Influence of dietary roughage level and *Megasphaera elsdenii* on feedlot performance and carcass composition of thin cull beef cows fed for a lean market

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ABSTRACT: One hundred forty-four cull cows (body condition score = 2.10 ± 0.61; BW = 456 ± 47 kg) were organized into a 2×2 factorial design (48 pens, 12 pens/treatment, and 3 cows/pen) to evaluate the effect of dietary roughage level and oral drenching of *Megasphaera elsdenii* NCIMB 41125 (*M. elsdenii* culture; Lactipro Advance; MS Biotec Inc., Wamego, KS) on performance and carcass characteristics. Cattle were finished over a 42-day realimentation period, and aggressively stepped up over a 10-day period to either a high roughage finisher (HRF; 25% roughage) or a low roughage finisher (LRF; 10% roughage). Within diet, cattle were administered no probiotic or 100 mL of *M. elsdenii* culture (*M. elsdenii* NCIMB 41125, 2×10^8 cfu/mL) on day 0. No diet × probiotic interactions were detected ($P \geq 0.15$), suggesting that the magnitude of the response was not influenced by the concentrate level of the diet. The main effect of diet triggered several significant responses. Decreasing roughage level tended to improve average daily gain (ADG) by 9.7% (0.26 kg, $P = 0.08$), while decreasing dry matter intake (DMI) by 0.9 kg ($P = 0.09$), provoking a 19.7% enhancement of feed efficiency (0.036 units, $P < 0.01$). However, interim data revealed declines of performance parameters among both diets with a significant difference between treatments only documented during the final phase of the realimentation period. During the final 14 days, LRF posted a 0.68 kg increase in ADG ($P = 0.05$) and a 2.0 kg decrease in DMI ($P = 0.01$), translating to improved feed efficiency (0.054 units, $P = 0.03$). This suggests that increasing the caloric density of finishing diets may help offset the regression of performance typically observed following a compensatory gain. No carcass traits were impacted by either diet or *M. elsdenii* culture ($P \geq 0.08$). Overall, oral drenching of *M. elsdenii* culture tended to augment ADG (0.26 kg, $P = 0.08$) and carcass ADG (0.20 kg, $P = 0.10$). Implying that *M. elsdenii* culture was effective at alleviating the acidosis risk prompted by the rapid step-up period employed in the trial and may help capitalize on the narrow timeline of compensatory gain in cull cow realimentation.

Key words: cull cow, *Megasphaera elsdenii*, Lactipro, realimentation, roughage level

INTRODUCTION

Characterized as a phase of rapid growth following a period of dietary restriction, exploiting compensatory gain is essential to

profitable reconditioning of cull cows (Parish, 2010). Although considerable variation among animals exists, a 20% reduction in NE_m (Birkelo et al., 1989; Carstens et al., 1989) over a 60 to 90 days phase is expected (NRC, 2016) during the compensatory state. Accordingly, following a prolonged period of nutrient restriction, realimentation of ruminants to an energy-dense diet, prompts improved animal gain and feed efficiency (Hornick et al., 2000). Rapidly adapting cattle to a calorically dense diet enables a higher proportion of the VFA propionate, which can further augment performance during the compensatory gain period. The major caveat to this approach is the elevated risk of ruminal acidosis, which has a pernicious effect on animal performance, morbidity, and mortality (Nagaraja and Lectenberg, 2007).

Research has investigated methods to bolster ruminal ecology and mitigate the prevalence of acidosis (Owens et al., 1998). In vitro mediation of ruminal pH has been achieved by the bacterium *Megasphaera wlsdenii,* which is credited with metabolizing 60% to 80% of lactate in vivo (Counotte et al., 1981). Lactipro advance (Megasphaera *elsdenii* culture; MS Biotec Inc., Wamego, KS) is a commercially available patented strain (NCIMB 41125) of *M. elsdenii* approved for use in beef and dairy cattle. Oral drenching of *M. elsdenii* culture maybe a tool to advert ruminal acidosis (ARC/Kemira Phosphates, 2006; Kettunen et al., 2008; Horn et al., 2009; McDaniel et al., 2009; Henning et al., 2010b; Muya et al., 2015), but its role in augmenting performance remains ambivalent (McDaniel et al., 2009; Drouillard et al., 2012; Miller 2013; Thieszen et al., 2015). Collectively, the objective of this project was to evaluate the interrelationship between *M. elsdenii* NCIMB 41125 and finishing diet roughage level during a rapid step-up realimentation period in thin, cull beef cows.

MATERIALS AND METHODS

All experimental procedures were reviewed and approved by the Texas Tech University Institutional Animal Care and Use Committee (IACUC #17054-05). The experiment was conducted at the Texas Tech University Beef Center Teaching and Research Unit located 9.7 km east of New Deal, TX.

Pretrial Animal Selection and Management

On May 20, 2017 (day −10), five semi-loads of beef cull cows (*n* = 180) were procured from various sale barns in Nebraska (two loads), Oklahoma (two loads), and Wyoming (one load) and transported to Texas Tech University Beef Center Teaching and Research Unit, New Deal, TX. Upon arrival, cattle remained in semi-truck load groups (five loads; 36 cows per load) and were housed in soil surface pens (27 × 37 m) with ad libitum access to hay (native grass round bales) and water. Cattle were allotted 27 m^2 of pen space and ~0.70 m of linear bunk space. Cattle were palpated by a professional embryologist to determine pregnancy status and provided a unique identification tag. Prior to trial initiation cows were fed 4.5 kg of wet corn gluten feed (Sweet Bran; Cargill Corn Milling, Dalhart, TX) to elucidate each individual's willingness to consume a concentrate base diet. Only bunk broke, docile cows with acceptable general health were considered as trial candidates. On May 29, 2017, (day 0) possible trial candidates were processed (Silencer chute; Moly Manufacturing, Lorraine, KS; mounted on Avery Weigh-Tronix load cells, Fairmount, MN; readability ± 0.45 kg). Processing included subjective assignment of body condition score (BCS), chute disposition scores, and quantification of body weight (BW). Visual assessment of BCS was conducted by a trained evaluator using guidelines provided by Rasby et al. (2014). Understood to be a precursor of disposition, cows were assigned a subjective chute score of 1 to 5, using the method outlined by Curley et al. (2006). Selected cows for the study (*n* = 144) were either open (nonpregnant) or ≤5 months bred, ranged in visual BCS from 2 to 4, had manageable disposition scores, demonstrated a willingness to consume concentrate feed, appeared structurally sound, healthy, and not physically weak.

Experimental Design

Selected cows (*n* = 144) were organized into a 2 × 2 factorial arrangement of treatments and blocked by BW nested within pregnancy status (open or ≤5 months bred). A total of 12 blocks were utilized with half of the blocks containing open cows and the remainder containing bred cows. Cows were stratified into 48 pens (three cows per pen). Cattle were randomly allocated to treatments such that half of the cows on trial were fed a high roughage finishing diet (HRF, 25% roughage) and half were fed a low roughage finishing diet (LRF, 10% roughage) over a 42-day realimentation period. To complete the factorial protocol, within each finishing diet treatment, cows were bifurcated so that half were orally drenched with 100 mL of Lactipro Advance (*M. elsdenii* culture; 2×10^8 cfu/mL) with the remaining constituents receiving no probiotic

(Control) (12 pens/treatment; 24 pens/main effect). Treatments were randomly assigned to pen within a block, and respective finishing diets were blended with the starter ration and introduced to all cattle on day 1.

Cattle Management

In an effort to reduce variation between treatments selected cows were weighed and processed on consecutive days (May 29, 2017 day 0 and May 30, 2017, day 1). As a second individual BW was captured, cows were fitted with a unique individual tag that was color coded to denote treatment. Additionally, all cows received a trenbelone acetate/estradiol combination implant (Synovex Plus; Zoetis, Florham Park, NJ; Lots 605380 and 605383) an oral anthelmintic (Valbazeen; Zoetis, Florham Park, NJ, lot 150302). Furthermore, cows stratified to the *M. elsdenii* culture treatment were orally drenched with 100 mL of *M. elsdenii* NCIMB 41125 (2×10^8 cfu/mL; lot 4052017; MS Biotec Inc., Wamego, KS). Cattle were housed in soil surface pens (3 × 15.2 m) and allocated one linear meter of bunk space per cow. Each pen was equipped with a cloth canvas which provided ~16.7 m² of shade per pen, at all times during the day. Concrete bunks were fastened on top of 3 m concrete aprons. Aprons were cleaned once every 2 weeks.

All diets were formulated to meet or exceed National Research Council (1996) requirements for beef cattle and were milled at the Texas Tech Burnett Center Feed Mill. Ration composition and nutrient analyses of diets utilized during the trial are presented in Table 1. Both finishing diets contained monensin (Rumensin-90; Elanco, Greenfield, IN, formulated at a rate of 300 mg·animal^{-1}·d^{-1}), tylosin phosphate (Tylan-40; Elanco, Greenfield, IN, formulated at a rate of 12.1 mg/kg DM), melengestrol acetate (MGA 500, Zoetis Animal Health, Florham Park, NJ; targeted at a rate of 0.4 mg·animal^{-1}·d^{-1}). Additionally, during the final 28 d of realimentation, ractopamine hydrochloride (Actogain 45, Zoetis, Florham Park, NJ targeted at a rate of 300 mg·animal^{-1}·d^{-1}) was added to the premix, with a voluntary 1-day withdrawal applied. All diets included a supplemental premix which was stored in labeled bins, utilized a ground corn carrier, and blended in a commercial micro-mixer.

Cattle were stepped up to maximum intake over an expedited diet adaptation period. On day 1 of the trial, cows were fed ~1.75% of their BW on an as-fed basis. Pens received 25% of their treatment assigned finisher delivered over the top of a 75% starter diet. This blend was delivered from days 1 to 3. Cows were stepped up to 2.0% of their BW, from days 4 to 6 and were delivered a 50:50 blend of treatment assigned finisher to starter ratio. The final transition step was a 75:25 blend of treatment designated finisher to a starter, which was delivered from days 7 to 9. From day 10 to the completion of the trial, cows were delivered 100% of their earmarked finisher diet.

Ground cotton burrs and corn gluten feed were directly added by a front-end loader to a tractor-pulled mixer (Rotomix, Dodge City, KS). The remaining ingredients were batched in a paddle-type mixer, delivered via a drag chain conveyor system, to the Rotomixer. Upon completion of dietary ingredients arrival to the Rotomixer, a 5-min stationary mix was applied prior to delivery. Feed was delivered twice daily beginning at 0600 and 1300 h using a tractor-pulled Rotomix with a scale which measured within 0.45 kg.

Feed bunks were evaluated at ~0530 h each morning to estimate refusals and establish daily feed calls. Feed bunks were monitored with the goal of ≤0.45 kg of dry refusals. The slick bunk management technique employed in the study was extensively reviewed by Pritchard and Bruns (2003). Following consecutive days of clean bunks, cattle were challenged with an additional 0.45 kg of feed, on an as-fed basis.

Daily feed samples were obtained from the Rotomix and stored at ¯15.6 °C for further analysis. Following trial completion, composites were generated for each interim period for each diet. Samples were thawed, forced through a separator and placed in a bucket, and mixed thoroughly for 1 min to create composites within the period. Composites were submitted for proximate analysis (Servi-Tech Laboratories, Amarillo, TX) using the methodology outlined by AOAC (1995). The resulting chemical analysis is presented in Table 1. Additionally, weekly dietary and ingredient samples were collected for DM analysis (forced-air oven for at 100 °C for 24 h). Since cotton burrs and corn gluten feed were stored outside in concrete bunkers, these ingredients were sampled and dried by the method previously described following any precipitation event. Collectively, ingredient DM records were the basis of diet formulation and dry matter intake (DMI) computations. Finally, all daily feed refusals greater than ~5 kg were removed from the bunk and weighed. A representative subsample of the orts was dried (forced-air oven for at 100 °C for 24 h) to adjust DMI computations. Individual

Table 1. Ingredient and analyzed chemical composition (DM basis) of diets fed during the trial period

	Diets		
Ingredient	Starter[1]	HRF[2]	LRF[2]
Corn grain, steam flaked	0.00	47.70	62.05
Corn grain, cracked	15.00	0.00	0.00
Wet corn gluten feed[3]	52.00	20.00	20.00
Ground cotton burrs	30.00	25.00	10.00
Tallow	0.00	3.00	3.00
Limestone	2.00	1.55	2.00
TTU supplement,[4,5] %	1.00	2.00	2.00
Urea	0.00	0.75	0.95
Analyzed composition[6]			
Dry matter, % as-fed[7]	73.61	77.31	75.53
Crude protein, %	16.80	14.34	14.31
Net energy for maintenance, Mcal/kg	1.43	1.88	2.11
Net energy for gain, Mcal/kg	0.86	1.22	1.45
Neutral detergent fiber, %	33.67	25.55	17.81
Fat, %	2.93	5.60	6.23
Calcium, %	1.19	0.80	0.81
Phosphorus, %	0.80	0.42	0.42
Potassium, %	2.12	0.95	0.77
Magnesium, %	0.41	0.24	0.22

[1]The starter diet was blended with the finisher diet over the first 9 days of the trial. Cattle received a 75% starter to 25% finisher blend from days 0 to 3 on a DM basis, and 50% starter to 50% finisher blend from days 4 to 6 on a DM basis, and a 25% starter to 75% finisher blend on a DM basis from days 6 to 9 of the trial.

[2]The finisher diet was blended with the starter diet from days 0 to 9, and fed exclusively to all cattle following day 10, and throughout the 42-day trial.

[3]Sweet Bran (Cargill, Dalhart, TX).

[4]Supplement composition (DM basis): 67.755% cottonseed meal, 15.000% NaCl, 10.000% KCl, 3.760% urea, 0.986% zinc sulfate, 0.750% monensin (Rumensin-90; Elanco, Greenfield, IN), 0.506 Tylan-40 (Elanco), melengesterol acetate [MGA 500, Pfizer, New York, NY; 0.4 mg·animal^{-1}·d^{-1}], 0.500% Endox (Kemin Industries, Des Moines, IA), 0.196% copper sulfate, 0.167% manganese oxide, 0.157% vitamin E (500 IU/g), 0.125% selenium premix (0.2% Se), 0.083% iron sulfate, 0.010% vitamin A (1,000,000 IU/g), 0.003% ethylenediamine dihydroiodide, and 0.002% cobalt carbonate.

[5]Following the first weigh period, ractopamine hydrochloride (21.0 g/ton; Actogain 45, Zoetis, Florham Park, NJ) was added to the premix fed for the final 28 days.

[6]Composition of weekly composite samples (two starter diet, six high roughage, six low roughage finisher) analyzed at a commercial laboratory (Servi-Tech Laboratories, Amarillo, TX). DM calculated weekly (forced-air oven for 24 h at 100 °C).

[7]Diet DM was calculated using weekly ingredient sample DM records.

BW measurements were recorded on days 0, 1, and 42. Pen BW measurements were captured on days 14 and 28. Cattle were weighed prior to feeding at 0600 h. Prior to weighing, any residual feed was removed, weighed, and sampled for DM analysis. Automatic water troughs were cleaned twice weekly and a daily log was maintained to track health and monitor heat stress.

Postmortem Data Collection

Cattle were harvested on July 12, 2017 at Preferred Beef (Booker, TX). At the time of harvest HCW, liver score and estimated percentage of kidney heart and pelvic (KPH) were recorded by Texas Tech personnel. The liver score was evaluated in accordance with the Eli Lilly Liver Check System (Elanco, Greenfield, IN) as published by Brown and Lawrence (2010). At 24-h postmortem, carcasses were split between the 12th and 13th rib interface by plant employees and routine carcass data was evaluated by Texas Tech University Gordon W. Davis Meat Laboratory personnel. Carcass measurements taken were loin muscle area (LMA), 12th-rib fat (FT), marbling score, lean maturity, and skeletal maturity. Calculated yield grade was derived according to the standards set forth by the USDA (1997).

Statistical Analysis

Feedlot and carcass performance parameters were analyzed as a nested ANOVA with a 2 × 2 factorial arrangement of treatments using SPSS Statistics 25.0 (IBM; Armonk, NY). Pen served as the experimental unit for all computations. Factors used to calculate carcass average daily gain (ADG), carcass G:F, and carcass ADG:live ADG were derived by applying a 44% standard dressing yield to the initial shrunk BW (Travis Herod, Preferred Beef, Booker, TX; personal communication). Pen average carcass G:F was computed as the quotient of carcass gain divided by daily DMI. The diet, *M. elsdenii* culture, and diet × *M. elsdenii* culture interaction were treated as fixed effects, whereas block was treated as a random effect in the model. Several post hoc tests were conducted to evaluate the inherent assumptions of the model. The normality of errors assumption was tested with the Shapiro Wilk's test, homogeneity of variances assumption was confirmed with Bartlett's test, and the sphericity assumption was confirmed using a Mauchly's test. For the results of this trial, the significance is declared as $P \leq 0.05$; while all P-values ranging from 0.06 to 0.10 are discussed as tendencies.

Weights were shrunk 1% and 4% for all initial and interim/final measurements, respectively. Initial weights were derived from averaging measurements recorded on days 0 and 1. Given the thin, emaciated state of the cull cows employed in this study (BCS = 2.10 ± 0.61; initial BW = 456 kg ± 47), a 1% shrink was utilized as opposed to the standard 2%. All BCS were documented on a scale of 1 to 9, with

each number subdivided into thirds. With + denoting the top third and – denoting the bottom third. For statistical analysis these data were transformed to a 27-point scale. Following data analysis, values were divided by 3 and reported on a 1 to 9 scale.

Data analysis excluded eight cattle that were dead or removed from the study. Five cows died during the experiment, with a sixth cow euthanized under veterinarian orders. A cow from the LRF diet with *M. elsdenii* culture appeared to display polio-encephalomalacia, prior to death. An additional two cows were removed from the study for lameness associated with extreme mud due to above-average rainfall (24 cm in 42 days). In both cases, cows refused to consume concentrate diets were extremely weak, and were losing ambulatory functions. These high-risk cows in accordance with IACUC protocols were not eligible for harvest with their treatment groups. Cattle removed for each treatment were as follows: LRF, one removed (one dead); LRF with *M. elsdenii* culture, four removed (three dead), HRF one removed, and HRF with *M. elsdenii* culture, two removed (two dead). Deads and culls were removed from all calculations, pen values were averaged to a per animal basis to account for the removal of cattle. An additional four carcasses were excluded from Carcass ADG, Carcass ADG: Live ADG, Carcass G: F, HCW, and dressing percent

(DP) calculations. These four carcasses were noted for having considerable trim in the cooler and penciled with a DP of 25% to 39%. These carcasses represented the following treatments: two from LRF, one from LRF plus *M. elsdenii* culture, and one from HRF plus *M. elsdenii* culture.

RESULTS AND DISCUSSION

The goals of this trial were: (i) contrast the benefits and potential consequences of increasing caloric density in an attempt to maximize compensatory gain in cull cow realimentation periods and2(ii evaluate if oral drenching of *M. elsdenii* culture enhances performance in concentrate naive cows. There was no interaction between diet and *M. elsdenii* culture application for any parameter ($P \geq 0.11$). Accordingly, only the main effects will be discussed to address each objective.

Live Performance Traits

Descriptive statistics for live performance characteristics for the entire trial are presented in Table 2. Given the magnitude of caloric density between diets (Table 1), variances in animal gain and performance were expected. Concerning the trial on an aggregate basis, cattle consuming the

Table 2. Effects of *M. elsdenii*[1] and diet roughage level[2] on feedlot performance characteristics of beef cull cows finished for 42 days

| Item | Probiotic[1] | | Diet[2] | | | P-values | | |
	0 mL	100 mL	LRF	HRF	SEM[3]	Probiotic	Diet	Diet x Probiotic
Initial BW, kg	456.1	456.4	456.8	455.7	6.76	0.98	0.94	0.92
Final BW, kg	568.1	579.6	580.0	567.7	8.05	0.49	0.46	0.69
Days 0 to 14								
Average daily gain, kg	4.68	4.95	4.86	4.77	0.16	0.4	0.77	0.59
Gain:feed	0.386	0.392	0.395	0.383	0.009	0.76	0.53	0.96
DMI, kg/day	12.1	12.7	12.3	12.5	0.31	0.37	0.68	0.46
Days 14 to 28								
Average daily gain, kg	2.45	2.21	2.34	2.32	0.13	0.36	0.94	0.29
Gain:feed	0.179	0.164	0.182	0.162	0.014	0.61	0.51	0.24
DMI, kg/day	14.3	14.4	13.8	14.9	0.35	0.84	0.12	0.63
Days 28 to 42								
Average daily gain, kg	0.87	1.64	1.59	0.91	0.18	0.03	0.05	0.4
Gain:feed	0.055	0.103	0.106	0.052	0.013	0.05	0.03	0.32
DMI, kg/day	15.3	16.2	14.7	16.7	0.38	0.25	0.01	0.78
Entire trial								
Average daily gain, kg	2.67	2.93	2.93	2.67	0.08	0.08	0.08	0.39
Gain:feed	0.195	0.208	0.219	0.183	0.006	0.27	<0.01	0.19
DMI, kg/day	13.9	14.4	13.6	14.7	0.32	0.44	0.09	0.78

[1]Cows were orally dosed with either 0 mL or 100 mL of *M. elsdenii* (Lactipro Advance; MS Biotech, Inc., Wamego, KS) on day 0 of the trial.

[2]Cows were finished on an LRF (10% roughage on a DM basis) or an HRF (25.00% roughage on a DM basis).

[3]Pooled standard error of treatment means (diet: $n = 24$ pens/main-effect mean; probiotic: $n = 24$ pens/main-effect mean).

LRF diets tended to exhibit a 9.7% improvement in ADG (2.93 vs. 2.67 kg, P = 0.08), while consuming 1.1 kg less of DMI (13.6 vs. 14.7 kg, P = 0.09), inciting a 19.7% enhancement of G:F efficiency (0.219 vs. 0.183 units, P < 0.01). However, significant improvements were not consistently observed during each interim period. In fact, the only difference between diets was detected during the final interim period where LRF cows, outperformed HRF cattle by 75% in ADG (1.59 vs. 0.91 kg, P = 0.05). Cattle consuming LRF also posted lower DMI (14.7 vs. 16.7 kg, P = 0.01) leading to an enhanced G:F efficiency (0.106 vs. 0.052 units, P = 0.03) during the final interim period. These data suggest that the increased caloric concentration of the LRF diet may have provoked cows to exit the compensatory state sooner, explaining the nearly identical ADG and G:F observed during the second interim period. This also helps quantify why the largest discrepancy in ADG and G:F was documented in the last interim period between dietary treatments. Given the thin, emaciated state of the cull cows (BCS = 2.02 ± 0.61) utilized in this study, it is reasonable to expect most of the cohorts spent time in the compensatory state. Following a prolonged period of nutrient restriction, realimentation of ruminants to energy-dense diets, prompts impressive animal gain, and feed efficiency (Hornick et al., 2000, Parish, 2010). However, the data published in Table 2 insinuate the primary benefit of increasing caloric density in cull cows may be observed following a compensatory gain. In this case, providing additional dietary energy could be an effective strategy to combat declining animal performance generally observed during the final stages of cull cow realimentation.

The findings of the current study contrast with several cull cow trials, where the greatest gains were documented during the intermediate period of realimentation. For instance, a serial slaughter conducted by Matulis et al. (1987) reported the greatest ADG for British cows finished at 56 days, compared with cattle harvested on days 28 and 84. A similar study was conducted by Schnell et al. (1997), where the greatest ADG was also observed during the intermediate phase of realimentation. In the current study, despite the addition of the metabolic modifier ractopamine hydrochloride to diets following day 14, ADG values were cut in half during the intermediate period (days 0 to 14: LRF = 4.86 kg, HRF = 4.77 kg; days 14 to 28: LRF = 2.34 kg, HRF = 2.32 kg). Although the gains registered during the first 14-day in the current study are likely partially attributed to the large gastrointestinal tracts of mature cows and their subsequent physical fill due to rapid step-up, it fails to address the ADG timeline discrepancies with previous trials. This may be attributed to the pretrial selection phase of the current study, where cows were given 2 weeks to acclimate to their new environment and required to consume bunk delivered feed in order to be included in the experiment. These selection criteria possibly muted the hurdles associated with bunk breaking thin, stressed cull cows during realimentation periods.

The present study is similar to Sawyer et al., (2004), who evaluated the effect of caloric density of diets on 125 British cross cows. Cattle were finished over a 54-day realimentation period, but, during the diet acclimation period (weeks 1 to 2) cull cows lost weight. The greatest gains for cattle consuming calorically rich diets were observed during the 4-week period immediately following dietary transition. Over the final 2 weeks of the trial, these cows showed lower ADG (weeks 2 to 4 = 3.06 kg vs. weeks 4 to 6 = 3.00 kg vs. weeks 6 to 8 = 1.00 kg), suggesting that compensatory growth was only achieved during the intermediate period (weeks 2 to 6) of the study. In contrast, cows fed a conservative, high roughage diet, posted the greatest ADG 2 weeks following their more aggressive fed counterparts (weeks 2 to 4 = 1.85 kg vs. weeks 4 to 6 = 2.32 kg vs. weeks 6 to 8 = 1.60 kg), suggesting that the lower energy density of the diet enabled a prolonged compensatory growth period. However, the reduction in overall ADG and G:F posted by conservative fed cattle provoked a 30% greater cost of gain. Our findings are in concert with Sawyer et al. (2004), suggesting that the arc of compensatory gain is dependent on diet roughage level and energy concentration.

Surprisingly, the effect of *M. elsdenii* culture on performance parameters showed a similar response to diet caloric density. Table 2 shows a tendency for a 9.7% ADG improvement of *M. elsdenii* cultured-drenched cattle (2.93 vs. 2.67 kg, P = 0.08) compared with controls. Consistent with previous research, a numerical difference in ADG (4.95 vs. 4.68 kg) and DMI (12.7 vs. 12.1 kg) was registered during the diet adaptation phase (days 0 to 14); however, neither variable was significant (P ≥ 0.40). Cattle were rigorously screened during the pretrial period to identify candidates that would be willing to consume large quantities of fermentable carbohydrates. Despite averaging a DMI of 2.6% of BW during the diet adaptation period, statistical significance was not achieved for *M. elsdenii* culture application. This could be the result of

extraneous variables such as the large inherent difference among cull cows, or the variation in bunk adaptation to concentrate diets (SEM = 0.16, ADG days 0 to 14). It may also suggest that diets and the step-up protocol employed in the current study were not aggressive enough to cause acidosis conditions, abating the benefit of *M. elsdenii* culture.

The heterogeneity of *M. elsdenii* NCIMB 41125 results concurs with the previous literature. A pilot study conducted by Henning et al. (2010a) employed 12 steers over a 37-d finishing trial. Like the current study, short-fed cattle dosed with *M. elsdenii* culture, recorded higher ADG compared with negative controls. In another study with congruent objectives to the current trial, Drouillard et al. (2012) explored using *M. elsdenii* NCIMB 41125 to expedite the step-up process in feeder cattle. Receiving cattle were organized into a 2 ×2 factorial designed and transitioned to a finisher diet over an 8 or 17 d period. No live performance parameter was improved by *M. elsdenii* NCIMB 41125 application in either step-up period. Finally, Miller (2013) evaluated the health status and performance characteristics of high-risk feeder cattle dosed with *M. elsdenii* culture. The dissertation work featured four large studies (animal inventory ranging from 314 to 1,294 cattle). The instances where *M. elsdenii* culture activated a significant performance response coincided with a 0 day step up or ad libitum access to a concentrate diet.

Perhaps the most surprising performance characteristic of the current study was the probiotic's effect during the final phase of the finishing period. Cattle were under considerable duress during the final 2 weeks of the trial dealing with uncharacteristic precipitation (12.8 cm in 14 days). Of the eight cows that were removed from this study, five of them were removed during this timeline (three died, while two lost ambulatory function in the mud). Under these conditions, cattle drenched with 100 mL of *M. elsdenii* culture had an increase of 0.77 kg of ADG (1.64 vs. 0.87 kg, $P = 0.03$), and a 0.048-unit enhancement of G:F (0.103 vs. 0.055 units, $P = 0.05$). Traditionally, *M. elsdenii* culture has been most effective at regulating pH and lactate concentrations immediately (2 to 4 days) following application (Kettunen et al., 2008; McDaniel et al., 2009; Henning et al., 2010b). Normally, cattle are dependent on the slower-growing endogenous species of *M. elsdenii* to abate ruminal lactic acid (Rinttilä, 2009). However, it is possible that the immediate effects of *M. elsdenii* culture on the ecology of the rumen enables more robust colonization of *M. elsdenii* and various microbes equipping cattle

to handle subsequent stress or nonstructural carbohydrate challenges. A cull cow study conducted by DeClerck et al., (2019b) reported *M. elsdenii* culture improves ruminal absorptive surface area following a 35-day realimentation period. Improved volatile fatty acid absorption may also help explain the delayed performance improvement observed in the current study.

The results presented in Table 2 are analogous to those of Leeuw et al., (2009). With a similar design to the current trial, a 2 × 2 factorial study was constructed to investigate the effects of roughage level (2% vs. 8%) and *M. elsdenii* NCIMB 41125 on feedlot characteristics. Oral drenching of *M. elsdenii* NCIMB 41125 improved ADG and G: F between weeks 3 and 5, but no significant differences were distinguished during the remainder of the 13-week trial.

Finally, the numerical increase in ADG posted by control cattle during the second interim period may also be the result of a prolonged state of compensatory gain ($P = 0.36$). Cattle receiving 100 mL of *M. elsdenii* culture had numerically higher ADG from days 0 to 14 and subsequently lower gains from days 14 to 28 compared with negative controls ($P \geq 0.36$). Congruent to the effects of caloric density of diet, it is possible that the numerically higher ADG observed during the first 14 days for cattle drenched with *M. elsdenii* culture, enabled expedited rejuvenation of previous catabolized viscera tissue and restoration of normal cellular ion pumping and metabolite cycling, manifesting in a numerical decrease in performance characteristics compared with controls during days 14 to 28.

Body and Carcass Composition Parameters

A summary of estimated live carcass growth and transfer parameters is presented in Table 3. Considering the noticeable improvements in final BW (Table 2), prompted by increasing highly digestible carbohydrate levels in the diet, elevated subjective final BCS were not surprising, however, insignificant ($P = 0.16$). Although increasing diet caloric density incited live performance improvements, these gains were limited by modest DP and HCW responses (Table 4). Widely recognized for years as a major problem in cull cow carcasses, bruising, and subsequent trim have had a deleterious effect on red meat yield. The National Beef Quality audit (2016) reported that 64.1% of cull cow carcasses had some degree of bruising. A caveat to the data collected in this study was that HCW was recorded after the removal of trim on

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Table 3. Effects of *M. elsdenii*[1] and finishing diet roughage level[2] on carcass transfer parameters of beef cull cows finished for 42 days

	Probiotic[1]		Diet[2]			P-values		
Item	0 mL	100 mL	LRF	HRF	SEM[3]	Probiotic	Diet	Diet × probiotic
Initial BCS	2.04	1.99	2.12	1.91	0.16	0.64	0.14	0.50
Final BCS	5.02	5.23	5.34	4.98	0.26	0.53	0.16	0.72
Carcass ADG[4], kg	2.46	2.66	2.55	2.57	0.07	0.10	0.71	0.92
Carcass transfer[5]	92.1	90.7	86.9	96.1	2.61	0.58	0.10	0.20
Carcass gain: feed	0.177	0.185	0.188	0.175	0.006	0.20	0.14	0.32

[1]Cows were orally dosed with either 0 mL or 100 mL of *M. elsdenii* (Lactipro Advance; MS Biotech, Inc., Wamego, KS) on day 0 of the trial.

[2]Cows were finished on an LRF (10% roughage on a DM basis) or an HRF (25.00% roughage on a DM basis).

[3]Pooled standard error of treatment means (diet: $n = 24$ pens/main-effect mean; probiotic: $n = 24$ pens/main-effect mean).

[4]Computations of carcass ADG, carcass G: F, and carcass ADG: live ADG were calculated by applying a 44% standard DP to the initial BW to estimate initial HCW.

[5]Calculated as the ratio of carcass ADG:live ADG.

Table 4. Effects of *M. elsdenii*[1] and finishing diet roughage level[2] on carcass traits of beef cull cows finished for 42 days

	Probiotic[1]		Diet[2]			P-values		
Item	0 mL	100 mL	LRF	HRF	SEM[3]	Probiotic	Diet	Diet × probiotic
Hot carcass weight, kg	303.9	312.4	308.0	308.3	4.0	0.31	0.97	0.89
DP	53.7	54.1	53.3	54.5	0.6	0.78	0.35	0.57
LMA, cm^2	66.13	66.03	66.11	66.05	1.01	0.96	0.98	0.61
12th rib fat, cm	0.68	0.61	0.67	0.62	0.04	0.32	0.43	0.69
Marbling score[4]	3.51	3.35	3.43	3.43	0.04	0.03	0.94	0.62
Calculated yield grade	2.68	2.63	2.69	2.62	0.05	0.61	0.54	0.11
Kidney pelvic heart fat, %	1.27	1.24	1.26	1.25	0.02	0.42	0.79	0.74
Skeletal maturity[5]	4.24	4.31	4.24	4.31	0.05	0.47	0.48	0.89
Lean maturity[6]	2.74	2.61	2.60	2.74	0.04	0.13	0.12	0.76
Liver score[7]	1.12	1.19	1.02	1.29	0.07	0.70	0.08	0.66

[1]Cows were orally dosed with either 0 mL or 100 mL of *M. elsdenii* (Lactipro Advance; MS Biotech, Inc., Wamego, KS) on day 0 of the trial.

[2]Cows were finished on an LRF (10% roughage on a DM basis) or an HRF (25.00% roughage on a DM basis).

[3]Pooled standard error of treatment means (diet: $n = 24$ pens/main-effect mean; probiotic: $n = 24$ pens/main-effect mean).

[4]3.00 = slight^{00}, 4.00 = small^{00}.

[5]10 to 19 = A maturity; 20 to 29 = B maturity; 30 to 39 = C maturity; 40 to 49 = D maturity; 50 to 59 = E maturity.

[6]10 to 19 = A maturity; 20 to 29 = B maturity; 30 to 39 = C maturity; 40 to 49 = D maturity; 50 to 59 E maturity.

[7]1 = normal liver; 2 = A- (1 to 2 small abscesses); 3 = A (2 to 4 small active abscesses); 4 = A+ (>4 small active abscesses).

the harvesting floor. Since numerically greater final BCS scores and back fat values, with similar LMA (Table 4), were documented among LRF treatments, it is possible the numerical discrepancy in DP, and subsequent carcass ADG is the result of random bruising and subsequent trim loss. The resulting numerical decline in DP led to a near-identical carcass ADG between finishing diets that calculated to a tendency for 9.2 unit increase in carcass ADG: live ADG ratio favoring HRF compared with LRF (96.1 vs. 86.9%, $P = 0.10$).

There was a tendency for cattle drenched with *M. elsdenii* culture to achieve an additional 0.20 kg of carcass ADG compared with controls (2.66 vs. 2.46 kg, $P = 0.10$). These findings are in concert with Drouillard et al. (2012) who also documented a tendency for improved carcass ADG in feeder cattle drenched with *M. elsdenii* NCIMB 41125 during an accelerated step-up process. Additionally, a review of domestic and South African Feedlot studies in 2010 by Messier et al. noted a 2.2% improvement for carcass ADG for cattle drenched with 1×10^{10} CFU of *M. elsdenii* NCIMB 41125. The authors used a probability test to establish significance among seven trials representing 7,663 cattle on a spectrum of diets and management systems.

Regardless of treatment, the cull cows utilized for this study recorded impressive carcass ADG: live ADG ratios (86.9% to 96.1%). These values are considerably higher than the figures logged in the

serial slaughter study discussed by DeClerck et al. (2019a). Although many producers fail to use concentrate feeding for realimentation of cull cows, the current findings implore retained ownership as a prudent management decision. Although the continuum of the ADG observed infers that cull cows in this study had exited the compensatory state, it appears beyond restoring previously catabolized visceral tissue, nearly all the live weight gain was transferred to the carcass.

Carcass Traits

A summary of carcass trait means is presented in Table 4. Surprisingly, cattle fed HRF diets tended to post greater liver scores compared with LRF cows (1.02 vs. 1.29 units, $P = 0.08$). However, the main effect of diet triggered no other significant impact on any other measured characteristics ($P \geq 0.12$). Despite the difference in caloric density (Table 1), additional steam flaked corn was unable to provoke a significant difference in subcutaneous back fat, although a modest numerical increase of 0.05 cm was observed (0.67 vs. 0.62 cm, $P = 0.43$). It is possible the short duration of the realimentation period (42 days) and the application of ractopamine hydrochloride enabled compositional gain throughout the feeding phase. This premise may help to explain why the greatest augmentation in ADG was observed for LRF cattle during the final interim period.

Cattle that were drenched with *M. elsdenii* culture tended to display 0.16 units lower marbling scores compared with their control counterparts (3.51 vs. 3.35, $P = 0.03$). Building onto this trend, a numerical 0.07 cm increase in subcutaneous back fat was register for control carcasses compared with *M. elsdenii* culture drenched cattle (0.68 vs. 0.61 cm, $P = 0.32$). There is limited data pertaining to the effect of *M. elsdenii* culture on carcass traits. Many of the previous studies only tracked cattle through the dietary transition phase when *M. elsdenii* culture is thought to have the most profound effects. However, the current finding contradicts those of Leeuw et al., (2009), McDaniel et al. (2010), Miller (2013), and Ellerman et al. (2017) who all documented no effect of *M. elsdenii* culture inclusion on any carcass trait. However, the most noteworthy numerical response in the current study is the added 9.4 kg of HCW (312.4 vs. 303.9 kg, $P = 0.31$). Further studies with expanded experimental units will be necessary to validate this biological response. Even with a rigorous screening of candidates before placement on trial, immense variance exists when feeding cull cows vs. young feeder cattle. This consideration should be noted when designing future studies with thin, cull beef cows.

IMPLICATIONS

The realimentation period associated with cull cow compensatory gain is likely shorter than traditional feeder cattle, and strategies should be employed to maximize the economy of compositional growth during this timetable. Following compensatory gain, a decline in ADG is traditionally observed, as maintenance values increase with the restoration of previously catabolized visceral organ tissue. An effective strategy to combat eroding animal gain and feed efficiency could be enhancing the caloric density of finishing diets and accelerating the step-up process. Traditionally, the short duration of finishing periods and the large intake potential of concentrate naive cull cows have prompted conservative dietary strategies in response to acidosis concerns. However, the administration of *M. elsdenii* culture may empower cattlemen to aggressively step-up cattle and exploit compensatory gain. Additionally, incorporating *M. elsdenii* culture into dietary adaption protocols can help minimize the burden on feedyard mills, tasked with batching multiple transition rations, often comprised of bulky roughages leading to expedited wear and tear of equipment.

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