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FORAGES AND FEEDS: *Original Research*

Using whole cottonseed to replace dried distillers grains plus solubles and prairie hay in finishing beef cattle rations balanced for physically effective neutral detergent fiber*

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ABSTRACT

Objective: The objective of this experiment was to determine the effects of replacing prairie hay and dried distillers grains plus solubles with whole cottonseed (WCS) in diets balanced for physically effective NDF on the growth, intake, feed efficiency, carcass characteristics, and plasma metabolites of finishing beef cattle.

Materials and Methods: Crossbred heifers (n = 103) and steers (n = 104) were blocked by BW within sex and randomly allocated to pens within block (6 pens per treatment) with 17 (n = 10 pens) or 18 (n = 2 pens) animals per pen. Pens were randomly allocated to experimental treatment: either a control diet (CON; prairie hay, dried distillers grains plus solubles, dry-rolled corn, and liquid supplement) or a WCS diet (CTN; WCS, dry-rolled corn, and molasses). A common vitamin and mineral supplement and urea were included in both diets at the same rate. Animals were slaughtered in 3 groups based on BW block.

Results and Discussion: Cattle fed the CTN treatment tended to have a greater final BW ($P = 0.10$) and had greater overall ADG and G:F ($P \leq 0.05$). There was no difference in overall DMI ($P = 0.23$). Fecal consistency scores were greater for cattle fed the CON treatment on d 42, at the beginning of the β-agonist feeding period, and at the final collection before slaughter ($P \leq 0.03$). Cattle fed the CTN treatment had a more neutral fecal pH on d 140 and at the final collection ($P < 0.01$). No treatment × day interactions ($P \geq 0.70$) were detected for plasma glucose, lactate, urea nitrogen, or nonesterified fatty acid concentrations. Cattle fed the CON treatment had greater plasma urea nitrogen concentrations ($P < 0.001$) and a tendency for a greater plasma lactate concentration ($P = 0.06$). A day effect was also observed for all plasma metabolites ($P < 0.001$).

Implications and Applications: This experiment suggests that feeding WCS improves the growth and feed efficiency of cattle when replacing the roughage and byproduct protein and fat sources within a finishing diet.

Key words: byproduct, feedlot, finishing diet, metabolites, performance

INTRODUCTION

Dried distillers grains plus solubles (**DDGS**) are used extensively in finishing diets being a readily available and competitively priced byproduct of ethanol production. The supply of DDGS varies due to changing demand for the primary production of ethanol. In recent years, the ongoing COVID-19 pandemic has resulted in a less reliable and simultaneously more expensive supply of DDGS, with the concomitant decline in ethanol production (Irwin, 2020). Although the effects of the ongoing pandemic have lessened, other regional, national, and global events will continue to affect the availability and price of commonly used byproducts. In addition to fluctuations in ethanol production, demand for DDGS from competing livestock industries has continued to increase, creating more competition for the available supply of DDGS (Swiatkiewicz et al., 2015).

With continually fluctuating commodity prices, there is an interest in finding alternative commodities to provide the needed protein and energy within feedlot diets in the Southern Plains. Because cotton is a popular crop in the southern United States, cotton byproducts have the potential to be an effective source of protein, fat, and roughage within cattle finishing rations (Warner et al., 2020a).

Within feedlot diets, DDGS are commonly used as a source of both protein and energy in place of more expensive protein sources. In feedlot diets, DDGS are typically used as a primary or secondary byproduct by 38.6% of

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Table 1. Particle separation and estimated physically effective NDF (peNDF) of treatment diet ingredients

	Ingredient[1]		
Item	**PH**	**DDGS**	**WCS**
NDF, % DM	69.7	34.3	54.0
Retained on sieve screen by screen size,[2] %			
18.0 mm	57.3	0.00	1.62
8.0 mm	18.1	0.47	93.4
4.0 mm	17.9	58.7	4.66
Less than 4 mm, % DM	6.70	40.8	0.30
Greater than 4 mm, % DM	93.3	59.2	99.7
Estimated peNDF,[3] % DM	65.0	20.3	53.8

[1]PH = prairie hay, DDGS = dry distillers grains plus solubles, WCS = whole cottonseed.

[2]Percentage of the commodity that remained on that respective sieve.

[3]Physically effective NDF (peNDF) percentage was estimated by multiplying the NDF as a decimal by the percentage of particles greater than 4 mm.

consulting feedlot nutritionists (Samuelson et al., 2016). For both receiving and finishing rations, it is common for byproducts to be in included anywhere between 10 and 20% (Vasconcelos and Galyean, 2007; Samuelson et al., 2016). No more than 40% DDGS (DM) should be included in the diet, and DDGS can be paired with low-quality fibrous roughage to minimize ruminal acidosis in finishing feedlot rations (NASEM, 2016). Low- to medium-quality hay (hay that is fibrous, mature, or low in nutritive value) is commonly used as a roughage in feedlot diets to provide physically effective NDF (**peNDF**) to stimulate muscle contractions within the rumen for rumination. Research suggests that whole cottonseed (**WCS**) is an effective source of protein, energy, and peNDF that can be mixed with less-nutrient-dense ingredients and processed grain such as steam-flaked or dry-rolled corn to create a balanced feedlot ration (Cranston, 2003; Warner et al., 2020a).

With protein content of 22.9 ± 2.53%, WCS contains less protein than DDGS (30.8 ± 2.67%) but is still high in protein compared with many other commodities (NASEM, 2016). The energy derived from WCS is primarily from the oil content of the seed, and the fiber is provided by the cottonseed hull and lint surrounding the seed (Rogers et al., 2002). When comparing peNDF, although prairie hay contains more peNDF than WCS (65.0 vs. 53.8%, respectively; Table 1), WCS contains sufficient peNDF to serve as a roughage source in feedlot diets at the recommended 7 to 10% peNDF of dietary DM (Fox and Tedeschi, 2002; NASEM, 2016). As a result, WCS has the potential to be an effective roughage source for feedlot cattle by providing sufficient physical stimulation to allow for proper rumination. However, research is unclear as to whether WCS is an as effective source of fiber as other common roughage sources. The objective of this experiment was to determine the effects of replacing prairie hay and DDGS with WCS in diets balanced for peNDF on the growth, intake, feed efficiency, carcass characteristics, and plasma metabolites of finishing beef cattle.

MATERIALS AND METHODS

All procedures were approved by the Institutional Animal Care and Use Committee at Oklahoma State University (Animal Care and Use Protocol number: AG-19-8).

Cattle and Processing

Brangus crossbred heifers (n = 103) and steers (n = 104) used in this experiment were transported on the same day in 3 separate trucks approximately 1,104 km from Wilson, Louisiana, to the Willard Sparks Beef Research Center (**WSBRC**) in Stillwater, Oklahoma, in April of 2021. Upon arrival to the WSBRC (d −1), calves were immediately unloaded, individual BW were recorded, and calves were administered individual identification tags before being sorted by sex. The calves were then placed in 2 separate holding pens (1 pen of heifers and 1 pen of steers) with *ad libitum* access to prairie hay (CP = 8.1%, NDF = 69.7%, ADF = 40.4%, and TDN = 57.0% DM) and water for approximately 10 h. The BW collected on d −1 were used to block cattle by BW within sex for allocation to experimental treatments.

On d 0, heifers, followed by steers, were randomly allocated within block based on d −1 BW within sex. After calves were allocated to pens (n = 12 pens; 6 pens of heifers, 6 pens of steers), calves were then ranked by BW within pen. The 6 calves nearest to the median pen BW were selected to serve as a subset for intensive blood sampling. On d 0, all calves were individually weighed, implanted

(steers = TE-IS, heifers = TE-IH; Elanco Animal Health), vaccinated against clostridial (Vision 7 with SPUR, Merck Animal Health) and viral and bacterial respiratory pathogens (Nuplura PH +3 and Titanium 5; Elanco Animal Health), and administered a pour-on insecticide (StandGuard; Elanco Animal Health) and anthelmintic (Safeguard; Merck Animal Health). In addition, fecal samples were collected to determine fecal consistency score (**FCS**; Ireland-Perry and Stallings, 1993; Woolsoncroft et al., 2018) and fecal pH. The subset of calves from each pen were bled via jugular venipuncture using 10-mL blood-collection tubes containing dipotassium EDTA (K_2EDTA, BD Vacutainer). After initial processing, the calves were housed in 31.0 m × 11.9 m dry lot pens, which included a 4.30 m × 11.9 m concrete bunk pad with a shared concrete water tank between 2 adjacent pens (model J 360-F; Johnson Concrete) for the remainder of the experiment. Collection of BW, FCS, fecal pH, and blood was completed again on d 14, 28, 42, 56, 84, 112, and 140; before feeding the β-agonist; and before shipping to slaughter. During collections on d 112, all cattle were reimplanted (steers = TE-S, heifers = TE-H; Elanco Animal Health).

There were 12 experimental pens with 6 pens per treatment (3 pens of heifers and 3 pens of steers). All pens used 17 heifers or steers, with the exception of 2 pens, which housed 18 steers in 1 block. During the feeding period, cattle were monitored daily for health and well-being as described by Wilson et al. (2015).

If deemed necessary, cattle pulled from the home pen due to health concerns were treated following WSBRC standard protocols. By d 10, 7 steers and 3 heifers from various pens had been removed from various home pens and placed in a hospital pen based on treatment and sex due to hoof abscesses, severe lameness, or both. On d 13, all cattle in the hospital pen were critically evaluated to determine eligibility to be returned to each animal's respective home pen. Upon evaluation, 7 of the 10 calves were permanently removed from the experiment due to the severity of injury or lameness. The remaining steer was returned to the home pen but later removed from the experiment on d 67, again due to lameness complications and the inability to compete for bunk space within the home pen. The remaining 2 heifers were returned to home pens and remained there for the duration of the experiment. The morning of collection on d 56, a heifer appeared to have labored breathing and later died the same day. Another heifer on d 90 appeared to have labored breathing and eventually became moribund. That heifer was euthanized later that same day. All animals in hospital pens were provided the respective treatment diet from the bunk of the respective home pen. This feed was recorded in the home pen feed delivery until the animal was either placed back in the home pen or removed from the experiment. In total 10 animals, 3 heifers [1 consuming the control diet (**CON**; prairie hay, dried distillers grains plus solubles, dry-rolled corn, and liquid supplement) and 2 consuming the WCS diet (**CTN**; WCS, dry-rolled corn, and molasses)] and 7 steers (2 consuming the CON diet and 5 consuming the CTN diet), were removed from the experiment due to severe lameness or complications from hoof abscesses resulting from cattle temperament or respiratory disease complications believed to be unrelated to experimental treatments.

Table 2. Receiving diet ingredients and analyzed nutrient composition for cattle upon arrival to feedlot

Item	RCV diet[1]
Ingredient, % of DM	
Dry-rolled corn	15.00
Prairie hay	28.44
Sweet Bran[2]	51.36
Dry supplement[3]	5.20
Nutrient composition, DM	
DM, %	70.4
CP, %	17.2
ADF, %	25.1
TDN, %	69.8
NE_m, Mcal/kg	0.74
NE_g, Mcal/kg	0.46
Calcium, %	0.72
Phosphorus, %	0.68
Magnesium, %	0.33
Potassium, %	1.32

[1]RCV diet = receiving diet; this was the common receiving diet for all cattle upon arrival. Diet was analyzed by Servi-Tech Laboratories.

[2]Sweet Bran (Cargill Inc.).

[3]Dry supplement was formulated to contain (% DM basis) 40.0% ground corn, 29.6% limestone, 20.0% wheat middlings, 7.0% urea, 1.0% salt, 0.53% magnesium oxide, 0.51% zinc sulfate, 0.17% manganese oxide, 0.13% copper sulfate, 0.08% selenium premix (0.6%), 0.0037% cobalt carbonate, 0.32% vitamin A (30,000 IU/g), 0.20% tylosin (Tylan-40, Elanco Animal Health), and 0.33% monensin (Rumensin-90; Elanco Animal Health).

Diets and Feed Management

Every morning at 0500 h feed bunks were visually evaluated by trained personnel. The evaluation of the bunk was used to adjust the feed amount offered daily in attempt to allow 0.045 kg of feed or less to remain in the feed bunk (modified slick bunk approach). All cattle received a common receiving ration (**RCV**; Table 2) for 10 d after arrival consisting of Sweet Bran (Cargill Inc.), prairie hay, dry-rolled corn, and a dry vitamin and mineral supplement, followed by a 28-d transition period using a step-up ration approach based on the final experimental diet composition (CON, Table 3 and CTN, Table 4) with 7 d per step.

On a DM basis, experimental dietary treatments consisted of CON (hay, DDGS, dry-rolled corn, liquid supple-

Table 3. Control treatment (CON) step-up diet ingredient inclusion percentages for feedlot steers and heifers

	CON step-up diet[1]				
Ingredient, % of DM	Step 1	Step 2	Step 3	Step 4	CON treatment
Prairie hay	24.30	20.16	16.01	11.87	7.73
Dried distillers grains	3.00	6.00	9.00	12.00	15.00
Dry-rolled corn	25.10	35.21	45.31	55.42	65.52
Sweet Bran[2]	41.09	30.81	20.55	10.27	6.00
Liquid supplement[3]	1.20	2.40	3.60	4.80	0.00
Dry supplement[4]	5.16	5.12	5.08	5.04	5.00
Urea	0.15	0.30	0.45	0.60	0.75

[1]Cattle were placed on a receiving diet for 10 d followed by steps 1 through 4, with 7 d per step, before starting the finishing ration for the remainder of the experiment.

[2]Cargill Inc.

[3]The liquid supplement was formulated to contain (% DM basis) 45.86% corn steep, 36.17% cane molasses, 6.00% hydrolyzed vegetable oil, 5.46% 80/20 vegetable oil blend, 5.20% water, 1.23% urea (55% solution), and 0.10% xanthan gum.

[4]The dry supplement was formulated to contain (% DM basis) 40.0% ground corn, 29.6% limestone, 20.0% wheat middlings, 7.0% urea, 1.0% salt, 0.53% magnesium oxide, 0.51% zinc sulfate, 0.17% manganese oxide, 0.13% copper sulfate, 0.08% selenium premix (0.6%), 0.0037% cobalt carbonate, 0.32% vitamin A (30,000 IU/g), 0.20% tylosin (Tylan-40, Elanco Animal Health), and 0.33% monensin (Rumensin-90; Elanco Animal Health).

ment) and CTN (WCS, dry-rolled corn, molasses; Table 5). Both diets contained a dry vitamin and mineral supplement that contained all feed additives and urea. Due to the increased fat from WCS, the CTN diet included 6.00% molasses as a ration conditioner, whereas the CON diet had 6.00% of liquid supplement that contained added fat as a conditioning agent. Thirty-one days before shipping to slaughter, the β-agonist ractopamine hydrochloride (Optaflexx 45; Elanco Animal Health) was added to both treatment supplements at a calculated intake of 390 $mg \cdot animal^{-1} \cdot d^{-1}$. All feed was mixed and delivered using a trailer-mounted 12B feed mixer (Roto-mix).

Table 4. Whole cottonseed treatment (CTN) step-up diet ingredient inclusion percentages for feedlot steers and heifers

	CTN step-up diet[1]				
Ingredient, % of DM	Step 1	Step 2	Step 3	Step 4	CTN treatment
Prairie hay	22.75	17.06	11.38	5.69	0.00
Whole cottonseed	3.00	6.00	9.00	12.00	15.00
Dry-rolled corn	26.65	38.30	49.95	61.60	73.25
Sweet Bran[2]	41.09	30.82	20.54	10.27	0.00
Molasses	1.20	2.40	3.60	4.80	6.00
Dry supplement[3]	5.16	5.12	5.08	5.04	5.00
Urea	0.15	0.30	0.45	0.60	0.75

[1]Cattle were placed on a receiving ration for 10 d followed by steps 1 through 4, with 7 d per step, before starting the CTN treatment finishing ration for the remainder of the experiment.

[2]Cargill Inc.

[3]Dry supplement was formulated to contain (% DM basis) 40.0% ground corn, 29.6% limestone, 20.0% wheat middlings, 7.0% urea, 1.0% salt, 0.53% magnesium oxide, 0.51% zinc sulfate, 0.17% manganese oxide, 0.13% copper sulfate, 0.08% selenium premix (0.6%), 0.0037% cobalt carbonate, 0.32% vitamin A (30,000 IU/g), 0.20% tylosin (Tylan-40, Elanco Animal Health), and 0.33% monensin (Rumensin-90; Elanco Animal Health).

Table 5. Ingredient analyzed nutrient composition of experimental treatment finishing diets

	Diet	
Item	**CON[1]**	**CTN[2]**
Ingredient, % of DM		
Dry-rolled corn	65.52	73.25
Dried distillers grains	15.00	—[3]
Prairie hay	7.73	—
Whole cottonseed	—	15.00
Liquid supplement[4]	6.00	—
Dry supplement[5]	5.00	5.00
Molasses	—	6.00
Urea	0.75	0.75
Nutrient composition, DM basis		
DM, %	81.48	83.98
CP,[6] %	15.45	15.65
NDF, %	21.20	17.75
ADF, %	7.55	13.15
peNDF,[7] %	8.07	8.07
TDN,[8] %	77.63	76.93
Fat, %	2.66	3.46
NE_m,[9] Mcal/kg	1.67	1.65
NE_g, Mcal/kg	1.06	1.04
Calcium, %	0.60	0.49
Phosphorus, %	0.48	0.42
Magnesium, %	0.21	0.23
Potassium, %	0.88	0.86

[1]CON = control diet, representative of a typical feedlot diet.

[2]CTN = whole cottonseed diet; whole cottonseed was used as the primary fiber source in the diet.

[3]A missing value under ingredient indicates there was 0.00% of that ingredient included.

[4]The liquid supplement is formulated to contain (% DM basis) 45.86% corn steep, 36.17% cane molasses, 6.00% hydrolyzed vegetable oil, 5.46% 80/20 vegetable oil blend, 5.20% water, 1.23% urea (55% solution), and 0.10% xanthan gum.

[5]The dry supplement is formulated to contain (% DM basis) 40.0% ground corn, 29.6% limestone, 20.0% wheat middlings, 7.0% urea, 1.0% salt, 0.53% magnesium oxide, 0.51% zinc sulfate, 0.17% manganese oxide, 0.13% copper sulfate, 0.08% selenium premix (0.6%), 0.0037% cobalt carbonate, 0.32% vitamin A (30,000 IU/g), 0.20% tylosin (Tylan-40, Elanco Animal Health), and 0.33% monensin (Rumensin-90; Elanco Animal Health).

[6]Analyzed by Servi-Tech Laboratories.

[7]peNDF = physically effective NDF provided by the roughage and byproducts in the diet.

[8]Calculated according to Weiss et al. (1992).

[9]Calculated according to NASEM (2016).

Treatment diets were sampled twice weekly, immediately after feed was dispersed into the bunks. Samples were collected from 3 bunks (the first, middle, and last bunk for the respective treatment) with 3 samples from each bunk (beginning, middle, and end of bunk) to create the composite sample that was then dried in a forced-air oven at 55°C for 48 h. Samples were composited monthly and stored in a freezer until further analysis could be completed. Feed refusals were collected and weighed on d 14, 28, 42, 56, 84, 112, and 140; before feeding the β agonist; before shipping to slaughter; and as needed if excess orts remained in the bunk. Ort samples were dried following same procedures as diet samples to determine DM. Ort (DM) was subtracted from feed delivered (DM) before calculating pen DMI.

Data Collection and Calculations

Individual BW were collected before the morning feeding at approximately 0430 h with no withdrawal from feed or water on d −1, 0, 14, 28, 42, 56, 84, 112, and 140; before starting the β-agonist feeding; and the morning of shipping for slaughter. All BW were adjusted using a calculated 4% pencil shrink to accommodate for rumen fill because cattle were not withheld from feed before obtaining BW (BW × 0.96; NASEM, 2016). All individual BW were averaged within a pen and used to calculate other growth, intake, and efficiency measures. Pen ADG was calculated by averaging the individual ADG of animals within a pen for each period. Within pen, DMI (kg/d) was calculated by summing pen daily DM feed deliveries, subtracting feed refusals (DM), and dividing by number of animals in that pen. Within pen, DMI as a percentage of BW was calculated by dividing the pen average DMI for the period by the average of the beginning and ending BW (mean feeding BW) for that period. The G:F was calculated by dividing pen ADG (kg) by pen DMI (kg/d).

Due to intake being measured on a pen basis rather than individual animal basis, intake had to be corrected for the cattle removed (n = 10) from the experiment by subtracting the average individual DMI from the pen until the animal in question ceased gaining BW. Once the animal ceased gaining BW, the NASEM (2016) equation was used to estimate the individual animal's energy intake at maintenance (NE_m), $NE_m = 0.077(\text{shrunk BW})^{0.75}$. This calculation and diet NE_m concentration was then used to estimate animal DMI. The estimated individual animal's intake was then subtracted from the pen DM deliveries from the day the animal ceased gaining BW until the animal was physically removed from the assigned pen (NASEM, 2016).

Blood and fecal samples were also collected on d 0, 14, 28, 42, 56, 84, 112, and 140; before starting β-agonist feeding; and the morning of shipping for slaughter. Blood was collected via jugular venipuncture from the subset (6 animals per pen) using 10-mL blood-collection tubes containing K_2EDTA (BD Vacutainer) and stored on ice until further processing. Blood samples were stored on ice for an average of 3 h before centrifuging at 3,000 × *g* for 20 min at 7°C. After centrifuging, plasma was collected and stored at –20°C until analysis for glucose, lactate, urea nitrogen

Table 6. Influence of using whole cottonseed in place of dried distillers grains plus solubles and prairie hay in finishing rations balanced for physically effective NDF on carcass characteristics of feedlot heifers and steers

	Treatment[1]			
Item	CON	CTN	SEM[2]	*P*-value
Hot carcass weight, kg	399	416	12.2	0.02
Rib eye area, cm^2	91.6	90.7	2.28	0.67
Fat thickness,[3] cm	1.77	1.91	0.108	0.05
DP	64.6	64.6	0.49	0.88
Calculated USDA YG	3.51	3.83	0.218	0.001
Marbling score[4]	480	477	20.1	0.84

[1]Treatments included (DM basis) CON = 7.73% hay, 15.00% dry distillers grains plus solubles, 65.52% dry-rolled corn, and 6.00% liquid supplement, or CTN = 15.00% whole cottonseed, 73.25% dry-rolled corn, and 6.00% molasses. Both rations contained 5.00% dry supplement and 0.75% urea.

[2]n = 6 pens per treatment—3 pens of heifers and 3 pens of steers per treatment.

[3]Fat measurement taken between the 12th and 13th ribs.

[4]Small[00] = 400; Modest[00] = 500; Moderate[00] = 600.

(**PUN**), and nonesterified free fatty acids (**NEFA**) could be completed.

Fecal samples were collected via rectal palpation from all animals. Fecal pH was measured immediately after collection (Accumet AE150 benchtop pH meter; Thermo Fisher). Fecal samples were also visually appraised and given a FCS. This method used a scale ranging from 1 to 5 characterized as follows: 1 = firm and hard, 2 = slightly firm, 3 = soft with high moisture, 4 = loose and runny, 5 = very loose and with a water consistency (Woolsoncroft et al., 2018). The same evaluator collected the fecal samples and determined the FCS during each collection day. Fecal pH and FCS change were determined by subtracting the previous period value from later period value.

Due to varying BW across blocks, cattle were shipped to slaughter in 3 different slaughter groups based on visual appraisal of condition and BW. The heaviest blocks (n = 4 pens total; 2 pens per treatment; 1 pen of heifers and 1 pen of steers per treatment) were shipped approximately 120 km on d 177 to be processed on d 178 at a commercial abattoir in Arkansas City, Kansas. It should be noted that one heifer out of the heaviest block on CTN diet was rejected by the commercial abattoir in Arkansas City, Kansas, due to failure to meet hide color requirements. On d 178, the rejected heifer was transported back 120 km to WSBRC, where the animal was held overnight before being shipped 61 km on d 179 to a different abattoir in Jennings, Oklahoma, for processing that same day. Trained personnel Oklahoma State University (Stillwater, OK) collected carcass data for this specific heifer from the morning after slaughter (d 180). Due to this issue, the remaining blocks of cattle were shipped approximately 435 km to a commercial abattoir in Dodge City, Kansas. The middle blocks (n = 4 pens total; 2 pens per treatment; 1 pen of heifers and 1 pen of steers per treatment) were shipped on d 205 to be processed on d 206, and the lightest blocks (n = 4 pens total; 2 pens per treatment; 1 pen of heifers and 1 pen of steers per treatment) were shipped on d 226 to be processed on d 227. Henceforth, the term "final" represents data collections that occurred the morning of shipping for slaughter, depending on the slaughter group (final = d 177, 205, or 226, respectively). The following carcass characteristics were measured for all slaughtered animals: hot carcass weight (**HCW**), fat thickness, and rib-eye area (**REA**). The DP, USDA YG, and marbling score were calculated or assigned by trained personnel from the abattoirs with the exception of the one heifer for which carcass data were collected by trained personnel from Oklahoma State University (Table 6).

Laboratory Analysis

Composited diet samples were shipped to a commercial laboratory for analysis of CP and minerals (Servi-Tech). Whole cottonseed, prairie hay, and DDGS particle size was determined using a 3-sieve forage particle separator (18-mm, 8-mm, and 4-mm sieves and a bottom pan; Nasco). The 3-sieve particle separator was placed on a flat surface with the sample placed on the top sieve. The particle separator was shaken 5 times and rotated 90°; this was repeated for a total of 40 shakes or 8 sets. The peNDF of WCS, DDGS, and prairie hay was calculated by multiplying the NDF of the specific commodity (DM basis) by the total percentage of the specific commodity retained in the top 3 sieves (sieves ≥4 mm; Table 1). To determine the amount of peNDF within the diets based on a desired inclusion rate of 15% WCS (DM), the peNDF of ingredients was multiplied by the percentage inclusion

rate within the diet. The peNDF was calculated within the CTN treatment based on WCS inclusion, and then, prairie hay was added to the CON treatment to create equal peNDF between the CTN and CON treatments. Entire treatment diets were not analyzed for peNDF due to possible inflation of peNDF from the pelleted supplement and other nonfibrous commodities within the diet that could be retained in the 4-mm sieve (NASEM, 2016).

Proximate analysis was performed on the composited treatment diet samples. Laboratory DM percentages were calculated by subtracting the weights of samples after drying in a 105°C oven for 24 h from the weight of the sample before drying. Diet samples were dried in a 55°C oven for 48 h before being ground through a 2-mm screen followed by a 1-mm screen (Puverisette 19, Fritsch). Neutral detergent fiber, ADF, and ADL were analyzed according to the manufacturer's instructions using an ANKOM 2000 automated fiber analyzer (ANKOM Technology). Ether extract was analyzed by ANKOM XT15 extract (ANKOM Technology), and ash percentages were calculated by weight difference when samples were placed in a furnace at 500°C for 12 h.

Plasma samples were thawed at room temperature and analyzed for glucose, lactate, and PUN. Plasma glucose and L-lactate were analyzed using an immobilized enzyme system (YSI Model 2950 D; YSI Inc.). Plasma urea nitrogen was analyzed using methods described by Marsh et al. (1965) with adaptations to a 96-well plate. Plasma NEFA were analyzed using a modified protocol of the NEFA-HR (2) kit (WAKO Pure Chemical Corporation) based on the acyl-CoE synthetase-acyl-CoA oxidase method. Samples were analyzed in duplicates using a flat-bottom 96-well polystyrene plates on microplate reader (Biotek EPOCH, Biotek Instrument Inc.) at 550 nm.

Statistical Analysis

This experiment used a randomized complete block design, with BW blocked within sex. There were 3 blocks based on BW (light, medium, and heavy). Data were analyzed using the MIXED procedure of SAS 9.4 (SAS Institute Inc.). For all growth, intake, feed-efficiency, fecal, and carcass data, treatment was the fixed effect, block was the random effect, and pen served as the experimental unit (n = 12). Plasma metabolite data were assessed for normality using UNIVARIATE procedures of SAS 9.4, and the Shaprio-Wilk test determined all data were normally distributed. The fixed effects of treatment, day, and treatment × day with block as a random effect were used when analyzing plasma metabolite data. The analysis included day as a repeated measure using the appropriate covariance structure with pen as the subject. The appropriate covariance structure was determined by comparing Akaike's information criteria. The covariance structure with the lowest Akaike's information criterion was used for metabolite analysis; plasma glucose and NEFA used heterogeneous compound symmetry, lactate used variance components, and PUN used heterogeneous autoregression 1. Data from heifers or steers that were removed or died during the experiment (n = 10) were excluded from all analysis. Significance was declared when $P \leq 0.05$, and tendencies were considered when $P > 0.05$ and $P \leq 0.10$.

RESULTS AND DISCUSSION

Experiment Diets

When creating the experimental diets, peNDF was determined for WCS, prairie hay, and DDGS using a 3-sieve forage particle separator (Table 3; Fort Atkinson, WI). Based on the desired fixed percentage of WCS and DDGS in the CTN and CON treatment diets, respectively, the percentage of prairie hay was adjusted in the CON diet to ensure equivalent peNDF (8.07%) between the experimental diets.

It was not possible to formulate the CON and CTN treatment diets to contain equivalent fat and protein. As such, the experimental objective was not to attempt to create treatments with equivalent fat and protein concentrations, but to determine whether WCS could effectively replace both prairie hay and DDGS to supply the majority of the roughage, fat, and protein in the diet when diets were balanced for peNDF.

Previous research by Warner et al. (2020a) and Cranston et al. (2006) has evaluated the inclusion of WCS in feedlot diets. The current experiment and the study by Warner et al. (2020a) both included WCS at 15% of the diet and attempted to provide the majority of protein, fat, and roughage in the diet from either WCS alone or a combination WCS and cotton gin trash (sometimes referred to simply as "gin trash," "cotton burrs," or "gin byproduct"). Cranston et al. (2006) evaluated the effects on cattle performance and carcass characteristics when replacing alfalfa hay, cottonseed meal, cottonseed hulls, and tallow with WCS in a finishing feedlot ration. Cranston et al. (2006) formulated treatment diets to provide similar amounts protein, fat, and NDF, whereas the current experiment formulated for equivalent peNDF between treatment diets.

Growth, Intake, and Feed Efficiency

Although there was no difference in BW between cattle consuming the CON and cattle consuming the CTN treatment on d 0 (Table 7; $P = 0.32$), it is important to note that all 207 animals that arrived at the WSBRC (103 heifers and 104 steers) were randomly allocated within block to experimental treatments. This resulted in an average BW of 324 kg for cattle allocated to both the CON and the CTN experimental treatments on the day of allocation. However, due to multiple animals being removed from the experiment due to severe injury, lameness, or mortality and the data associated with those animals being removed from the analysis, there was a small numerical difference (~7 kg) in initial BW (Table 7; $P = 0.32$).

Table 7. Influence of using whole cottonseed in place of dried distillers grains plus solubles and prairie hay in finishing rations balanced for physically effective NDF on growth of feedlot heifers and steers

	Treatment[1]			
Item	**CON**	**CTN**	**SEM[2]**	***P*-value**
BW,[3] kg				
d 0	332	339	15.0	0.32
d 14	339	345	14.4	0.32
d 28	378	389	15.9	0.15
d 42	407	418	16.5	0.20
d 56	429	443	16.6	0.06
d 84	466	484	16.4	0.03
d 112	488	507	16.9	0.01
d 140	533	550	17.1	0.03
Beta-agonist[4]	571	584	10.5	0.10
Final[5]	615	636	14.9	0.10
ADG,[6] kg				
d 0 to 14	0.44	0.49	0.140	0.67
d 15 to 28	2.83	3.17	0.156	0.02
d 29 to 42	2.09	2.00	0.089	0.47
d 43 to 56	1.49	1.84	0.077	0.01
d 57 to 84	1.35	1.46	0.048	0.13
d 85 to 112	0.73	0.84	0.059	0.17
d 113 to 140	3.32	3.54	0.154	0.27
Beta-agonist to final	1.39	1.56	0.188	0.24
d 140 to final	1.34	1.48	0.130	0.35
d 0 to final	1.40	1.53	0.048	0.03

[1]Treatments included (DM basis) CON = 7.73% hay, 15.00% dry distillers grains plus solubles, 65.52% dry-rolled corn, and 6.00% liquid supplement, or CTN = 15.00% whole cottonseed, 73.25% dry-rolled corn, and 6.00% molasses. Both diets contained 5.00% dry supplement and 0.75% urea.

[2]n = 6 pens per treatment—3 pens of heifers and 3 pens of steers per treatment.

[3]Body weight was adjusted using a calculated 4% pencil shrink.

[4]Cattle were slaughtered in 3 groups: d 178 (n = 4 pens total; 2 pens per treatment; 1 pen heifers and 1 pen steers per treatment), d 206 (n = 4 pens total; 2 pens per treatment; 1 pen heifers and 1 pen steers per treatment), and d 227 (n = 4 pens total; 2 pens per treatment; 1 pen heifers and 1 pen steers per treatment). Beta-agonist BW was obtained the day the pens started ractopamine hydrochloride (Optaflexx 45; Elanco Animal Health), 31 d before slaughter.

[5]Final BW were taken the day of shipping for slaughter.

[6]Pen ADG were calculated from individual shrunk BW gain in kilograms, divided by days on feed for each period.

By d 56, cattle consuming the CTN treatment tended to be heavier ($P = 0.06$). It should be noted that by d 56, cattle had been completely transitioned to finishing diets and had been consuming the experimental treatment diets for 18 d. By d 84 and until d 140, cattle consuming the CTN treatment had a greater BW compared with those consuming the CON treatment ($P \leq 0.03$). The BW of cattle consuming the CTN treatment at the beginning of the β-agonist feeding period and final collection also tended to be greater compared with those consuming the CON treatment ($P = 0.10$). The increased BW observed in cattle consuming the CTN treatment across those intervals was a result of increased ADG from d 15 to 28, d 43 to 56, and over the duration of the experiment (Table 7; $P \leq 0.03$). Although numerical differences in BW were observed on d 0, the absolute difference in BW increased over the duration of the study, as indicated by detectable differences in ADG.

Cattle consuming the CON treatment had a greater DMI (kg/d) from d 0 to 14 (Table 8; $P = 0.03$). During this time, cattle were fed the RCV diet (Table 2) for 10 d and step 1 (Tables 3 and 4), of the assigned treatment,

for 4 d. This difference in DMI, then, is not likely due to experimental treatments, unless there was some initial aversion to the CTN diet during the first 4 d of feeding step 1. There were no other differences in DMI among cattle consuming either treatment for the remainder of the experiment ($P \geq 0.35$). When analyzing DMI as a percentage of BW, cattle receiving the CON treatment tended to have a greater DMI as a percentage of BW from d 0 to 14 ($P = 0.06$) and d 113 to 140 ($P = 0.08$), while having a greater DMI as a percentage of BW during the β-agonist period ($P = 0.05$) and from d 140 to final ($P = 0.04$). The G:F was not different from d 0 to 14 (Table 8; $P = 0.42$). However, G:F was greater for cattle consuming the CTN treatment from d 15 to 28 ($P < 0.01$) and d 43 to 56 ($P = 0.02$). There were no differences in G:F from d 57 through 140 ($P \geq 0.17$), but G:F was again greater for cattle consuming the CTN treatment during the β-agonist feeding period ($P = 0.01$) and for the overall experiment (d 0 to final; $P = 0.05$).

Previous studies have reported inconsistent results when cattle fed WCS were compared with cattle fed more traditional ingredients in diets based on dry-rolled or steam-flaked corn. Cranston et al. (2006) reported no difference in ADG, an increase in DMI, and a decrease in G:F when steers were fed a diet containing WCS compared with a steam-flaked corn finishing ration containing a majority cottonseed meal, alfalfa hay, and cottonseed hulls. Warner et al. (2020a) compared a diet containing WCS and cotton gin trash to a control diet containing dry-rolled corn, prairie hay, and Sweet Bran and reported similar results to the current experiment, where cattle consuming the diet containing WCS had a tendency for greater final BW and overall greater ADG. However, Warner et al. (2020a) reported cattle consuming the treatment diet containing WCS and cotton gin trash had greater overall DMI, and thus, there was no difference in G:F in their experiment.

There are several possible explanations for lower intake of cattle fed the CTN diets during adaptation. One explanation for the greater DMI for cattle consuming the CON treatment from d 0 to 14 could potentially be a result of the animal's lack of previous exposure to WCS as a dietary ingredient. The RCV ration along with step 1 of the CON step-up diets would potentially have been more recognizable to the calves than the potentially unfamiliar WCS in the CTN diet (Table 2, Table 3, Table 5). Savell et al. (2007) compared WCS to soybean meal as a supplement to grazing backgrounding calves. The author reported that the calves being fed the WCS supplement consumed inadequate amounts of WCS, eventually leading to a decreased BW compared with the soybean meal control. It was speculated this was due to greater dietary fat inhibiting fiber digestion. The lack of difference in DMI for the remainder of the experiment is likely due to the treatment diets being balanced for peNDF. Galyean and Defoor (2003) suggested DMI for feedlot cattle is the result of metabolic factors such as chewing, rumination rates, and acid production rather than bulk fill. With effective NDF and peNDF being highly correlated with measuring particle size (NASEM, 2016), this previous research likely explains the similar DMI throughout the duration of the experiment.

Fecal Characteristics

The characteristics of feces can be an indicator of what is occurring within the digestive tract (Owens et al., 1998). When evaluating feces, the consistency can indicate site and extent of digestion, along with potential digestive upsets (Church, 1988; Monteiro and Faciola, 2020). By evaluating the fecal consistency and assigning a score based on the Ireland-Perry and Stallings (1993) method adapted by Woolsoncroft et al. (2018), an animal's digestive health can be evaluated. An increase in ruminal passage rate corresponding to an increase in hindgut fermentation, as well as increased fat intake, can cause the fecal consistency to appear more "loose" or watery (Kononoff et al., 2002; Hall, 2007). A loose fecal consistency can also be a sign of digestive upset, potentially due to insufficient peNDF within the diet (Yang and Beauchemin, 2009). With both treatments being balanced for peNDF, it is assumed that differences in nutrient composition, fermentation, and passage rate potentially produced the changes observed in the FCS of the cattle.

Upon arrival to the feedlot, cattle had the lowest overall FCS compared with all other periods (CON, FCS = 2.94; CTN, FCS = 3.01). This was not unexpected due to cattle grazing forage before arrival. Between d 0 and 28, there was no difference in FCS for cattle consuming either treatment (Table 9; $P \geq 0.67$). This was expected as cattle were receiving the same RCV diet for 10 d and respective treatment step 1 and 2 for a total of 14 d. However, there was a difference in FCS on d 42 with cattle consuming the CON treatment having a greater FCS ($P = 0.03$). It should be noted that all cattle were transitioned to the final experimental treatment diets by d 38, 4 d before d-42 collection. Between d 56 and 140, no differences in FCS were detected ($P \geq 0.12$). The FCS at the beginning of β-agonist feeding and before shipping were greater ($P < 0.01$) in cattle fed the CON treatment. Although a difference in FCS was present between cattle fed the CON and the CTN treatments during the β-agonist feeding period and before shipping, the difference may be of limited biological significance given the sensitivity of the scale used (Table 9) and a lack of observed differences in rumen health indicators such as incidence of acidosis or low rumen pH. The overall FCS change was greatest for cattle consuming the CON treatment with an overall change of 0.69 (Table 9; $P = 0.06$). Cattle consuming the CON treatment also tended to have a greater FCS change from d 43 to 56 ($P = 0.09$). These results are similar to those of Warner et al. (2020a), where cattle fed the cotton byproduct diet had a numerically greater FCS until d 28 and cattle fed the control diet had a greater or numerically greater FCS for the remainder of the experiment.

Table 8. Influence of using whole cottonseed in place of dried distillers grains plus solubles and prairie hay in finishing rations balanced for physically effective NDF on feed intake and efficiency of feedlot heifers and steers

	Treatment[1]			
Item	**CON**	**CTN**	**SEM[2]**	***P*-value**
DMI,[3] kg/d				
d 0 to 14	6.1	5.8	0.12	0.03
d 15 to 28	11.2	11.1	0.25	0.62
d 29 to 42	12.0	11.7	0.35	0.37
d 43 to 56	14.0	12.3	1.18	0.35
d 57 to 84	11.1	10.3	1.03	0.58
d 85 to 112	10.2	10.3	0.33	0.89
d 113 to 140	10.3	10.1	0.29	0.35
Beta-agonist to final	11.1	10.9	0.40	0.68
d 140 to final	11.1	10.9	0.30	0.56
d 0 to final	10.8	10.4	0.36	0.49
DMI,[4] % of BW				
d 0 to 14	1.84	1.73	0.094	0.06
d 15 to 28	3.14	3.05	0.143	0.32
d 29 to 42	3.07	2.92	0.105	0.20
d 43 to 56	3.32	2.89	0.249	0.25
d 57 to 84	2.48	2.26	0.229	0.45
d 85 to 112	2.15	2.09	0.078	0.31
d 113 to 140	2.02	1.92	0.070	0.08
Beta-agonist to final	1.87	1.79	0.056	0.05
d 140 to final	1.94	1.85	0.054	0.04
d 0 to final	2.37	2.24	0.090	0.23
G:F[5]				
d 0 to 14	0.073	0.086	0.0236	0.42
d 15 to 28	0.253	0.286	0.0124	<0.01
d 29 to 42	0.175	0.171	0.0073	0.76
d 43 to 56	0.112	0.151	0.0103	0.02
d 57 to 84	0.122	0.172	0.0330	0.30
d 85 to 112	0.071	0.082	0.0055	0.17
d 113 to 140	0.324	0.353	0.0185	0.24
Beta-agonist to final	0.125	0.143	0.0164	0.01
d 140 to final	0.121	0.135	0.0106	0.19
d 0 to final	0.130	0.148	0.0063	0.05

[1]Treatments included (DM basis) CON = 7.73% hay, 15.00% dry distillers grains plus solubles, 65.52% dry-rolled corn, and 6.00% liquid supplement, or CTN = 15.00% whole cottonseed, 73.25% dry-rolled corn, and 6.00% molasses. Both diets contained 5.00% dry supplement and 0.75% urea.

[2]n = 6 pens per treatment—3 pens of heifers and 3 pens of steers per treatment.

[3]Pen DMI were calculated from pen as-fed intake for period multiplied by the treatment diet DM percentage.

[4]Dry matter intake as a percentage of BW was calculated by dividing the pen average DMI for the period by the average of the beginning and ending BW (mean feeding BW) for that period.

[5]The G:F was calculated by dividing pen ADG by pen daily DMI for each period.

Although peNDF was balanced between roughage and byproduct sources within the treatment diets, potential correlation between ingredient particle size and FCS when feeding a TMR could help explain the overall greater FCS for cattle consuming the CON treatment (Melendez and Roy, 2016). When determining peNDF, prairie hay had the greatest particle percentage collect on the 18.0-mm sieve, and DDGS had the greatest particle percentage collect on the 4.0-mm sieve, whereas WCS had the overall greatest particle percentage of any sieve collected on the 8.00-mm sieve (Table 1). Although prairie hay and WCS are both viable sources of peNDF based on the accepted

Table 9. Influence of using whole cottonseed in place of dried distillers grains plus solubles and prairie hay in finishing rations balanced for physically effective NDF on fecal scores of feedlot heifers and steers

	Treatment[1]			
Item	**CON**	**CTN**	**SEM[2]**	***P*-value**
Fecal score[3]				
d 0	2.94	3.01	0.112	0.69
d 14	3.45	3.43	0.048	0.67
d 28	3.49	3.52	0.123	0.88
d 42	3.33	3.12	0.065	0.03
d 56	3.31	3.25	0.036	0.24
d 84	3.36	3.21	0.086	0.12
d 112	3.32	3.19	0.077	0.23
d 140	3.35	3.29	0.134	0.70
Beta-agonist[4]	3.45	3.21	0.090	<0.01
Final[5]	3.56	3.32	0.055	<0.01
Fecal score change[6]				
d 0 to 14	0.504	0.420	0.130	0.66
d 15 to 28	0.049	0.094	0.139	0.82
d 29 to 42	−0.168	−0.399	0.124	0.22
d 43 to 56	−0.021	0.123	0.060	0.09
d 57 to 84	0.056	−0.035	0.077	0.41
d 85 to 112	−0.040	−0.025	0.099	0.92
d 113 to 140	0.025	0.105	0.153	0.68
Beta-agonist to final	0.118	0.114	0.112	0.93
d 140 to final	0.179	0.032	0.135	0.10
d 0 to final	0.622	0.315	0.125	0.11

[1]Treatments included (DM basis) CON = 7.73% hay, 15.00% dry distillers grains plus solubles, 65.52% dry-rolled corn, and 6.00% liquid supplement, or CTN = 15.00% whole cottonseed, 73.25% dry-rolled corn, and 6.00% molasses. Both diets contained 5.00% dry supplement and 0.75% urea.

[2]n = 6 pens per treatment—3 pens of heifers and 3 pens of steers per treatment.

[3]Fecal score on a scale from 1 to 5, with a score of 5 indicating looser fecal consistency and a score of 1 representing a cow on dry hay.

[4]Cattle were slaughtered in 3 groups: d 178 (n = 4 pens total; 2 pens per treatment; 1 pen heifers and 1 pen steers per treatment), d 206 (n = 4 pens total; 2 pens per treatment; 1 pen heifers and 1 pen steers per treatment), and d 227 (n = 4 pens total; 2 pens per treatment; 1 pen heifers and 1 pen steers per treatment). Beta-agonist fecal scores were obtained the day the pens started ractopamine hydrochloride (Optaflexx 45; Elanco Animal Health), 31 d before slaughter.

[5]Final fecal scores were taken the day of shipping for slaughter.

[6]Change in collection is the difference between collection periods; subtract a later collection period from an earlier collection period.

definition of peNDF, there is still a difference in absolute particle size present between these 2 ingredients. The CTN treatment contained higher levels of dry-rolled corn and had only WCS to serve as a roughage source. With WCS having a smaller particle size than prairie hay and the roughage portion of WCS being associated with the seed itself, the differences in FCS are likely not strictly a function of peNDF, but potentially also the result of differences in roughage composition and site and extent of digestion. Reveneau et al. (2005) compared WCS processing methods and determined that decreasing the particle size of WCS through processing increased animal productivity potentially due to increasing the rate of passage. This could explain a lower FCS resulting from a slower passage rate of the unprocessed WCS within the CTN treatment compared with ingredients in the CON diet. Future research is needed to determine whether processing WCS to decrease particle size could alter site and extend of digestion.

There was no difference in fecal pH between cattle consuming the CON and CTN treatments on d 0, 28, or 42 (Table 10; $P \geq 0.54$) as the cattle were being transitioned to experimental finishing diet treatments. However, cattle fed the CON treatment tended to have a more neutral fecal pH on d 14 ($P = 0.08$). Because all cattle were on the same RCV diet for 10 d, this difference in fecal pH is not likely due to experimental treatments, unless this was a result of the intake difference observed during the first 14 d. On d 56 and 84, cattle fed the CTN treatment tended to have a more neutral fecal pH ($P \geq 0.06$). Similarly, on d 140 and at the final collection, cattle fed the CTN treatment had a more neutral fecal pH ($P < 0.01$). Fecal pH change differed from d 15 to 28 ($P = 0.02$) and tended to differ from d 113 to 140 ($P = 0.08$) with cattle consuming the CON treatment having a greater fecal pH change. Fecal pH change differed again during the β-agonist feeding period ($P = 0.02$), with cattle consuming the CTN treatment having a greater change toward a more neutral fecal pH. Warner et al. (2020a) reported no difference in fecal pH throughout the duration of the experiment but reported cattle consuming the diet containing WCS consistently had a numerically more neutral fecal pH.

The more acidic fecal pH in cattle fed the CON diet is interesting due to the CTN treatment having an assumed greater intake of starch due to the greater inclusion of

Table 10. Influence of using whole cottonseed in place of dried distillers grains plus solubles and prairie hay in finishing rations balanced for physically effective NDF on fecal pH of feedlot heifers and steers

	Treatment[1]			
Item	**CON**	**CTN**	**SEM[2]**	***P*-value**
Fecal pH				
d 0	6.98	7.03	0.072	0.54
d 14	6.77	6.71	0.030	0.08
d 28	6.27	6.29	0.035	0.67
d 42	6.27	6.30	0.052	0.69
d 56	6.13	6.29	0.059	0.07
d 84	6.10	6.24	0.047	0.06
d 112	6.45	6.50	0.054	0.53
d 140	6.15	6.37	0.038	<0.01
Beta-agonist[3]	6.40	6.47	0.045	0.09
Final[4]	6.45	6.63	0.026	<0.01
Fecal pH change[5]				
d 0 to 14	0.211	0.326	0.087	0.17
d 15 to 28	0.500	0.416	0.035	0.02
d 29 to 42	−0.001	−0.013	0.065	0.90
d 43 to 56	0.140	0.019	0.057	0.16
d 57 to 84	0.033	0.043	0.061	0.86
d 85 to 112	−0.351	−0.254	0.058	0.27
d 113 to 140	0.299	0.125	0.067	0.08
Beta-agonist to final	−0.050	−0.158	0.061	0.02
d 140 to final	−0.298	−0.254	0.050	0.49
d 0 to final	0.533	0.408	0.084	0.15

[1]Treatments included (DM basis) CON = 7.73% hay, 15.00% dry distillers grains plus solubles, 65.52% dry-rolled corn, and 6.00% liquid supplement, or CTN = 15.00% whole cottonseed, 73.25% dry-rolled corn, and 6.00% molasses. Both diets contained 5.00% dry supplement and 0.75% urea.

[2]n = 6 pens per treatment—3 pens of heifers and 3 pens of steers per treatment.

[3]Cattle were slaughtered in 3 groups: d 178 (n = 4 pens total; 2 pens per treatment; 1 pen heifers and 1 pen steers per treatment), d 206 (n = 4 pens total; 2 pens per treatment; 1 pen heifers and 1 pen steers per treatment), and d 227 (n = 4 pens total; 2 pens per treatment; 1 pen heifers and 1 pen steers per treatment). Fecal pH were obtained the day the pens started ractopamine hydrochloride (Optaflexx 45; Elanco Animal Health), 31 d before slaughter.

[4]Final fecal pH were taken the day of shipping for slaughter.

[5]Change in collection is the difference between collection periods; subtract a later collection period from an earlier collection period.

dry-rolled corn. Wheeler and Noller (1977) reported that a decrease in fecal pH was associated with increased levels of starch within the feces where lower levels of starch indicate a further extent of starch digestion. Although treatments were not analyzed for starch levels, the CTN treatment contained more dry-rolled corn (72.1 ± 3.18% starch; NASEM, 2016) compared with the CON treatment (Table 5). The more acidic fecal pH for cattle consuming the CON treatment suggests that fecal pH may not strictly be a function of starch digestion (Gentry et al., 2016) but potentially a result of increased passage rate of the smaller particles within the diet, thus leading to increased hindgut fermentation and lower fecal pH.

Plasma Metabolites

No treatment × day interaction ($P \geq 0.70$) was detected for plasma glucose, lactate, PUN, or NEFA concentrations (Table 11). Cattle consuming the CON treatment had greater PUN concentrations ($P < 0.001$) and tended to have greater plasma lactate concentrations ($P = 0.06$). No treatment effect was observed for plasma glucose or NEFA ($P \geq 0.24$). A day effect was observed for all analyzed metabolites ($P < 0.001$). The greatest plasma glucose concentrations were observed on d 14 (99.6 mg/dL), before gradually decreasing until d 84 when the glucose concentrations began to increase through the final collection. Plasma lactate was greatest on d 14 (0.54 g/L) but fluctuated in concentration for the remainder of the experiment. The concentration of PUN was lowest on d 0 (0.75 mmol/L) and increased in concentration until d 84. The NEFA concentrations were greatest on d 0 (671.6 μEq/L) and decreased until d 28 with subsequent increase on d 56.

According to Cao et al. (2021), increasing amounts of peNDF can potentially increase plasma glucose concentrations. This may help explain the results of the current experiment where no difference in plasma glucose was observed between treatments when diets were balanced for peNDF. Warner et al. (2020a) also reported no difference in plasma glucose or lactate when cattle fed a control diet were compared with cattle fed a diet containing cotton byproducts during finishing. However, Warner et al. (2020a) did report a treatment × day interaction for PUN where cattle fed the control treatment had a greater PUN concentration on d 28 and 56. Low concentrations of PUN on d 0 could be a result of low feed intake before and during shipping. Cattle fed the CON treatment having greater concentrations of PUN may be due to observed differences in carcass composition (Table 6).

Elevated NEFA concentrations are commonly a result of fat mobilization in response to stress or a negative energy balance (Drackley, 2000; Kang et al., 2017). As a result, it would be expected that the highest NEFA concentrations would occur on d 0 after transportation, feed restriction, and feeding a low-quality forage upon arrival. After a decrease in NEFA concentration from d 0 and 28, the NEFA concentrations increased on d 42 and again on d 84 and

Table 11. Effects of using whole cottonseed in place of dried distillers grains plus solubles and prairie hay in finishing rations balanced for physically effective NDF on plasma metabolite concentrations of feedlot heifers and steers

	Treatment[2]				Days on feed									
Variable[1]	CON	CTN	SEM[3]	*P*-value	0	14	28	42	56	84	112	140	Beta-agonist[4]	Final[5]	SEM[3]	*P*-value
Glucose, mg/dL	92.7	86.1	4.72	0.24	91.5^{b}	99.6^{a}	97.8^{a}	87.1^{bc}	82.1^{c}	82.8^{c}	84.1^{c}	87.3^{bc}	90.5^{b}	91.1^{b}	7.12	<0.0001
Lactate, g/L	0.47	0.35	0.049	0.06	0.49^{ac}	0.54^{a}	0.43^{bcd}	0.34^{ef}	0.31^{f}	0.38^{de}	0.43^{bd}	0.35^{ef}	0.49^{ab}	0.37^{def}	0.06	<0.0001
PUN, mmol/L	1.46	1.24	0.04	<0.001	0.75^{d}	1.05^{c}	1.04^{c}	1.09^{c}	1.82^{a}	2.03^{a}	1.32^{a}	1.53^{b}	1.42^{b}	1.45^{b}	0.10	<0.0001
NEFA, μEq/L	223.9	215.5	16.7	0.72	671.6^{a}	183.7^{cd}	140.7^{ef}	155.6^{de}	129.5^{f}	130.2^{f}	245.3^{b}	180.0^{c}	186.3^{c}	174.4^{cd}	38.0	<0.0001

$^{a–f}$Values within row with unlike subscripts differ ($P \leq 0.05$).

[1]PUN = plasma urea nitrogen; NEFA = nonesterified fatty acids.

[2]Treatments included (DM basis) CON = 7.73% hay, 15.00% dry distillers grains plus solubles, 65.52% dry-rolled corn, and 6.00% liquid supplement, or CTN = 15.00% whole cottonseed, 73.25% dry-rolled corn, and 6.00% molasses. Both diets contained 5.00% dry supplement and 0.75% urea.

[3]n = 6 pens per treatment—3 pens of heifers and 3 pens of steers per treatment.

[4]Beta-agonist plasma was obtained the day the pens started ractopamine hydrochloride (Optaflexx 45; Elanco Animal Health), 31 d before slaughter.

[5]Cattle were slaughtered in 3 groups: d 178 (n = 4 pens total; 2 pens per treatment; 1 pen heifers and 1 pen steers per treatment), d 206 (n = 4 pens total; 2 pens per treatment; 1 pen heifers and 1 pen steers per treatment), and d 227 (n = 4 pens total; 2 pens per treatment; 1 pen heifers and 1 pen steers per treatment).

140, with the greatest NEFA concentration increase occurring from d 84 to 112 (Table 11). With no difference in glucose and NEFA concentrations between cattle fed the treatment diets, it is presumed that both diets supplied sufficient energetic nutrients to result in sufficient body reserve turnover (van Knegsel et al., 2007).

Carcass Traits

Consistent with the tendency observed in greater final live BW (Table 7; $P = 0.10$), cattle fed the CTN treatment also had greater HCW (Table 6; $P = 0.02$). Although cattle consuming both treatments had similar DP ($P = 0.88$), cattle fed the CTN treatment had greater fat thickness ($P = 0.05$) and final calculated USDA YG ($P = 0.001$). There was no difference in REA or marbling score between cattle fed either treatment ($P \geq 0.67$).

Results from the carcass data are in contrast to the results of Cranston (2003), who reported no difference in HCW, fat thickness, or USDA YG but a difference in DP and marbling score when comparing cattle fed a diet containing WCS to cattle fed a more typical feedlot diet balanced for NDF and fat. The carcass results in the current experiment are in agreement with those of Huerta-Leidenz et al. (1991), who reported that cattle fed a finishing diet containing 15% WCS had a greater USDA YG compared with cattle fed a control diet. The results from the current experiment are also in agreement with the results of Warner et al. (2020a), where the inclusion of WCS and cotton gin trash compared with a control diet resulted in cattle having no difference in REA or marbling score but greater HCW and fat thickness and a tendency for a greater DP.

The similarity in the BW, ADG, HCW, and fat thickness results from the current experiment and the experiment by Warner et al. (2020a) is most likely due to the difference in fat content or other aspects of WCS in the experimental treatment diets of both experiments. Within each experiment, the treatment diets were similar in overall energy content based on NASEM (2016) calculations. However, the diet containing WCS in each experiment contained a greater overall fat content. It is possible that these NASEM (2016) energy calculations or those energy calculations used by commercial laboratories potentially undervalue the fat content or other nutritional aspects of WCS in these energy calculations. In an experiment evaluating the ruminal degradability and metabolism of feedlot diets with or without cotton byproducts, Warner et al. (2020b) reported increased ruminal acetate proportions in steers consuming a diet containing cotton byproducts compared with a control diet. Warner et al. (2020b) speculated that this difference in acetate production resulted in an increase in s.c. fat accretion in cattle fed WCS.

According to Rhoades et al. (2007), acetate primarily increases the deposition of s.c. fat compared with i.m. fat, which supports the differences reported by Warner et al. (2020a) and observed in the current experiment. This increase in acetate production and a subsequent increase in fat thickness could explain why cattle consuming the CTN treatment had greater fat thickness (0.14 cm greater; $P = 0.05$) with no difference in REA or DP ($P \geq 0.67$), in the current experiment. In addition, with cattle being fed the CTN treatment having more s.c. fat but no difference in marbling score, it appears that cattle fed the CTN treatment also shifted more fat deposition to s.c. and perhaps intermuscular depots instead of into i.m. fat. This increased carcass fat resulted in a 17-kg increase in HCW (Table 6) for cattle consuming the CTN treatment, which accounted for over 80% of the difference observed in final BW (21 kg; Table 7). This repartitioning of the retained energy as s.c. fat suggests that cattle potentially retained more energy from the CTN treatment and that excess energy was preferentially stored as s.c. fat.

APPLICATIONS

The objective of this experiment was to determine the effects of replacing prairie hay and DDGS with WCS in diets balanced for peNDF on growth, intake, feed efficiency, carcass characteristics, and plasma metabolites of finishing cattle. Animals receiving the CTN treatment had improved performance compared with animals receiving the CON treatment, with greater ADG and no difference in DMI, resulting in overall greater G:F. The FCS were greater and fecal pH were more acidic for cattle fed the CON treatment after animals were fully transitioned onto experimental treatment diets. Cattle fed the CON treatment had greater PUN concentrations and a tendency for greater plasma lactate concentrations, suggesting the potential for greater glucose metabolism and AA catabolism in cattle fed the CON treatment. There was no difference in REA, DP, or marbling score between treatments, but cattle fed the CTN treatment had a greater HCW, fat thickness, and USDA YG.

This experiment suggests that WCS can effectively replace the roughage supplied by prairie hay and the protein and fat supplied by DDGS within finishing feedlot diets while simultaneously resulting in increased growth and feed efficiency. With constant price fluctuations and variability in availability of commodities, these results provide an alternative feeding strategy for finishing cattle with the replacement of 2 commonly used commodities with a single commodity while maintaining or increasing animal performance in the feedlot.

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