04$) for WDGS20 and SB20 than COMBO and CON. No difference ($P = 0.13$) was observed for performance-calculated NE (Mcal/kg; maintenance or gain).

Implications and Applications: The results of this study suggest that addition of WDGS, SB, or both into finishing diets based on steam-flaked corn increases DMI and subsequently improves performance of feedlot cattle.

The authors have not declared any conflicts of interest.
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Key words: cattle, corn-milling products, feedlot, Sweet Bran, wet distillers grains

INTRODUCTION

Corn-milling products are a widely used ingredient in beef cattle diets to improve performance and reduce cost of gain (Irwin and Good, 2013). In a survey of consulting nutritionists (Samuelson et al., 2016), 70.8, 16.7, 8.33, and 4.17% of the nutritionists surveyed indicated they were using either wet distillers grains with solubles (**WDGS**), dry distillers grains with solubles (**DDGS**), wet corn gluten feed (**WCGF**), or dry corn gluten feed in feedlot cattle diets, respectively. Use of Sweet Bran (**SB**; Cargill Corn Milling), a branded feed product from the wet corn-milling industry, has also become popular in feedlot cattle diets. When used as a substitute for processed corn, cattle consuming SB exhibited either similar or greater DMI, ADG, and G:F (Macken et al., 2004; Block et al., 2005; Siverson et al., 2014). In contrast, feeding WDGS has resulted in variable responses in cattle performance. For example, cattle consuming diets based on dry-rolled corn (**DRC**) frequently have greater performance when WDGS is substituted for a portion of the grain, whereas cattle may have reduced performance when WDGS is used as a replacement for steam-flaked corn (**SFC**; Larson et al., 1993; Corrigan et al., 2009).

Direct comparisons of WDGS versus WCGF or SB in SFC-based diets are limited. Furthermore, using combinations of multiple grain-milling products is common in feedlot cattle diets (Samuelson et al., 2016). Previous studies investigating combinations of SB and WDGS indicate cattle performance was maximized when 30.0 to 75.0% of corn-milling products were included in diets based on high-moisture corn (**HMC**), DRC, or both (Bremer et al., 2009; Loza et al., 2010). In contrast, combining SB and WDGS in SFC-based diets to supply 20.0 to 27.0% of total corn-milling products improved performance of finishing cattle compared with a control containing no corn-milling products (Vasconcelos and Galyean, 2007). Overall, this suggests additional research is needed to compare WDGS and SB either alone or in combination when included at less than 30.0% of DM in SFC-based finishing cattle diets. Therefore, the objective of this study was to evaluate feedlot cattle performance and carcass characteristics when feeding SB, WDGS, or both to beef finishing steers.

MATERIALS AND METHODS

Receiving Cattle Management

All procedures involving live animals were approved by the West Texas A&M University Institutional Animal Care and Use Committee (approval number 2019.05.002). Before initiation of the study, a total of 478 crossbred bull and steer calves (234 ± 14.2 kg) were purchased from an order buyer in east Texas and received at the West Texas A&M University Research Feedlot from January 23, 2019, to April 3, 2019. During initial processing, all calves were administered a clostridial-tetanus toxoid (Calvary 9, Merck Animal Health), *Mannheimia haemolytica* bacterin (Nuplura, Elanco Animal Health), parenteral anthelmintic (Normectin, Norbrook Labs), and a growth-promoting implant (Component E-S with Tylan, 20 mg of estradiol and 200 mg of progesterone, Elanco Animal Health). Bulls were castrated via banding (Callicrate Pro, No-Bull Enterprises) and administered meloxicam (Unichem Pharmaceuticals) at 1 mg/kg of BW. Calves were then used for a 56-d receiving study to compare the efficacy of using tulathromycin (Draxxin, Zoetis) as a metaphylactic treatment, administering a pentavalent respiratory vaccine (Titanium 5, Elanco Animal Health) plus revaccination, or doing both (Munoz et al., 2020). During and after com-

Table 1. Ingredient composition and nutrient analysis of finishing diets including no fibrous corn-milling products or wet distillers grains with solubles, Sweet Bran, or both

Item	Growing diet[1]	Treatment[2]			
		CON	WDGS	SB	COMBO
Ingredient, % of DM					
Corn grain, flaked	28.54	76.55	63.92	62.55	53.22
Sweet Bran[3]	42.00	—	—	20.00	20.00
Wet distillers grains with solubles	—	—	20.00	—	10.00
Corn stalks	19.00	8.00	8.00	8.00	8.00
Cottonseed meal	—	6.00	—	—	—
Corn oil	—	2.45	1.08	2.45	1.78
Molasses blend[4]	7.00	2.50	2.50	2.50	2.50
Growing supplement[5]	3.46	—	—	—	—
Finishing supplement[6]	—	4.50	4.50	4.50	4.50
Nutrient composition, DM basis[7]					
DM, %	70.80	82.90	63.20	74.90	66.30
CP, %	15.00	13.50	15.90	13.60	15.10
RDP,[8] %	9.47	7.90	7.68	8.57	8.26
RUP,[8] %	5.53	5.59	8.22	5.03	6.84
NDF, %	22.50	14.46	18.78	18.82	21.70
ADF, %	17.40	8.20	9.80	9.30	10.70
Crude fat, %	3.30	5.30	5.30	5.50	5.50
Total starch, %	30.00	58.30	51.10	51.50	46.70
NE_m,[8] Mcal/kg	1.94	2.15	2.18	2.17	2.16
NE_g,[8] Mcal/kg	1.27	1.46	1.48	1.47	1.47

[1]Growing diet used during the preceding study (Munoz et al., 2020) and transition period.

[2]CON = control, no corn-milling products; WDGS = 20% wet distillers grains with solubles; SB = 20% Sweet Bran; COMBO = 20% Sweet Bran and 10% wet distillers grains with solubles.

[3]Corn Milling, Cargill.

[4]72 Brix Molasses Blend (Westway Feed Products LLC).

[5]Formulated to meet or exceed NASEM requirements (NASEM, 2016) and supplied 24 mg/kg monensin sodium (DM basis).

[6]Formulated to meet or exceed NASEM requirements (NASEM, 2016) and supplied 37 mg/kg monensin sodium and 9 mg/kg tylosin phosphate on a DM basis.

[7]Analysis by Servi-Tech Laboratories.

[8]Calculated based on tabular values (NASEM, 2016).

pletion of the receiving study, calves were fed a common growing diet (Table 1) until initiation of the current study on June 12, 2019.

Animal Management and Treatments

For the present study, 455 crossbred steers were used in a randomized complete block design. Steers that received greater than 2 antimicrobial treatments for bovine respiratory disease during the preceding receiving study or those not of uniform weight or breed type were excluded from the pool of study candidates. On d −1, steers were weighed and administered a growth implant (Revalor XS, 40 mg of estradiol and 200 mg of trenbolone acetate, Merck Animal Health) in the caudal aspect of the right ear. On d 0, steers were allocated to 48 soil-surfaced pens (27.4 m × 6.10 m) in 12 BW blocks with 4 pens per block and 9 or 10 animals per pen. Within each block, steers were stratified based on initial BW and the number of previous antimicrobial treatments such that these were similar among pens within each block. Pens were then randomly assigned to 1 of 4 dietary treatments (Table 1). Treatments were SFC-based diets containing no corn-milling products (**CON**); 20% WDGS (**WDGS20**); 20% SB (**SB20**); or a combination of 10% WDGS and 20% SB (**COMBO**) on a DM basis. Consulting feedlot nutritionists commonly use multiple grain-milling products in feedlot diets, with the majority of consultants including 10.0 to 20.0% of dietary DM as the primary grain-milling product and 10.0% or less of dietary DM as a secondary grain-milling product (Samuelson et al., 2016). Therefore, the COMBO treatment was designed to represent current industry standards for corn-milling product inclusion in finishing cattle diets. Diets were formulated to contain similar concentrations of RDP, total fat, and a commercially available molasses blend. In preparation for this study, both SB (Cargill Corn Milling) and WDGS (Green Plains) were purchased in bulk from a single source, delivered, and stored in plastic silage bags on the same day to minimize the variance that could be caused by differences in commodity blends, moisture, oil content, or added steep liquor. Steam-flaked corn was manufactured off site and delivered to the feedlot as needed (Dimmitt Flaking).

Feed Delivery and Bunk Management

On the first day of the study (d 0), cattle began transition from a common growing diet to their respective treatment diets using a 2-ration blending system. Dietary transition was completed using a programmed transition model where cattle were fed a common growing diet for 2 d, after which the amount of finishing diet was increased to replace 10.0% of the growing diet every 2 d so that all cattle were fully transitioned to the finishing diet on d 20. Feed bunks were visually evaluated twice daily at 0630 and 1830 h to determine the amount of feed to offer each pen. Bunk management was designed to allow little to no feed remaining each morning. Feed was mixed fresh daily in a stationary mixer (84-8, Roto-Mix) and delivered to each pen beginning at 0730 h. The daily feed delivery order was CON, WDGS20, SB20, and COMBO. Feed refusals were removed from the feed bunk when ≥2.27 kg was visually estimated to remain at the 0630-h bunk reading, weighed, and analyzed for DM in a forced-air oven (645, Precision Scientific) at 100°C for 24 h to calculate daily DMI.

Data Collection and Laboratory Analysis

Samples of SB and WDGS were collected daily and composited by week for analysis of DM (100°C for 24 h) and nutrient content (Servi-Tech Laboratories). Other feed ingredients such as SFC, corn stalks, cottonseed meal, and supplement were collected once weekly in duplicate. One sample was used to determine DM (100°C for 24 h) and adjust each diet formulation on an as-fed basis, whereas the other was composited monthly for nutrient analysis (Servi-Tech Laboratories). Additional SFC samples were collected from each corn delivery for analysis of total starch and starch availability (Servi-Tech Laboratories). Diet samples were collected twice weekly from the same 3 pens and split into 2 portions using a riffle splitter (H-3992, Humboldt Manufacturing Co.). One portion was immediately analyzed for DM (100°C for 24 h), and the second portion was composited twice per month for complete nutrient analysis by a commercial laboratory (Servi-Tech Laboratories). Initial BW (373 ± 15.5 kg) was averaged over 2 consecutive days to mitigate differences in gut fill when steers were fed ad libitum, and all BW measurements were adjusted using a 4.0% pencil shrink. A single interim BW measurement was recorded at the end of the dietary transition period to determine the effects of dietary treatments on performance during the transition period (d 0 to 20), after the transition period (d 20 to final), and over the entire finishing period (d 0 to final). Cattle were shipped to a commercial processing facility (Tyson Fresh Meats) by block once the majority of cattle within a BW block were deemed to have sufficient finish to grade USDA choice and reached a target unshrunk BW of 660 kg. The average days on feed for all 12 blocks was 157 d. Similar to initial BW, final BW were calculated as the average BW over 2 consecutive days immediately before slaughter. Throughout the course of the study, 7 steers were removed because of poor performance and 7 steers died from respiratory illness, bloat, or heart failure (4, 1, 5, and 4 animals for CON, WDGS, SB, and COMBO, respectively). Hot carcass weight (**HCW**) and liver scores were collected on the day cattle were slaughtered, and carcass data including marbling score, 12th-rib fat, LM area, KPH, and QG were collected after a 36- to 48-h chill. All carcass data were collected by personnel from the West Texas A&M University Beef Carcass Research Center.

Calculations

The proportion of carcasses grading select, choice, and premium choice as well as the proportion of liver abscesses for each pen were calculated by dividing the number of carcasses in each category by the number of carcasses within a pen. Yield grades were calculated using the previously described carcass measurements (USDA, 2017). To calculate empty body fat, empty BW, and adjusted final BW (AFBW), equations were adapted from Tylutki et al. (1994) and Guiroy et al. (2001). Equivalent shrunk BW (EQSBW) was calculated using EQSBW = BW × (478/AFBW), where BW = average BW × 0.96 (NASEM, 2016). Performance-calculated NE (Mcal/kg) for each diet was determined using the following equations: dietary $NE_m = -b \pm \sqrt{(b^2 - 4ac)}/2c$ and dietary $NE_g = 0.877 \times NE_m - 0.41$, where $a = -0.41 \times$ energy requirements for maintenance (EM; Mcal/d); $b = 0.877 \times EM + 0.41 \times DMI +$ energy requirements for gain (EG; Mcal/d); and $c = -0.877 \times DMI$ (Zinn and Shen, 1998). The following equations were used to calculate EM and EG: $EM = 0.077 \times BW^{0.75}$, and $EG = 0.00557 \times EQSBW^{0.75} \times ADG^{1.097}$ (Lofgreen and Garrett, 1968; NASEM, 2016). Only data from the end of the dietary transition to final were used in these calculations to represent the period when cattle were consuming 100% of their DMI as the dietary treatment. The ratio of observed versus expected NE was then calculated by dividing the performance-calculated NE by the NE density of each treatment diet. Dietary energy density was calculated based on tabular values from the NASEM (2016).

Statistical Analysis

Performance data and carcass data with continuous variables were analyzed as a randomized complete block design using the MIXED procedure of SAS (SAS Institute Inc.), whereas categorical data such as liver scores and QG were analyzed as binomial proportions using the GLIMMIX procedure of SAS. Pen was considered the experimental unit for all dependent variables. Diet was included in the model as a fixed effect, and block was random. Treatment means were reported as LSM ± SEM. Treatment mean differences were considered statistically significant when $P \leq 0.05$ and a tendency when $0.05 < P \leq 0.10$.

RESULTS AND DISCUSSION

The nutrient concentrations of individual feed ingredients sampled throughout the study are presented in Table 2. These values were not statistically analyzed because of inherent differences among the feedstuffs used in this study; however, evaluating nutrient concentrations over time allows for improved understanding of ingredient variability. Consequently, this could provide information for nutritionists and feedlot managers making decisions regarding diet formulations and commodity management. Of particular interest is the nutrient composition of SB and WDGS, as these feedstuffs are believed to have more variable nutrient concentrations because of inconsistencies in the wet and dry milling processes used to manufacture these ingredients. The average DM, CP, and crude fat concentrations were 60.33, 22.45, and 2.93% and 31.02, 35.35, and 10.37% for SB and WDGS, respectively. These values are similar to those reported by the NASEM (2016), except the CP concentration was slightly greater for the WDGS used in this study (35.35 vs. 30.63%; NASEM, 2016).

Dry matter concentrations were most variable for WDGS, followed by SB, and least for cottonseed meal. Interestingly, ground corn stalks exhibited the greatest CV of the ingredients used in this study for CP and crude fat. This could be a function of sampling error or high variability in the composition of the ground corn stalks. Corn stalks were processed through a grinder before feeding to improve distribution and mixing ability but contained a mixture of stalks, cobs, and fines. It may also be more challenging to obtain a representative sample of corn stalks because of the degree of variation in particle size and density present within the ground feed. The average total starch and starch availability of SFC was 78.93% (minimum = 74.40%; maximum = 83.40%; CV = 3.02%; data not shown) and 58.56% (minimum = 44.00%; maximum = 75.00%; CV = 11.90%; data not shown), respectively. The starch availability of SFC used in this study is typical for feedlot cattle (Schwandt et al., 2016).

Initial BW and BW at the end of the transition period did not differ ($P \geq 0.85$) among dietary treatments (Table 3). Similarly, DMI, ADG, and G:F did not differ during the transition period (d 0 to 20; $P \geq 0.44$). The lack of difference in performance during the transition period was expected because all cattle were consuming at least a portion of their daily DMI as the common growing diet during this time. Although the amount of each dietary treatment cattle were consuming increased as the transition period progressed, this may not have allowed enough time to result in detectable differences in performance. Final BW was greater ($P < 0.01$) for cattle consuming WDGS20, SB20, and COMBO than CON but was similar among cattle consuming the diets containing corn-milling products. The difference in final BW is a direct reflection of greater ($P < 0.01$) DMI and ADG for WDGS20, SB20, and COMBO compared with CON from transition to final (d 20 to final) and overall (d 0 to final). Over the entire feeding period, DMI was 6.81, 7.25, and 5.93% greater for WDGS20, SB20, and COMBO than CON, respectively. Similarly, ADG was 5.77, 5.77, and 3.85% greater for WDGS20, SB20, and COMBO than CON. Because dietary concentrations of NE_g were relatively similar among treatments (1.46, 1.48, 1.47, and 1.47 Mcal/kg for CON, WDGS, SB20, and COMBO, respectively), the greater ADG and final BW of cattle consuming corn-milling products was primarily influenced by increased DMI. However, it is important to note that both the NE_m and NE_g concentrations depicted in Table 1 were calculated based on tabular values (NASEM, 2016), and the energy estimates could vary from actual energy content calculated from the GE of a specific feed sample. Therefore, it is important to use caution when interpreting performance of cattle

Table 2. Individual feed ingredient[1] nutrient composition of finishing diets containing different concentrations of corn-milling products

Item	SB	WDGS	SFC	CS	CSM
n	26	26	6	6	6
Nutrient,[2] % of DM					
DM					
Mean	60.33	31.02	83.97	87.45	90.72
Minimum	56.60	29.00	80.40	86.10	89.50
Maximum	63.90	33.10	86.40	90.50	92.70
CV	3.39	3.63	2.55	2.05	1.19
CP					
Mean	22.45	35.35	8.35	5.92	46.02
Minimum	21.60	33.60	7.50	4.70	44.20
Maximum	23.50	36.70	9.20	7.10	47.00
CV	2.13	2.53	8.79	16.33	2.10
Fat					
Mean	2.93	10.37	3.13	0.63	3.05
Minimum	2.30	9.20	2.70	0.20	2.70
Maximum	3.60	11.70	3.50	1.00	3.40
CV	10.91	5.45	8.72	49.60	9.45
ADF					
Mean	10.86	18.04	3.87	52.32	18.45
Minimum	8.10	11.20	3.10	47.40	16.00
Maximum	12.30	22.20	5.50	56.50	20.40
CV	8.29	11.70	22.47	6.61	8.14

[1]SB = Sweet Bran (Cargill, Corn Milling); WDGS = wet distillers grains with solubles; SFC = steam-flaked corn; CS = corn stalks; and CSM = cottonseed meal.

[2]Analyzed by Servi-Tech Laboratories.

consuming diets containing corn-milling products because of potential variation in the actual energy content of feeds such as WDGS and SB from variations in the manufacturing process. Also, the tabular values reported for NE_m and NE_g of WDGS have increased over time as revealed in the NASEM (2000) versus NASEM (2016) publications, which were reported as 2.24 and 1.55 Mcal/kg and 2.47 and 1.74 Mcal/kg, respectively. These differences also present challenges because it can be difficult to delineate which tabular value is most appropriate for use in calculations and interpretations of animal performance. Because both DMI and ADG increased proportionally from including corn-milling products in the diet, G:F did not differ ($P \geq 0.48$) from transition to final or overall.

Greater final BW, DMI, and ADG concomitant with similar G:F of cattle consuming SB is consistent with previous studies evaluating feedlot performance of cattle fed SFC-based diets. For example, increasing SB from 0.0 to 40.0% of DM quadratically increased DMI and ADG but did not affect G:F (Block et al., 2005). Consequently, Block et al. (2005) concluded that finishing cattle performance is maximized when 17.0 to 23.0% of dietary DM is supplied by SB. Greater DMI, ADG, and similar G:F were also observed by Scott et al. (2003) and Loza et al. (2010). In a study completed by Parsons et al. (2007), DMI was also greater when diets contained either 20.0 or 40.0% SB compared with no SB. In contrast to the current study, ADG only tended to be greater with SB, which resulted in less G:F because the improvements in live gain in the study by Parsons et al. (2007) were not proportional to the increase in DMI. Macken et al. (2004) reported DMI tended to be greater when diets included 20.0 to 35.0% SB, but only numerical increases in final BW and ADG were observed. However, the study completed by Macken et al. (2004) only consisted of 4 pen replicates per treatment and therefore may have not had adequate statistical power to detect differences in cattle DMI and performance.

Results from research evaluating WDGS in finishing cattle diets are less consistent than studies completed using SB. Generally, replacing a portion of diets based on HMC, DRC, or both with WDGS results in similar DMI, increased ADG, and greater G:F than diets containing no corn-milling products (Klopfenstein et al., 2008). However, in SFC-based feedlot cattle diets, the response to added WDGS is less clear. It has been suggested that WDGS has a lower energy value than SFC, and therefore replacing SFC with WDGS may reduce dietary energy concentration and negatively affect animal performance. Consequently, the interaction between corn processing method and WDGS has been extensively studied, but results are

Table 3. Effects of diets containing no fibrous corn-milling products or wet distillers grains with solubles, Sweet Bran, or both on finishing cattle performance

	Treatment[1]					
Item	CON	WDGS20	SB20	COMBO	SEM	*P*-value
BW,[2] kg						
Initial	373	374	373	373	15.54	0.85
Transition[3]	417	418	418	417	16.07	0.94
Final	616[b]	630[a]	630[a]	626[a]	4.79	<0.01
DMI, kg						
d 0 to transition	9.51	9.60	9.66	9.71	0.33	0.44
Transition to final	9.02[b]	9.72[a]	9.75[a]	9.61[a]	0.16	<0.01
d 0 to final	9.10[b]	9.72[a]	9.76[a]	9.64[a]	0.18	<0.01
ADG, kg						
d 0 to transition	2.18	2.21	2.24	2.18	0.10	0.96
Transition to final	1.46[b]	1.56[a]	1.56[a]	1.54[a]	0.03	<0.01
d 0 to final	1.56[b]	1.65[a]	1.65[a]	1.62[a]	0.04	<0.01
G:F						
d 0 to transition	0.230	0.234	0.233	0.226	0.011	0.93
Transition to final	0.162	0.160	0.161	0.160	0.003	0.87
d 0 to final	0.171	0.170	0.169	0.168	0.003	0.48

[a,b]Means within a row with different superscript letters differ, $P < 0.05$.

[1]CON = control, no corn-milling products; WDGS20 = 20% wet distillers grains with solubles; SB20 = 20% Sweet Bran (Cargill, Corn Milling); COMBO = 20% Sweet Bran and 10% wet distillers grains with solubles.

[2]BW were adjusted using a 4.0% shrink.

[3]Transition period included 20 d of adaptation from a common grower diet to treatment diets.

inconsistent (Corrigan et al., 2009; Leibovich et al., 2009; Buttrey et al., 2012).

Similar to the current study, Ponce et al. (2019) reported greater DMI and ADG and similar G:F when 15.0% of WDGS was added to SFC-based diets. Corrigan et al. (2009) also observed DMI and ADG increased when WDGS was included in the diet at 10.0 or 15.0% of DM but was less for cattle fed 27.5% of DM or greater as WDGS. In a study completed by Depenbusch et al. (2008), cattle fed diets containing 25.5% WDGS had less ADG, similar DMI, and lower G:F compared with cattle consuming no corn-milling products. When combined with the results of the present study, these data suggest the optimum concentration of WDGS in SFC-based diets is likely between 15.0 and 25.0% of DM. In contrast, May et al. (2010) reported adding 15.0 or 30.0% of WDGS to SFC-based diets tended to decrease DMI, decreased ADG, and did not affect G:F. Alternatively, Depenbusch et al. (2009) observed no difference in DMI, ADG, or G:F of cattle consuming diets with 15.0% or no WDGS, and other research has reported increased DMI but reduced ADG and G:F with WDGS (McDaniel et al., 2021). The variation in research outcome associated with WDGS could be a function of differences in diet formulations between studies such as inclusion rate and starch availability of SFC, overall energy concentration, source and quality of roughage, dietary concentration of RDP, or both total and added fat concentration. For example, in the study by May et al. (2010), 15.0% WDGS replaced a proportion of cottonseed meal, urea, yellow grease, molasses, and SFC and therefore only reduced the dietary concentration of SFC by 3.7%. In the current study as well as those by Corrigan et al. (2009) and Ponce et al. (2019), SFC concentrations were reduced by 12.6, 10.0, and 10.0%, respectively. Less SFC likely contributed to lower dietary starch and perhaps influenced DMI. Furthermore, ethanol production has changed in the past 20 yr as greater amounts of fat are extracted from the final WDGS product, thus influencing nutrient composition and possibly performance of cattle consuming diets with WDGS.

In the current study, replacing SFC with WDGS, SB, or both resulted in greater DMI and ADG compared with a diet containing SFC and no corn-milling products, but G:F was not affected. The mechanism of action for greater DMI when corn-milling products are added to the diet is difficult to delineate but could be influenced by several factors. In comparison to fibrous ingredients, fermentation of grains increases the molar proportion of propionate in the rumen (Penner et al., 2011). In a study by Montgomery et al. (2004), less ruminal propionate was observed as the WCGF concentration of the diet was increased from 0.0 to 40.0% of dietary DM in place of SFC. Similar results have also been observed with WDGS (Luebbe et al., 2012). Greater hepatic oxidation of propionate may contribute to satiety (Allen et al., 2009). Although not measured in the present study, greater concentrations of propionate as a result of increased fermentation of starch by cattle consuming the CON diet could have initiated satiety and contributed to lower DMI. Differences in DMI among treatments could also be because of lower palatability of CON, possibly contributed by the greater DM concentration of this diet (82.90, 63.20, 74.90, and 66.30% for CON, WDGS20, SB20, and COMBO, respectively). However, adding water to the diet in an effort to equalize DM differences has decreased DMI in previous research (Lahr et al., 1983; Ham et al., 1994), suggesting that the lower DMI of CON in the present study was not because of differences in dietary DM. Alternatively, more rapid fermentation of starch in the rumen of cattle consuming CON could have caused feed aversion via initiation of a negative postingestive feedback response associated with low ruminal pH from the increased production of ruminal VFA (Provenza, 1995). It has been proposed that replacing processed grains with fibrous, corn-milling products such as WDGS and SB reduces DMI variation, modulates ruminal pH, and alters rumen microbial populations (Krehbiel et al., 1995; Fron et al., 1996). In a companion study, Spowart et al. (2020) reported ruminal pH was greater for cattle consuming WDGS20, SB20, and COMBO than it was for cattle consuming CON, which supports the hypothesis that the increased DMI in the present study was caused by a reduction in ruminal acidosis.

Similar performance between WDGS20 and SB20 in the present study indicates that WDGS and SB can be used interchangeably in feedlot diets without sacrificing performance. This is interesting because WDGS and SB have different nutrient concentrations and energy densities (NASEM, 2016). To our knowledge, there is a limited amount research that directly compares WDGS and SB or WCGF, particularly in cattle consuming SFC-based diets. In a receiving study, cattle fed DRC-based diets containing no corn-milling products, 30.0% WDGS, and 30.0% WCGF for 58 d followed by a 14-d adaptation period had similar DMI, but ADG and G:F were greater for cattle receiving 30.0% WDGS compared with 30.0% WCGF or the control diet (Schlegel et al., 2013). Similarly, Loza et al. (2010) reported cattle consuming HMC and DRC diets with 30.0% WDGS had less DMI, greater ADG, and greater G:F compared with cattle consuming diets with 30.0% SB. Again, dissimilarities between these results and those observed in the current research could be because of differences in dietary formulations or nutrient profile of the corn-milling products.

Because DMI and ADG were not reduced compared with WDGS20 or SB20 by replacing an additional 10.0% of SFC with WDGS in the COMBO treatment, replacing up to 30.0% of dietary DM with WDGS, SB, or both may improve DMI and live performance and reduce feed cost of gain of finishing cattle. Research evaluating SB in combination with WDGS in finishing cattle diets is also limited; however, feeding combinations of these ingredients in cattle diets is a common management practice in the commercial feedlot industry. This concept was explored by Loza et al. (2010) to evaluate possible associative effects between SB and WDGS. The results reported by Loza et al. (2010) are similar to the current study, where cattle consuming a 30.0% blend (1:1 ratio) of corn-milling products exhibited greater growth performance than those consuming a diet without corn-milling products but similar growth performance compared with those consuming either SB or WDGS alone. Alternatively, Bremer et al. (2009) investigated the optimal inclusion rate of WDGS (ranging from 0.0 to 40.0%) when added to a 35.0% SB diet. However, with the increased fixed value of SB, all performance variables reported were either similar to the control diet (35.0% SB only) or decreased with added WDGS. In the studies completed by Loza et al. (2010) and Bremer et al. (2009), SB replaced a combination of DRC and HMC or HMC only. In contrast, Vasconcelos and Galyean (2007) fed a SFC-based diet with no corn-milling products, 7.0% DDGS, 20.0% SB, 13.0% SB and 7.0% DDGS, and 20.0% SB and 7.0% DDGS. Dry matter intake and ADG in the study by Vasconcelos and Galyean (2007) were less for cattle consuming the diet containing no corn-milling products and did not differ among the diets containing various combinations of SB and DDGS, which agrees with the present research.

Similar to final BW, cattle consuming WDGS20, SB20, and COMBO had heavier carcasses (Table 4; $P = 0.04$) than CON, but DP did not differ ($P = 0.21$), which is in agreement with previous research (Block et al., 2005; Loza et al., 2010). Marbling score, 12th-rib fat thickness, LM area, and the percentage of KPH did not differ ($P \geq 0.33$) between cattle receiving WDGS20, SB20, COMBO, or CON. This also agrees with Buttrey et al. (2012), who reported no difference in carcass characteristics when SFC was replaced with WDGS. Depenbusch et al. (2008) observed lower HCW, DP, and LM area when WDGS was included in the diet, but all other carcass variables were not different. Marbling score, QG, and LM area also did not differ when SB was included in the diet as a replacement for corn (Macken et al., 2004; Block et al., 2005). However, when associated with heavier carcasses, carcass characteristics such as 12th-rib fat thickness increased as SB was added to the diet in some studies (Scott et al., 2003; Domby et al., 2014). A tendency ($P = 0.09$) for greater YG for WDGS20 and SB20 than CON likely occurred because of the greater HCW of cattle consuming the corn-milling product diets, as HCW is a variable in the YG equation (USDA, 2017). Similar results were observed by Domby et al. (2014), as greater YG were associated with heavier carcasses when SB replaced SFC in the diet.

Quality grade and liver abscess scores were not different ($P \geq 0.25$) among treatments. However, the proportion of abscessed livers was numerically less for the corn-milling product diets than CON (19.5, 14.5, 12.2, and 11.2% for

Table 4. Effects of no fibrous corn-milling products or wet distillers grains with solubles, Sweet Bran, or both on finishing cattle carcass characteristics

	Treatment[1]					
Item	CON	WDGS20	SB20	COMBO	SEM	*P*-value
HCW, kg	398[b]	407[a]	408[a]	404[ab]	3.42	0.04
DP, %	64.6	64.6	64.7	64.6	0.02	0.99
Marbling score[2]	44.2	43.8	45.0	43.9	1.15	0.63
12th-rib fat, cm	1.40	1.50	1.43	1.41	0.06	0.41
LM area, cm^2	100.0	99.1	99.4	99.2	1.02	0.50
KPH, %	2.28	2.26	2.29	2.26	0.06	0.33
YG[3]	2.66	2.92	2.85	2.80	0.11	0.09
QG,[4] %						
Select	30.4	35.6	25.1	30.2	6.05	0.37
Choice	45.7	40.0	51.3	49.5	5.50	0.32
Premium Choice	23.0	22.8	22.6	19.7	5.98	0.89
Abscessed livers, %	19.5	14.5	12.2	11.2	3.99	0.47

[a,b]Means within a row with different superscript letters differ, $P < 0.05$.

[1]CON = control, no corn-milling products; WDGS20 = 20% wet distillers grains with solubles; SB20 = 20% Sweet Bran (Cargill, Corn Milling); COMBO = 20% Sweet Bran and 10% wet distillers grains with solubles.

[2]Leading digit in marbling number indicates marbling score: 2 = trace, 3 = slight, 4 = small, 5 = modest, 6 = moderate, 7 = slightly abundant, 8 = moderately abundant, 9 = abundant. Following digits indicate degree of marbling within marbling score.

[3]Calculated using the USDA (2017) regression equation.

[4]Because of low incidence, standard and prime carcasses were not independently analyzed.

CON, WDGS20, SB20, and COMBO, respectively). Liver abscesses have been linked to intensive feeding strategies and are believed to be caused from ruminitis. Haskins et al. (1967) demonstrated that liver abscesses are more pronounced when cattle are fed highly fermentable concentrate diets such as the CON diet used in the present study. The numerical but not statistical difference in liver abscesses observed in this study is expected because it is historically challenging to delineate differences among treatments for binomial outcomes, such as the proportion of liver abscesses, in small pen research. Because liver abscesses are relatively infrequent, a statistical difference between treatments may have been observed with a larger sample size.

Calculated empty body fat did not differ ($P = 0.25$), but empty BW of steers was greater ($P = 0.04$) for SB20 and WDGS20 than COMBO and CON because of increased HCW of cattle consuming SB20 and WDGS20 (Table 5). Adjusted final BW was not different ($P = 0.91$). Performance-calculated NE_m and NE_g did not differ ($P = 0.13$) between treatments but were numerically less for WDGS20, SB20, and COMBO compared with CON. The ratio of observed versus expected NE_m and NE_g was less ($P \geq 0.02$) for WDGS20, SB20, and COMBO than CON. The ratio of observed versus expected NE ranged from 0.98 to 1.03 in the present study and suggests that cattle performed as expected given the dietary energy density. Lower observed versus expected NE for cattle consuming the diets containing corn-milling products compared with CON indicates that perhaps the tabular values reported by NASEM (2016) may overestimate the energy value of diets including corn-milling products such as WDGS and SB and underestimate the energy value of diets without corn-milling products. Again, because the ratio of observed versus expected NE is calculated by comparing performance-calculated NE to dietary NE projected from tabular values, it is important to note that this comparison is not as valuable if the dietary NE projected from NASEM (2016) does not accurately represent the true energy density of the diet. Furthermore, despite statistical differences among treatments, the numerical differences for observed versus expected NE are small and influenced by slight changes in performance or dietary energy concentrations. Therefore, caution should be taken when interpreting the relationship between observed versus expected NE.

APPLICATIONS

Corn-milling products from the manufacturing of sweeteners and ethanol are high energy, fibrous feed ingredients that can replace a portion of processed grains in feedlot cattle diets without sacrificing performance. Results of the present study suggest that although replacing a portion of SFC in the diet with corn-milling products is beneficial,

Table 5. Effects of no fibrous corn-milling products or wet distillers grains with solubles, Sweet Bran, or both on empty body fat, empty BW, adjusted BW, and performance-calculated energy

	Treatment[1]					
Item	CON	WDGS20	SB20	COMBO	SEM	*P*-value
EBF,[2] %	29.7	30.4	30.2	29.9	0.38	0.25
EBW,[3] %	563[b]	566[a]	568[a]	563[ab]	4.49	0.04
AFBW,[4] %	587	586	591	590	7.50	0.91
Performance-calculated NE[5]						
NE_m, Mcal/kg	2.18	2.15	2.14	2.14	0.02	0.13
NE_g, Mcal/kg	1.50	1.48	1.46	1.46	0.02	0.13
Observed:expected NE[6]						
NE_m	1.02[a]	0.99[b]	0.98[b]	0.99[b]	0.01	0.02
NE_g	1.03[a]	1.00[b]	0.99[b]	1.00[b]	0.01	0.03

[a,b]Means within a row with different superscript letters differ, $P < 0.05$.

[1]CON = control, no corn-milling products; WDGS20 = 20% wet distillers grains with solubles; SB20 = 20% Sweet Bran (Cargill); COMBO = 20% Sweet Bran and 10% wet distillers grains with solubles.

[2]EBF = empty body fat; EBF = 17.76207 + (4.6812 × fat thickness) + (0.01945 × HCW) + (0.81855 × QG) − (0.06754 × LM area), where HCW = hot carcass weight (Guiroy et al., 2001).

[3]EBW = empty body weight; EBW = (1.316 × HCW) + 32.29 (Guiroy et al., 2001).

[4]AFBW = adjusted final BW, AFBW = [EBW + (28 − EBF) × 19]/0.891 (Tylutki et al., 1994; Guiroy et al., 2001).

[5]Performance-calculated dietary $NE_m = -b \pm \sqrt{(b^2 - 4ac)}/2c$ and performance-calculated dietary $NE_g = 0.877 \times NE_m - 0.41$, where $a = -0.41 \times EM$; $b = 0.877 \times EM + 0.41 \times DMI + EG$; and $c = -0.877 \times DMI$ (Zinn and Shen, 1998). Energy maintenance (EM; Mcal/d) was estimated using $EM = 0.077 \times BW^{0.75}$, where BW = average BW × 0.96 (Lofgreen and Garrett, 1968), and energy gain (EG; Mcal/d) was estimated using the equation $0.0557 \times EQSBW^{0.75} \times ADG^{1.097}$, where EQSBW = BW × 478/AFBW (Zinn and Shen, 1998; NASEM, 2016). Values were calculated using data from transition to final when all cattle were consuming 100% of each treatment diet.

[6]Net energy ratios were calculated by dividing the performance-calculated energy by the dietary NE_m of each treatment diet (2.15, 2.18, 2.17, and 2.16 Mcal/kg for CON, WDGS20, SB20, and COMBO) or NE_g (1.46, 1.48, 1.47, and 1.47 Mcal/kg for CON, WDGS20, SB20, and COMBO).

there was no clear advantage between SB20, WDGS20, or their combination on cattle performance. Therefore, the competitive cost in comparison with corn and improved performance associated with including SB, WDGS, or both in the diet may allow feedlot producers to maximize economic returns. Additionally, because corn-milling products contain less dietary starch and greater fiber concentrations than processed grains, additional research is needed to quantify changes in ruminal buffering associated with replacing a portion of the grain in feedlot diets with either SB or WDGS and determine how these changes relate to finishing cattle performance.

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