Evaluation of active dried yeast in the diets of feedlot steers. I. Effects on feeding performance traits, the composition of growth, and carcass characteristics¹

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ABSTRACT: The use of active dried yeast (ADY) in the diets of feedlot steers may improve feed efficiency, growth performance, and reduce days on feed. Strategic timing of ADY inclusion in the diet may increase feed conversion or aid in the dietary transition from growing to finishing diets. One hundred twenty steers, blocked by weight, were fed four diets for 164 d: grower (70 d), first transition diet (7 d), second transition diet for (7 d), and finisher (80 d) in a GrowSafe System. Four treatment sequences of ADY inclusion were evaluated in a Balaam's design where steers were fed a control diet before and after the grower phase (CC), control before and ADY after the grower phase (CY), ADY before and control after the grower phase (YC), and ADY before and after the grower phase (YY). A random coefficients model was used to evaluate the following variables of interest: feeding performance and growth traits, including biometric measurements and carcass ultrasound measurements, and carcass characteristics. Treatment was a fixed effect and block was a random effect. Treatment did not affect feeding performance or behavior ($P \geq 0.14$). The rate of change of biometric measurements were not different ($P \geq 0.16$) across treatment groups except

for rib girth circumference, which was greater for the YY and CY groups intermediate for the CC group and least for the YC group (0.828 and 0.809 vs. 0.751 vs. 0.666 cm/d, respectively; $P < 0.01$). Faster growth rates of rib girth circumference resulted in larger final measurements for steers that were finished on ADY ($P < 0.01$). Ultrasound measurements (backfat, LM area, intra-muscular fat, and rump fat) were not different across treatments ($P \geq 0.15$). However, there was a tendency for the YC group to have a slower rate of back fat deposition than other treatment groups ($P = 0.09$). Steers' final shrunk BWs did not differ ($P = 0.61$), but shrink percentage was greater for CC than for YY groups (3.7% vs. 2.7%, respectively; $P = 0.05$). Carcass characteristics were not different across treatments ($P \geq 0.20$). Crude fat, CP, ash and moisture analyses of the 9th to 11th rib section were not different across treatments, and there was no difference in adjusted final shrunk BW ($P \geq 0.45$). Feeding the ADY strain used in this study to growing and finishing feedlot steers increased rib girth circumference development rate and reduced shrink loss without affecting feeding behavior, feeding performance, or carcass characteristics.

Key words: beef cattle, development, feed additives, yeast

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INTRODUCTION

The use of active dried yeast (ADY), specifically *Saccharomyces cerevisiae*, has been proposed as a growth promoting feed additive for use in the diets of feedlot cattle to potentially replace the use of antibiotics in their diets (Broadway et al., 2015). Extensive research has been conducted on the effects of ADY in the diets of dairy cattle with favorable performance outcomes including DMI and milk yield (Desnoyers et al., 2009; Humer et al., 2018). However, there have been few studies that isolate the effect of ADY from other feed additives to elucidate their true feeding value in the diets of growing and finishing steers. Recently, Crossland et al. (2018) fed ADY in the diets of finishing steers and reported an improvement in digestibility, which consequently improved the available DE and ME to the animal.

Several studies that supplemented yeast to ruminant diets have documented improvements in the growth of lactic acid utilizing bacteria with subsequent reduction in lactic acid concentration in the rumen and the risk of rumen acidosis, stimulation of the growth of cellulolytic bacteria, and the removal of oxygen from the rumen (Shurson, 2018). Based on these observations, there is reason to believe that feeding ADY to beef cattle throughout the growing and finishing phase or by implementing ADY at strategic times of dietary stress during the feeding period may improve growth performance (e.g., feed conversion, ADG, and shrunk BW gain) and potentially reduce days on feed. Adding ADY during dietary transition or priming cattle before dietary transition is may improve feeding and growth performance during this time resulting in overall greater performance during the finishing phase. In addition to traditional growth performance indicators and carcass traits, the use of multiple collection of biometric and ultrasonic measurements during the feeding period may increase our understanding of the pattern of the composition of growth response to feed additives. The collection of such measurements has been used to estimate nutritional requirements, animal performance, and cost of production (Fisher, 1975; Tedeschi et al., 2004), but may also be used to recognize changes in body composition influenced by dietary modifications such as the inclusion of feed additives. Differences

in carcass composition may also be determined postmortem by the dissection of the 9th to 11th rib section for moisture, crude fat, CP, and ash percentage (Hankins and Howe, 1946).

The objective of this study was to determine the effects of adding ADY to the diets of feedlot steers using an automated intake system on (i) animal intake and feeding behavior traits, (ii) animal growth performance and biometrics, and (iii) carcass characteristics via ultrasound measurements, carcass traits, and the 9th to 11th rib section composition.

MATERIALS AND METHODS

Animal Description and Care

Animal procedures were approved by the Institutional Animal Care and Use Committee of Texas A&M University (Animal Use Protocol 2016-0269). One hundred twenty steers ($\frac{3}{4}$ *Bos taurus* × $\frac{1}{4}$ *Bos indicus*; BW = 254 ± 40 kg and age = 246 ± 32) born and raised at the McGregor AgriLife Research Center, McGregor, TX, were randomly selected from ~300 contemporaries, 30 d after weaning. Steers were assigned an radio frequency identification tag (Allflex USA Inc., Dallas, TX) and adapted to the GrowSafe feeding system (GrowSafe Systems Ltd., Airdrie, AB, Canada) for 21 d consuming a backgrounding diet before the commencement of the 164-d trial. Facilities included four pens, each equipped with four GrowSafe feed bunks ($n = 16$ feed bunks). Upon day -21, steers were blocked by BW according to the median BW, resulting in two pens of light and two pens of heavy BW steers (221 ± 26 and 288 ± 16 kg, respectively). Within blocks, steers were randomly assigned to one of two pens. At the commencement of the trial (day 0), animals' average BW in the light and heavy blocks were 253 ± 32 and 322 ± 21 kg, respectively.

Diets and Feeding

Steers were fed four diets over the course of the trial (Table 1) in two phases: growing (days 0 to 70) and finishing (days 71 to 164). Chemical analysis of the diet was performed by Cumberland Valley Analytical Services (Waynesboro, PA) on composite

Table 1. Ingredient and chemical composition of diets fed to growing steers with or without the inclusion of an active dried yeast

Items ¹	Diets ²							
	GROWER		STEP1		STEP2		FINISHER	
	CON	ADY	CON	ADY	CON	ADY	CON	ADY
% of the diet, DM								
Alfalfa hay	30	30	25	25	20	20	15	15
Cracked corn	40	40	50	50	60	60	70	70
Dried distiller's grain	20	17	15.5	12.5	10.5	7.5	5.5	2.5
Molasses	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Mineral ³	2.5	2.5	1	1	1	1	1	1
Limestone	0	0	1	1	1	1	1	1
Urea	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Premix ⁴		3		3		3		3
DM, % of the diet	82.7		82.5		82.3		82.2	
CP	16.3		14.9		13.3		11.8	
Soluble protein, % CP	21.4		20.7		19.9		19.1	
NDF	30.1		27.4		24.5		21.7	
ADF	20.2		17.6		15.0		12.4	
Lignin	4.4		3.8		3.3		2.7	
Crude fat	4.1		3.9		3.7		3.5	
Sugar	4.9		4.8		4.7		4.6	
Starch	29.0		35.8		42.5		49.2	
Ash	7.2		6.1		5.5		4.9	
Calcium	0.7		0.8		0.8		0.7	
Phosphorus	0.6		0.4		0.4		0.4	
peNDF ⁵	16		14		12		10	
TDN	76		78		80		82	
NEm, Mcal/kg	1.57		1.63		1.68		1.74	
NEg, Mcal/kg	1.00		1.05		1.10		1.14	

¹Items are feed ingredients and chemical composition of diets (DM basis) evaluated by Cumberland Valley Analytical Services (Hagerstown, MD).

²Diets are GROWER (fed days 1 to 70), STEP1 = transition step 1 (fed days 71 to 77), STEP2 = transition step 2 (fed days 78 to 85), FINISHER (fed days 86 to 164), CON = no active dried yeast supplement, ADY = control diet + 1.5 g/d of an active dried yeast (3×10^{10} CFU/d).

³Mineral: Proprietary blend of 17% calcium, 7% phosphorus, 2% sodium chloride, 1.5% magnesium, 850 ppm copper, 23 ppm selenium, 300,000 IU/lb vitamin A, 20,000 IU/lb vitamin D, and 200 IU/lb vitamin E.

⁴Premix was included in 3% of the diet where DDG was the carrier ingredient. The additive was Vistacell (AB Vista, Marlborough, UK) and its amount (g) was based on the average of the interquartile range of the previous week's DMI to allow for feed delivery containing 1.5 g of Vistacell per subject each day.

⁵peNDF (physically effective NDF = proportion of particles larger than 4 mm $\times$ NDF proportion of the diet).

batch samples, obtained weekly, within diets. The physically effective NDF was determined using the Penn State Particle Size separator and multiplying the proportion of particles >4 mm by the proportion of NDF in the diet (Heinrichs and Kononoff, 1996). The Large Ruminant Nutrition System (<http://www.nutritionmodels.com/lrns.html>; accessed on January 21, 2017; Tedeschi and Fox, 2018) was used to formulate the diets using the following ingredients: cracked corn, dried distiller's grain, an alfalfa hay (theoretical chop length of 15 mm), molasses, and mineral supplements (Table 1).

The grower diet (NEg of 1.0 Mcal/kg) was fed for 70 d to yield a mean BW of 365 kg between blocks at the time of dietary transition. The first

and second transition diets were fed for 7 d each (days 71 to 85), and the finishing diet (NEg of 1.14 Mcal/kg) was fed from days 86 to 164 to yield a final mean BW of 500 kg. Feed delivery occurred at ~0800 and 1700 hours, and feed calls allowed for 5% residual orts for ad libitum intake of the diet.

Treatment Assignment

Pens, within a weight block, were assigned to receive either control (CON) or diets supplemented daily with ~1.5 g/d (3×10^{10} CFU/d) of ADY, *S. cerevisiae* (Vistacell, AB Vista, Marlborough, UK) per the label recommended dosage for growing beef cattle. To ensure proper daily dosage of ADY under

an ad libitum feeding scenario, individual intake was downloaded weekly from the GrowSafe Feed Intake System, and the interquartile mean of DMI between blocks was used to formulate a fresh pre-mix to allocate ~1.5 g/d of ADY per steer throughout the trial. Treatment was the sequence of ADY supplementation, as follows. On day 70, at the conclusion of the grower phase, 15 steers from each pen were randomly exchanged within their block to the opposite pen to proceed through the dietary transition (days 71 to 164) with or without ADY. This exchange yielded four TRT assignments: steers fed CON before and after the exchange (CC), steers fed CON before and ADY after the exchange (CY), steers fed ADY before and CON after the exchange (YC), and steers fed ADY before and after the exchange (YY).

Data Collection

Steers were weighed on day 0 and every 2 wk thereafter, before the morning feeding (0800 hours), except for the final weight in which only 10 d elapsed between weighing events. Data from the GrowSafe Feed Intake System were used to model growth rates and feeding performance by linear regression against the days of trial with an average coefficient of determination of 0.986. The regression coefficients were used to compute mean initial (day 0), mid-test (day 84), and final BW (day 164); mean metabolic BW (MBW); and ADG. As-fed feed intake data were converted to DM based on the chemical analysis of the diet. Residual feed intake (RFI) was computed as the difference between actual DMI and the predicted DMI from its regression on MBW and ADG. G:F was calculated as ADG divided by DMI. Feeding behavior traits

(meal frequency, meal size, and bunk visit duration and meal criterion) were obtained as described by Mendes et al. (2011), and they were used to compute meal criteria for each animal using the Meal Criterion Calculation (MCC) software (<http://nutritionmodels.tamu.edu/mcc.html>; accessed on July 25, 2018), which uses the R software (R Core Team, 2017) and the *mixdist* package to determine meals within bunk visits (Bailey et al., 2012). The MCC v. 1.7.6788.20669 was used for calculations and the R script from August 2, 2018 that has adjustments for ghost events and missing nonfeeding intervals (i.e., missing feedbunk visit intervals).

Growth variables consisted of BW, biometric measurements, and carcass ultrasound. Carcass ultrasound and biometric measurements were taken at least three times (initial, mid-test, and final/pre-slaughter) throughout the feeding period. Growth variables were modeled using linear regression against the days of trial. Biometric data collection was achieved following the description by Fernandes et al., (2010) and de Paula et al. (2013), using a large adjustable caliper (Hipômetro Bengala, Walmur, Porto Alegre, Brazil) and a flexible ribbon, measuring tape. Table 2 lists each measurement along with descriptive statistics. At the end of the feeding trial, a final shrunk BW (SBW) was taken after an 18 h fast and 12 h restriction from water and percent BW shrink was calculated.

Real-time ultrasound measurements for body composition traits were collected by an Ultrasound Guidelines Council certified technician using an Aloka 500V instrument with a 17-cm, 3.5-MHz transducer (Aloka Co. Ltd., Wallingford, CT) to collect LM area (uLMA), back fat thickness (uBF), intramuscular fat (uIMF) between the 12th and 13th rib, rump fat thickness (uRUMP) (Realini

Table 2. Description of biometric measurements and descriptive statistics of final body measurements

Items ¹	Mean	SD	CV, %	Minimum	Maximum	r ²
M1 Shoulder height, cm	114	3.81	3.33	104	123	0.955
M2 Rib depth, cm	65.3	2.89	4.42	58.1	73.8	0.916
M3 Body diagonal length, lateral point of shoulder to pelvic hook, cm	96.6	6.15	6.37	83.6	114	0.882
M4 Body length, the dorsal point of shoulder to pelvic hook, cm	78.3	4.53	5.79	66.9	90.3	0.921
M5 Pelvic girdle length (hook to pin), cm	41.5	3.05	7.34	35.4	49.5	0.677
M6 Rump depth, cm	60.5	3.30	5.46	53.5	69.3	0.884
M7 Hip height, cm	126	4.78	3.81	107	137	0.943
M8 Pin width, cm	31.2	2.40	7.70	26.4	38.1	0.723
M9 Hook width, cm	46.5	2.38	5.13	39.0	53.0	0.928
M10 12th/13th rib width, cm	57.1	4.12	7.22	47.0	73.7	0.932
M11 Rib circumference, cm	166	23.6	14.2	91.8	196	0.830

¹Items are measurements taken on finishing steers adapted from the illustrations by Fernandes et al. (2010).

²Statistics includes the mean across treatments; minimum and maximum across treatments; and coefficient of determination of the regression of the variable on the day of the trial.

et al., 2001) as well as kidney fat depth (Ribeiro and Tedeschi, 2012). Images were collected and stored using the Ultrasound Image Capture System (The Centralized Ultrasound Processing Lab (CUP Lab), Ames, IA). Images were then submitted to the CUP Lab for interpretation by UGC certified technician.

Post-mortem data were collected at Kane Beef (Corpus Christi, TX). Carcass characteristics were measured by trained personnel from Texas A&M AgriLife Research and Extension and Texas A&M University—Kingsville, and included hot carcass weight (HCW), backfat thickness, LM area (LMA), yield grade (YG), and quality grade (QG). A subset of steers ($n = 64$, stratified by TRT) were randomly selected for 9th to 11th rib dissection according to the protocol by Hankins and Howe (1946) to estimate carcass water, protein, fat, and ash. The 6th to 12th rib section was removed from the right side of the carcass in the subset group. To ensure uniformity across different carcass weights, anatomical reference points were used to scale incision points for rib removal. Briefly, to separate the rib from the plate, a cut was made on the ventral side of the carcass, crowding the anterior side of the 6th rib, being parallel with the shank and extending to approximately two-thirds the distance to the dorsal side of the carcass. A line was made with an aluminum yardstick from the point of the split vertebra of the 12th rib to the rib-end cartilage of the 13th rib. At 61.5% of the distance of that line starting from the vertebra, a *t*-square ruler was used to make a perpendicular cut to the line extending to the outer circumference of the carcass. The cut was extended from the 12th to the 6th rib and the rib section removed (Shackelford et al., 1995). Whole rib sections were vacuum packaged and shipped to Texas A&M University for further processing.

The 9th to 11th rib section was detached from the whole rib by performing two cuttings adjacent to the posterior side of the 8th rib and the posterior side of the 11th rib. Then, the soft tissue of the 9th to 11th rib section was removed and separated into lean and fat proportions, and weighed. The lean and fat proportions were then rejoined and the soft tissue was course ground twice through a 0.25 cm diameter screen plate and twice through a 0.125 cm diameter screen plate. The homogenized ground sample was subsampled and frozen at -4°C until further chemical analysis. Subsamples were thawed and used for determination of moisture (method #934.01), crude fat (method #920.39), CP (method #992.15), and ash (method #923.03) based on AOAC (2012).

Calculations

Several equations were used to compare carcass composition using different regression approaches and combinations, as discussed by Tedeschi and Fox (2018). The empty BW (EBW) was calculated from the final SBW where $\text{EBW} = \text{SBW} \times 0.891$ (Garrett and Hinman, 1969) as well as the method by Garrett et al., (1978) (EBW_c) using the HCW, where $\text{EBW}_c = (1.316 \times \text{HCW}) + 32.29$. The chemical analysis of the 9th to 11th rib section, assumed to be representative of the total carcass fat (Hankins and Howe, 1946; Dikeman, 2013), was used to calculate the empty body fat (EBF) where ether extract from the 9th to 11th rib section and carcass fat are used interchangeably and $\text{EBF} = 0.9246 \times \text{carcass fat} - 0.647$ (Garrett and Hinman, 1969). Other models which calculate EBF using frequently measured carcass characteristics (EBF_c) were also calculated where $\text{EBF}_c = ((0.351 \times \text{EBW} + 21.6 \times \text{YG} - 80.8) / \text{EBW}) \times 100$ (Perry and Fox 1997) or $\text{EBF}_c = 17.76207 + 4.68142 \times \text{fat thickness} + 0.81855 \times \text{quality grade code} - 0.06754 \times \text{LMA}$ (Guiroy et al., 2001). Adjusted final SBW (AFSBW) was calculated using the EBW and EBF to determine the optimal slaughter weight to achieve 28% EBF (or USDA low-choice QG) using equations from Perry and Fox (1997) where $\text{AFSBW} = (\text{EBW} + (28 - \text{EBF}) \times 19) / 0.891$ or from Guiroy et al. (2001) where $\text{AFSBW} = (\text{EBW} + (28 - \text{EBF}) \times 14.26) / 0.891$.

Statistical Analyses

Three steers in the heavy block (two from the YY group, one of which was designated for rib dissection, and one from the YC group) were removed from the analysis due to illness. Therefore, $n = 63$ for the analysis of the composition of 9th to 11th rib dissection and $n = 117$ for growth performance, feeding behavior, and carcass traits and characteristics. Unfortunately, during the assignment of animals, the CY group contained one additional steer intended to be in the CC group. However, this did not exceed the GrowSafe System user recommended number of head per bunk. Steers per bunk were 7.25, 7.75, 7.25, and 7.0 for CC, CY, YC, and YY, respectively, and GrowSafe Systems recommends not exceeding 8.

Growth performance, feeding behavior, and carcass characteristics. The feeding trial was designed as a four sequence (CC, CY, YC, and YY) Balaam's design with a random variable of arrival weight block (heavy, HVY, and light, LT; $n = 2$). It was

unknown a priori if the effect of yeast would elicit any carry-over effects. Therefore the Balaam's design was chosen to be the most suitable statistical design as it is strongly balanced so that the treatment difference is not confounded with differential first-order carryover effects (Chow and Liu, 1992; Mori and Kano, 2015). Additionally, the uniformity of equal representation of TRT within the period (growing or finishing phases) of the Balaam's design allows for the removal of the period effect to ascertain the effect of sequence resulting in the final model which was analyzed using the PROC MIXED of SAS (SAS Inst. Inc., Cary, NC):

$$Y_{ij} = \mu + \text{TRT}_i + b_j + e_{ij},$$

where Y is the variable of interest for growth performance and feeding behavior (DMI, ADG, G:F, RFI, initial BW, mid-test BW, final BW, FSBW, BW shrink, and biometrics M1–M11, uBF, uLMA, uRUMP, uIMF, meal frequency, mean meal size, and bunk visit duration) and carcass characteristics (HCW, dressing percentage, 12th rib backfat thickness, LMA, calculated USDA YG, and marbling score, EBW, EBF, AFSBW), i = is the treatment (CC, CY, YC, and YY), j = is the weight block (HVY or LT), μ and TRT_i are fixed parameters such that the mean for the i th treatment is $\mu_i = \mu + \text{TRT}_i$, b_j is the random effect associated with the j th block, and e_{ij} is the random error associated with the experimental unit in block j that received treatment i . Growth, feeding performance, and behavior were analyzed for the total trial ($n = 164$) and the days spanning the dietary transition (days 56 to 106; $n = 50$ d).

Ordinal data (USDA Quality Grade, USDA Yield Grade) were analyzed using the χ^2 test of probability and the strata of the block effect in the PROC FREQ of SAS (SAS Inst. Inc., Cary, NC), observing the Mantel–Haenszel statistic. The distribution of data count is provided for reference and was discussed as significant at $P < 0.05$ and tendencies discussed at $0.05 < P < 0.10$.

RESULTS AND DISCUSSION

Growth Performance and Feeding Behavior

Feeding and behavior. The effects of treatment on the feeding performance and behavior for the total feeding period ($n = 164$ d) and transition period ($n = 50$ d) are shown in Table 3. Analysis of the total feeding period revealed the feeding performance variables initial BW, mid-test BW, final

BW, ADG, DMI, G:F, and RFI were not different across treatment groups ($P \geq 0.60$). Feeding behavior traits, meal frequency, meal size, meal criterion, and bunk visit duration were also *not different* ($P \geq 0.14$). Within the scope of the transition period feeding performance, variable analysis was not different from the total feeding period ($P \geq 0.17$).

While the means for ADG and G:F numerically favored the CY and YY group ($P \geq 0.37$; Table 3), the variation within these groups was larger than expected (CV between animals for ADG and G:F were 25% and 34%, respectively). Therefore, differences were undetectable with the current sample size. In a previous study, Crossland et al. (2018) reported that steers consuming twice the dosage (3 g/d) of the same strain of ADY on a finishing diet similar to the current study had 2.4% greater DMD than steers consuming control diet, thereby increasing the available digestible and ME available to the steers. Another study using the same ADY strain investigated two levels (1.33 g and 2.66 g/d) fed to 144 steers in a finishing diet and did not detect an effect on DMI, ADG, or G:F (Ovinge et al., 2018). In a study by Hinman et al. (1998), seventy-two steers were fed 84 g/d of a live yeast culture for the first 28 d of the finishing period and 28 g/d for the remaining 85 d and found that yeast-fed steers had 6.9% greater ADG and 4.5% greater feed efficiency. Valdés-García et al. (2011) fed 60 heifers a finishing diet for 63 d using supplementation levels of 0, 10, 20, and 30 g/d of a chromium enriched live yeast and found a linear effect on ADG, feed efficiency, and improvements in the NE available for maintenance and gain without affecting DMI. Although the colony forming units of the yeast cultures used in the latter two studies are not known, the findings may allude to a dose-dependent effect size to identify benefits of feeding performance. Further investigation is warranted into how ADY affects steers during dietary transition and long-term feeding plan.

Biometric measurements. The biometric analysis is presented in Table 4 for the measurements of shoulder height, cm, rib depth, cm, body diagonal length, lateral point of shoulder to pelvic hook, cm, body length, dorsal point of shoulder to pelvic hook, cm, pelvic girdle length (hook to pin), cm, rump depth, cm, hip height, cm, pin width, cm, hook width, cm, 12/13th rib width, and rib circumference, cm. The linear rate of change of each body measurement within each treatment group was not different ($P \geq 0.16$) with the exception of k of rib circumference ($P < 0.01$). There were no treatment

Table 3. Effect of feed treatment regimen on feedlot performance and eating behavior of growing and finishing steers

Items ¹	Treatments ²				SEM	P-value
	CC	CY	YC	YY		
Transition period³						
<i>n</i> = 50 d						
Initial BW, kg	374	366	370	372	36.7	0.73
Final BW, kg	447	444	445	449	33.3	0.94
ADG, kg/d	1.34	1.46	1.38	1.44	0.088	0.60
DMI, kg/d	11.6	11.6	11.4	11.6	0.376	0.80
G:F	0.115	0.122	0.111	0.127	0.013	0.37
RFI, kg/d	0.026	0.095	−0.026	−0.063	0.144	0.87
Meal frequency	8.47	8.68	8.89	8.76	0.398	0.82
Meal size, kg/meal	1.43	1.38	1.33	1.38	0.082	0.64
Bunk visit DUR, min/d	137	140	123	124	6.74	0.17
Meal criterion, min	8.35	8.91	8.09	8.90	0.705	0.65
Total feeding⁴ period						
<i>n</i> = 164 d						
Initial BW, kg	296	291	296	294	36.5	0.91
Mid-test BW, kg	429	424	425	432	33.4	0.70
Final BW, kg	500	492	490	500	30.7	0.60
ADG, kg/d	1.31	1.30	1.27	1.33	0.044	0.69
DMI, kg/d	11.1	11.1	10.8	11.1	0.420	0.68
G:F	0.119	0.118	0.118	0.120	0.007	0.94
RFI, kg/d	0.050	0.061	−0.097	−0.013	0.1319	0.82
Meal frequency	8.21	8.33	8.47	8.45	0.349	0.91
Meal size, kg/meal	1.42	1.39	1.34	1.38	0.086	0.70
Bunk visit DUR, min/d	138	137	125	121	6.41	0.14
Meal criterion, min	8.34	9.06	8.43	8.78	1.00	0.75

¹Items are performance variables of growing steers. Mid-test BW = BW on day 84; G:F = gain to feed; RFI = residual feed intake, kg/d; DUR = duration of feeding time; meal criterion = longest non-feeding interval considered to be part of a meal.

²Treatments are CC = control, no ADY fed throughout the transition; YY = yeast fed throughout the entire transition; CY = control fed during the grower diet and transitioned onto diets containing yeast; YC = yeast fed during the grower diet and transitioned onto diets without yeast.

³Transition period includes days 56 to 106 during the dietary transition from grower to finisher diets.

⁴Total feeding period: initial BW is day 0, mid-test BW is day 84, final BW is day 164.

effects for the biometrics shoulder height, rib depth, dorsal point of shoulder to pelvic hook, rump depth, hip height, pin width or 12/13th rib width at initial, mid-test or final measurement ($P \geq 0.13$). The rate of body diagonal length change was not affected by treatment ($P = 0.27$); however, by the final measurement there was a tendency ($P = 0.08$) for steers in the CY group to be shorter than the CC, YC, and YY groups (94.6 vs. 96.6, 97.3, and 98.4 cm, respectively). Likewise, the pelvic girdle length change was not affected by treatment ($P = 0.24$) but there were differences between the final measurements where steers in the CC, CY, and YY groups were larger than the YC group (42.4, 41.6, 41.9 vs. 40.4 cm, respectively; $P = 0.05$). However, it should be noted here that the coefficient of determination for this measurement was lower than expected ($r^2 = 0.68$) when compared with other measurements and it does not seem reasonable that

this measurement would decrease over time for the YC group (-0.003 cm/d). Accurate identification of body markers is crucial for biometric measurement data. Posture as well as palpating for these markers become more difficult as animals accrue more body fat which may result in measurement errors especially around fat depots (Fisher, 1975; Fernandes et al., 2010). Indeed, pin width also featured the second lowest r^2 of 0.723 and this anatomical point was likely prone to errors in measurements. There was a tendency for the mid-test measurement of the pelvic hook width to be different between treatment groups where the CC group tended to be wider than the CY group (42.3 vs. 41.2 cm, respectively; $P = 0.08$). It is unclear at this time if there is any biological significance in this measurement, but it might be associated with hindquarter growth. There was a significant effect of treatment on the growth of the rib girth circumference of steers where the

Table 4. The effects of feed treatment regimen on biometrics of growing and finishing steers

Items ¹	Treatments ²				SEM	P-value
	CC	CY	YC	YY		
M1, cm						
<i>k</i> , cm/day	0.054	0.057	0.058	0.055	0.007	0.86
Initial	107	105	105	104	2.49	0.17
Mid-test	111	110	109	109	1.99	0.13
Final	115	114	114	114	1.54	0.24
M2, cm						
<i>k</i> , cm/day	0.054	0.053	0.048	0.060	0.009	0.16
Initial	56.7	56.5	56.9	56.1	2.34	0.66
Mid-test	61.2	60.8	60.8	61.0	1.62	0.89
Final	65.6	65.1	64.8	65.9	0.98	0.40
M3, cm						
<i>k</i> , cm/day	0.084	0.077	0.087	0.100	0.013	0.27
Initial	82.8	82.0	83.1	82.1	4.05	0.76
Mid-test	89.7	88.3	90.2	90.2	3.11	0.20
Final	96.6	94.6	97.3	98.4	2.31	0.08
M4, cm						
<i>k</i> , cm/day	0.080	0.084	0.079	0.085	0.008	0.90
Initial	65.2	64.6	64.6	65.0	2.70	0.96
Mid-test	71.8	71.5	71.1	72.0	2.29	0.81
Final	78.3	78.4	77.6	79.0	1.99	0.68
M5, cm						
<i>k</i> , cm/day	0.006	0.006	-0.003	0.008	0.004	0.24
Initial	41.4	40.5	40.9	40.5	1.31	0.53
Mid-test	41.9	41.0	40.7	41.2	1.17	0.12
Final	42.4 ^a	41.6 ^a	40.4 ^b	41.9 ^a	1.11	0.05
M6, cm						
<i>k</i> , cm/d	0.054	0.044	0.048	0.050	0.004	0.48
Initial	52.0	53.1	52.8	52.3	1.60	0.62
Mid-test	56.4	56.7	56.7	56.3	1.50	0.92
Final	60.8	60.3	60.7	60.4	1.47	0.91
M7, cm						
<i>k</i> , cm/d	0.082	0.081	0.083	0.082	0.006	0.99
Initial	113	112	112	112	2.9	0.72
Mid-test	120	119	119	118	2.5	0.67
Final	126	126	125	125	2.2	0.81
M8, cm						
<i>k</i> , cm/d	0.038	0.046	0.039	0.041	0.004	0.37
Initial	24.8	24.2	24.7	24.2	0.80	0.36
Mid-test	28.0	28.0	27.9	27.6	0.97	0.61
Final	31.1	31.7	31.1	31.0	1.21	0.53
M9, cm						
<i>k</i> , cm/d	0.059	0.059	0.060	0.056	0.004	0.85
Initial	37.4	36.4	37.0	37.1	1.83	0.29
Mid-test	42.3	41.2	41.9	41.7	1.57	0.08
Final	47.1	46.0	46.7	46.3	1.34	0.17
M10, cm						
<i>k</i> , cm/d	0.077	0.083	0.070	0.073	0.007	0.22
Initial	44.5	44.6	44.8	44.9	2.33	0.96
Mid-test	50.8	51.3	50.5	50.9	1.88	0.75
Final	57.0	58.1	56.2	56.9	1.51	0.31
M11, cm						
<i>k</i> , cm/d	0.751 ^{ab}	0.809 ^a	0.666 ^b	0.828 ^a	0.064	< 0.01
Initial	38.8	39.4	45.0	39.8	9.08	0.23
Mid-test	100.3 ^{bc}	105.8 ^{ab}	99.6 ^c	107.7 ^a	4.57	0.01
Final	161.9 ^{bc}	172.1 ^{ab}	154.2 ^c	175.6 ^a	4.23	< 0.01

^{a,b}Least squares means within a row with different superscripts differ at $P < 0.05$.

¹Variables M1= shoulder height, cm; M2 = rib depth, cm; M3 = body diagonal length, cm; M4 = body length, cm; M5 = pelvic girdle length, cm; M6 = rump depth, cm; M7 = hip height, cm; M8 = pelvic pin width, cm; M9 = pelvic hook width, cm; M10 = 12th/13th rib width, cm; M11 = rib circumference, cm; *k* = rate of growth in centimeter per day.

²Treatments are CC = control, no ADY fed throughout the transition; YY = yeast fed throughout the entire transition; CY = control fed during the grower diet and transitioned onto diets containing yeast; YC = yeast fed during the grower diet and transitioned onto diets without yeast.

CY and YY groups grew the fastest, the YC group grew the slowest, and the CC group was intermediate (0.809 and 0.828 vs. 0.666 and 0.751 cm/d, respectively; $P < 0.01$). The faster rib circumference growth rate for the CY and YY treatment groups resulted in greater mid-test ($P = 0.01$) and final ($P < 0.01$) measurements in which the YY group had the largest final rib circumference and was significantly greater than the CC and YC group (175.6 vs. 161.9 and 154.2 cm, respectively). The CY group (172.1 cm) was second largest and different from the YC group but did not differ from the CC or YY group ($P < 0.01$). It is possible that the addition of yeast during the finishing phase or fed throughout the entire feeding period (the CY and YY group) may have played a role in the growth rate of rib circumference resulting in larger mid-test and final measurements.

Ultrasound measurements. Table 5 summarizes the results of the effect of treatment on ultrasound variables. There were no significant treatment effects on the rate of change or amount of fat deposition over the rump at the initial, mid-test, or final time points ($P \geq 0.17$). There was a tendency ($P = 0.09$) for the rate of backfat deposition to be

slower for the YC treated group than CC, CY, and YY (0.0024 vs. 0.0027, 0.0027, and 0.0028 cm/d, respectively); however, there was no difference in the amount of backfat at the mid-test ($P = 0.25$) or final measurements ($P = 0.15$) among treatment groups. No treatment differences were detected for the rate of change or size of LMA growth ($P \geq 0.56$) nor were there differences in the rate of change or accumulated percentage of intramuscular fat deposition ($P \geq 0.20$). However, it should be noted that the coefficient of variation for ultrasound variables was $>13\%$ and therefore at the current sample size it was unlikely that a difference of $<10\%$ would be detected.

Carcass Characteristics, 9th to 11th Rib Dissection, and Predicted EBF

Carcass characteristics of the finished steers are shown in Table 6. Cattle were preshrunk before shipment (18 h without feed, 12 h without water). Final SBW was not affected by treatment ($P = 0.61$). Interestingly, the percentage of BW shrink was affected by treatment ($P = 0.05$) in which CC steers had greater body water loss than YY steers (3.7% vs. 2.7%, respectively), and

Table 5. The effects of feed treatment regimen on ultrasound characteristics of growing and finishing steers

Items ¹	Treatments ²				SEM	P-value
	CC	CY	YC	YY		
uRUMP						
<i>k</i> , cm/d	0.0022	0.0020	0.0020	0.0023	0.0001	0.17
Initial, cm	0.261	0.252	0.264	0.255	0.062	0.97
Mid-test, cm	0.439	0.416	0.426	0.443	0.060	0.82
Final, cm	0.618	0.580	0.589	0.630	0.060	0.56
uBF						
<i>k</i> , cm/d	0.0027	0.0027	0.0024	0.0028	0.0001	0.09
Initial, cm	−0.014	−0.015	−0.017	−0.002	0.031	0.79
Mid-test, cm	0.211	0.204	0.177	0.227	0.037	0.25
Final, cm	0.436	0.423	0.371	0.455	0.044	0.15
uLMA						
<i>k</i> , cm ² /d	0.028	0.028	0.026	0.026	0.002	0.56
Initial, cm ²	7.71	7.59	7.82	7.70	0.605	0.81
Mid-test, cm ²	9.98	9.92	9.96	9.86	0.465	0.95
Final, cm ²	12.3	12.3	12.1	12.0	0.357	0.84
uIMF						
<i>k</i> , %/d	0.003	0.002	0.003	0.004	0.0009	0.61
Initial, %	3.03	3.23	3.18	3.27	0.126	0.36
Mid-test, %	3.28	3.42	3.40	3.58	0.126	0.20
Final, %	3.53	3.61	3.62	3.90	0.154	0.28

¹Variables are regression derived means; uRUMP = ultrasound measured rump fat depth, cm; uBF = ultrasound measured subcutaneous fat over the 9th to 11th rib section, uREA = ultrasound measured LM area of the 9th to 11th rib section, cm²; uIMF = ultrasound measured intra-muscular fat of the 9th to 11th rib section, %; *k* = rate of growth or deposition in either cm, cm² or % per day.

²Treatments are CC = control, no ADY fed throughout the transition; YY = yeast fed throughout the entire transition; CY = control fed during the grower diet and transitioned onto diets containing yeast; YC = yeast fed during the grower diet and transitioned onto diets without yeast.

Table 6. Effects of treatment on carcass characteristics of finishing beef steers

Items ¹	Treatments ²				SEM	P-value
	CC	CY	YC	YY		
N	29	31	29	28		
SBW, kg	498	492	489	499	21.4	0.61
BW shrink, %	3.7 ^a	3.3 ^{ab}	3.1 ^{ab}	2.7 ^b	0.549	0.05
HCW, kg	313	307	310	313	14.0	0.70
Dressing %	62.9	62.4	63.4	62.8	0.466	0.52
12th rib backfat thickness, cm	1.9	1.8	1.6	1.8	0.103	0.20
Calculated yield grade	3.2	3.1	2.9	3.1	0.138	0.62
LM area, cm ²	12.0	11.9	11.9	12.1	0.220	0.87
Quality grade distribution, %						0.99
Prime	0.0	0.0	3.4	3.6		
Choice	62.1	67.7	65.5	71.4		0.86
Modest/moderate	24.1	22.6	20.7	14.3		
Small	37.9	45.2	44.8	57.1		
Select	37.9	32.3	31.0	25.0		
Yield grade distribution, %						0.57
Yield grade 1	6.9	6.5	10.3	7.1		
Yield grade 2	24.1	29.0	41.4	28.6		
Yield grade 3	62.1	54.8	37.9	50.0		
Yield grade 4	6.9	9.7	10.3	14.3		

^{a,b}Least squared means within a row without a common superscript differ at $P < 0.05$.

¹Items are carcass characteristics; SBW = shrunk BW.

²Treatments are CC = control, no ADY fed throughout the transition; YY = yeast fed throughout the entire transition; CY = control fed during the grower diet and transitioned onto diets containing yeast; YC = yeast fed during the grower diet and transitioned onto diets without yeast.

CY and YC were intermediate and not different (3.3% and 3.1%, respectively). This finding is interesting because other sectors of the beef production chain, especially where hydration may be a key factor in health status such as receiving cattle (Schaefer et al., 1997), may make necessary modifications in the management to ensure product quality and animal health. Though Crossland et al. (2018) reported no difference in water consumption between control and ADY treated animals, the latter ones tended to consume more water than control animals, suggesting that ADY treated animals may drink more water, although it was not measured in the current study.

There was no treatment effect ($P \geq 0.20$) on HCW, dressing percent, 12th rib fat thickness, LMA or overall YG. The USDA quality grade distribution and marbling scores were not different across treatment groups ($P = 0.99$). The 9th-11th rib dissection and predicted EBF variables yielded similar results across treatment groups (Table 7). There were no treatment effects on the percentage of moisture ($P = 0.52$), percentage of ether extract ($P = 0.62$), percentage of CP ($P = 0.68$), or percentage of ash ($P = 0.94$). Therefore, it was not surprising that the predicted variables EBW, EBF, EBP, and AFSBW yielded no treatment effects ($P \geq 0.43$).

The addition of the ADY strain used in the current study for growing and finishing steer diets did not affect carcass quality or composition which is consistent with previous research (Mir and Mir, 1994; Hinman et al., 1998; Maggioni et al., 2009). However, some researchers have identified linear effects of yeast inclusion on carcass quality (Ovinge et al., 2018) or carcass composition (Valdés-García et al., 2011). Ovinge et al. (2018) found that the addition of yeast linearly increased the proportion of steers grading premium choice but did not detect any differences in carcass composition. In contrast, Valdés-García et al. (2011) found that yeast linearly increased HCW, 12th rib fat thickness, and kidney, pelvic, and heart fat percentage but not carcass quality (i.e., marbling scores were similar). The differences in experimental findings are likely a result of a combination of different varieties of yeast strains and inclusion rates as well as other factors that might affect feeding and growth performance of finishing beef cattle, including dietary ingredients and associative effects, environment and management, and animal breed types and genetics.

The current study was a comprehensive feed-through-slaughter assessment of the effects of feeding a supplemental strain of ADY to beef steers. The supplementation of this specific strain of ADY did not alter feeding behavior, feeding

Table 7. Effects of treatment on the composition of the 9th to 11th rib section of growing and finishing steers and predicted variables derived from model equations using measured carcass composition

Items ¹	Treatments ²				SEM	P-value
	CC	CY	YC	YY		
<i>n</i> = 63						
Rib analysis						
Moisture, %	43.7	44.1	45.2	44.8	1.25	0.52
EE, % DM	41.9	41.4	40.0	40.9	1.65	0.62
CP, % DM	33.7	35.1	35.0	33.9	1.06	0.68
Ash, % DM	1.62	1.65	1.67	1.63	0.052	0.94
Garrett and Hinman (1996)						
EBW, kg	441	443	430	438	20.1	0.58
EBF, %	38.1	37.7	36.3	37.1	1.52	0.62
EBP, %	30.7	31.8	31.7	30.8	0.826	0.68
<i>n</i> = 117						
Garrett et al. (1978)						
EBW _c , kg	386	380	383	387	15.8	0.70
Perry and Fox (1997)						
EBF _c , %	31.9	31.4	30.5	31.7	0.814	0.63
AFSBW, kg	350	352	376	355	17.5	0.66
Guiroy et al. (2001)						
EBF _c , %	35.7	35.5	34.6	35.7	0.556	0.43
AFSBW, kg	310	306	324	310	19.1	0.45

^{a,b} Least squared means within a row without a common superscript differ at $P < 0.05$.

¹Items are component variables of the 9th to 11th rib section and predicted variables based on model equations using measured carcass characteristics; EE = ether extract; EBW = empty BW; EBF = empty body fat; EBP = empty body protein; EBFc = empty body fat when carcass traits were measured; AFSBW = adjusted final shrunk BW, adjusted to a target of 28% fat. Rib analyses were performed on 63 steers. Predicted variables are based on carcass measurements from all 118 steers.

²Treatments are CC = control, no ADY fed throughout the transition; YY = yeast fed throughout the entire transition; CY = control fed during the grower diet and transitioned onto diets containing yeast; YC = yeast fed during the grower diet and transitioned onto diets without yeast.

performance, or carcass quality and composition, but additional studies are warranted. Feeding ADY at the time of dietary transition or throughout the entire feeding period increased the growth rate of rib circumference. Additionally steers fed ADY for the entire 164 days tended to accrue subcutaneous fat faster than steers only fed ADY for the first 70 d. Steers fed ADY for 164 d also showed less BW shrink prior to slaughter. Based on previous meta-analysis and our current research findings, future studies investigating the effect of ADY on feeding performance and carcass characteristics should strongly consider designing experiments to detect a difference of 5% or less from the control.

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