Impacts of added roughage on feedlot performance, digestibility, and ruminal fermentation characteristics of steers fed wheat-based feedlot diets

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INTRODUCTION

Wheat can be used as an alternative grain in feedlot diets; however, the rapid fermentation rate of wheat increases the acidosis risk (Kreikemeier et al., 1990; Bock et al., 1991). Cattle fed high-grain diets are at risk of digestive disorders that can be offset with increased dietary roughage (Owens et al., 1998; Gentry et al., 2016). The absence of starch in ethanol coproducts may reduce the occurrence of acidosis, potentially reducing the roughage needed in a diet (Krehbiel et al., 1995; Klopfenstein et al., 2008). Survey data indicated that 8% to 12% roughage inclusion is typical for feedlots (Samuelson et al., 2016). Less roughage may cause reduced rates of gain as a result of digestive disorders (Galyean and Hubbert, 2014; Gentry et al., 2016). Increasing roughage from 5% to 10% increases ruminal pH, minimizing the risk of digestive upset, without affecting dry matter intake (DMI; Weiss et al., 2017). The objective of this study was to evaluate the impacts of additional roughage on feedlot performance and ruminal pH and fermentation of steers fed wheat-based feedlot diets including 30% modified distillers grains with solubles (MDGS). We hypothesized that increasing dietary roughage in wheat-based diets including MDGS would decrease feedlot performance and reduce digestibility while increasing ruminal pH.

MATERIALS AND METHODS

This study was approved by the North Dakota State University Institutional Animal Care and Use Committee.

Study 1

Seventy-two steers (initial body weight [BW]; 391.6 ± 46.3 kg) were assigned to 1 of 12 pens (n = 3 per treatment). Steers were stratified by BW and randomly assigned to pen with pen randomly assigned to treatment. Dietary treatments consisted of 1) control; 10% roughage, 2) 12% roughage, 3) 14% roughage, and 4) 16% roughage. As wheat decreased, it was replaced by straw. Survey data indicated that 8% to 12% roughage inclusion is typical for feedlots (Samuelson et al., 2016). Less roughage may cause reduced rates of gain as a result of digestive disorders (Galyean and Hubbert, 2014; Gentry et al., 2016). Increasing roughage from 5% to 10% increases ruminal pH, minimizing the risk of digestive upset, without affecting dry matter intake (DMI; Weiss et al., 2017). The objective of this study was to evaluate the impacts of additional roughage on feedlot performance and ruminal pH and fermentation of steers fed wheat-based feedlot diets including 30% modified distillers grains with solubles (MDGS). We hypothesized that increasing dietary roughage in wheat-based diets including MDGS would decrease feedlot performance and reduce digestibility while increasing ruminal pH.

Study 2

Animal diets and treatments. Four ruminally cannulated steers (393.4 ± 33.0 kg initial BW) were
used in a $4 \times 4$ Latin square design to evaluate the impacts of added roughage in a wheat-based diet containing 30% MDGS. Treatments were similar to Study 1, but Study 2 used corn silage (20% DM basis) in place of the 10% mixture of grass hay/straw and 10% dry-rolled corn (DM basis; Study 1). Steers were housed individually and fed a total mixed ration twice daily at 0700 and 1900 h with free access to water. Feed was provided at DMI ($\text{kg/d} = 3.830 + [0.0143 \times (\text{BW} \times 0.96)]$) (NASEM, 2016).

**Sample collection.** Each period had a 7-d adaptation and 7-d collection period. Feed and ort samples were collected daily from days 7 through 14 and composited for each steer and period. Chromic oxide (8 g) was ruminally dosed twice daily at feed delivery as an external marker. Fecal grab samples were collected from days 10 to 12.

Ruminal fluid was collected on day 13 at −2, 0, 2, 4, 6, 8, 10, and 12 h relative to morning feeding. Ruminal fluid pH was recorded, and then the sample was acidified with 1 mL of 7.2N H$_2$SO$_4$ and stored until ammonia and volatile fatty acids (VFA) analysis. Ruminal fluid and fecal samples were frozen at $-20^\circ\text{C}$ prior to analysis.

**Laboratory analysis.** Collected diet, ort, and fecal samples were dried in a forced air oven (55°C; The Grieve Corporation, Round Lake, IL) for a minimum of 72 h. Dried samples were ground using a Wiley Mill (Arthur H. Thomas Co., Philadelphia, PA) to pass a 2-mm screen. Diet, ort, and fecal samples were analyzed for dry matter (DM), ash, and crude protein (CP; AOAC, 2010), and neutral and acid detergent fibers (NDF and ADF, respectively, Ankom Technologies). Chromium was analyzed in fecal samples by the spectrophotometric method (Fenton and Fenton, 1979). Ruminal fluid was analyzed for VFA (Goetsch and Galyean, 1983).

**Statistical analysis.** Data were analyzed with PROC MIXED (SAS Inst. Inc., Cary, NC). Pen was the experimental unit for Study 1. Individual animal data (BW, average daily gain [ADG], and carcass characteristics) were averaged within pen to create pen values. Study 2 was analyzed as a $4 \times 4$ Latin square design. The model included period and treatment as fixed effects. Data over time were analyzed as repeated measures, and the model included period, treatment, and time. The treatment $\times$ time interaction was initially included but was not significant for any variables and was therefore removed from the model. Covariant structures were tested, and Simple was used based on fit statistics. Means were separated based on increasing roughage inclusion rate using linear, quadratic, and cubic contrast statements. $P$-values $\leq 0.05$ were considered significant, and $P$-values $> 0.05$ and $\leq 0.10$ were considered tendencies.

### RESULTS

Feedlot performance and carcass characteristics were not affected by roughage inclusion ($P \geq 0.20$; Table 2). In Study 2, roughage inclusion did not affect DMI or organic matter intake ($P \geq 0.80$; Table 3). Digestibility of DM, organic matter, CP, NDF, and ADF were not affected by additional dietary roughage ($P \geq 0.23$). Ruminal pH increased while total VFA concentrations (mM) decreased linearly with increasing roughage ($P < 0.01$; Table 4). Proportions of acetate and butyrate increased and propionate decreased ($P < 0.01$), increasing the acetate and butyrate to propionate ratio ($P < 0.01$) with increasing dietary roughage.

### DISCUSSION

In Study 1, DMI and ADG were unaffected by roughage inclusion in steers fed wheat at 36% to 42% of dietary DM. Bock et al. (1991) found a decrease in ADG, final weight, and hot carcass weight with greater inclusion of wheat. A study by Kreikemeier et al. (1987) reported in vitro starch digestion was more rapid for wheat than corn, potentially leading to acute acidosis and decreased intake in feedlot cattle, which is contrary to our results.
Hales et al. (2014) found no difference in DMI when alfalfa hay increased from 2% to 14% in steers fed high concentrate diets. While our feedlot study showed no effect of increasing roughage from 10% to 16% on ADG, previous research reported increased ADG when alfalfa hay increased from 2% to 6% but decreased ADG when alfalfa hay increased from 6% to 14% (Hales et al., 2013). Increased dietary roughage potentially led to an increase of buffers entering the rumen and offsetting acidosis, increasing intake and ADG. Differences in results from Hales et al. (2013; 2014) and the current feedlot study could be explained by the differences in roughage or grain sources and inclusion level.

In feedlot diets, roughage inclusion is a crucial component to maintain ruminal pH above 5.5 and decrease cases of digestive upset. Weiss et al. (2017) reported increased ruminal pH when roughage increased from 5% to 10%. Similarly, Sindt et al. (2003) found a linear increase in ruminal pH when

### Table 2. Impacts of added roughage on feedlot performance and carcass characteristics of feedlot cattle fed wheat-based diets

| Treatment<sup>a</sup> | 10  | 12  | 14  | 16  | SEM | P-value<sup>b</sup> |
|-----------------------|-----|-----|-----|-----|-----|---------------------|
| Feedlot performance   |     |     |     |     |     |                     |
| Initial weight, kg    | 391.0 | 391.2 | 386.9 | 393.4 | 2.66 | 0.40               |
| Final weight, kg      | 650.2 | 645.7 | 635.1 | 646.8 | 10.17 | 0.70               |
| Average daily gain, kg/d | 2.20 | 2.14 | 2.05 | 2.19 | 0.074 | 0.50               |
| Dry matter intake, kg/d | 13.2 | 13.1 | 13.0 | 13.2 | 0.36 | 0.99               |
| Gain:feed             | 0.168 | 0.163 | 0.159 | 0.166 | 0.008 | 0.87               |
| Carcass characteristics|     |     |     |     |     |                     |
| Hot carcass weight, kg | 381.2 | 380.2 | 369.4 | 383.2 | 4.84 | 0.30               |
| Ribeye area, cm²      | 83.3 | 81.0 | 80.2 | 81.7 | 1.08 | 0.30               |
| Marbling<sup>c</sup>  | 499  | 439  | 455  | 445  | 15.7  | 0.11              |
| Back fat, cm          | 1.10 | 1.18 | 1.20 | 1.22 | 0.09 | 0.76               |
| Quality grade<sup>d</sup> | 10.4 | 9.8  | 10.0 | 10.0 | 0.19 | 0.20               |
| Yield grade           | 3.1  | 3.3  | 3.3  | 3.4  | 0.13 | 0.60               |

<sup>a</sup>Treatment: 10 = 5% grass hay and 5% straw; 12 = 5% grass hay and 7% straw; 14 = 5% grass hay and 9% straw; and 16 = 5% grass hay and 11% straw.

<sup>b</sup>P-values: Overall effect of treatment.

<sup>c</sup>Marbling score based on 400 = Small00.

<sup>d</sup>Quality grade based on Low Choice (Ch−) = 10, High Prime (Pr+) = 15.

### Table 3. Impacts of added roughage on OM and DM digestion of steers fed wheat-based diets

| Treatment<sup>4</sup> | 10  | 12  | 14  | 16  | SEM | TRT | L | Q | C |
|-----------------------|-----|-----|-----|-----|-----|-----|---|---|---|
| Intake                |     |     |     |     |     |     |   |   |   |
| DM, kg/d              | 10.0 | 9.9  | 9.8  | 10.1 | 0.42 | 0.94 | 0.91 | 0.62 | 0.77 |
| OM, kg/d              | 9.4  | 9.3  | 9.2  | 9.5  | 0.40 | 0.96 | 0.97 | 0.64 | 0.80 |
| OM, g/kg BW           | 22.4 | 22.0 | 21.7 | 22.4 | 0.60 | 0.80 | 0.93 | 0.37 | 0.78 |
| Digestibility<sup>c</sup>, % |     |     |     |     |     |     |   |   |   |
| DM                    | 70.2 | 73.2 | 72.5 | 69.4 | 1.66 | 0.39 | 0.70 | 0.12 | 0.86 |
| OM                    | 73.26| 76.28| 75.07| 72.41| 1.358| 0.27 | 0.56 | 0.08 | 0.67 |
| CP                    | 73.53| 75.70| 74.66| 70.64| 1.730| 0.29 | 0.26 | 0.12 | 0.98 |
| NDF                   | 63.93| 65.24| 66.18| 61.91| 1.905| 0.48 | 0.57 | 0.19 | 0.59 |
| ADF                   | 49.56| 50.73| 61.07| 47.69| 4.385| 0.23 | 0.82 | 0.15 | 0.14 |

<sup>4</sup>Treatment: 10 = 10% corn silage assuming 50:50 of roughage to concentrate in the corn silage, 12 = 10% corn silage and 2% straw, 14 = 10% corn silage and 4% straw, and 16 = 10% corn silage and 6% straw.

<sup>4</sup>P-values: Overall effect of treatment (TRT), linear (L), quadratic (Q), and cubic (C) contrasts.

<sup>c</sup>Total tract digestibility of dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF).
roughage increased from 0% to 6% (DM basis). This directional change was also observed in our research. Increasing ruminal pH with increased roughage can potentially be explained by increased chewing time, essentially increasing saliva that carries buffers to the rumen (Allen et al., 1997).

Including MDGS can reduce the amount of roughage needed in the diet (Krehbiel et al., 1995; Klopfenstein et al., 2008). Adding MDGS reduces the amount of starch in the diet while increasing fiber, protein, and fat, which reduces the need for excess roughage (Klopfenstein et al., 2008). Both portions of the current study included 30% MDGS across treatments, potentially offsetting a decrease in ruminal pH and avoiding subacute acidosis that may have been observed with greater wheat inclusion. Our study did not observe a pH that dropped below the subacute acidosis level of 5.6 (Owens et al., 1998), a potential result of grain processing without production of fines or perhaps a result of the use of MDGS as a secondary energy source in the diet of the current study.

Similar to Study 2 data, ruminal acetate and butyrate along with acetate:propionate (Ac:Pr) increased with increasing dietary roughage while propionate decreased (Chibisa et al., 2020). With increasing wheat concentration, Axe et al. (1987) found an increase in propionate and total VFA production and a decrease in acetate and Ac:Pr. Differences between our data and that of Axe et al. (1987) could be explained by wheat concentration and MDGS inclusion. Given these results, we reject our hypothesis of feedlot performance decreasing with additional roughage as performance was not affected and failed to reject our hypothesis of ruminal pH increasing with additional dietary roughage.

### IMPLICATIONS

Our data indicate that increased roughage inclusion in wheat-based diets including modified distillers grains with solubles increased ruminal pH without affecting feedlot performance. The lack of subacute acidosis and our feedlot performance data indicate that feedlot producers feeding combinations of MDGS and wheat may not need to increase roughage inclusion. As our current study used a small number of feedlot cattle, additional research is needed to validate these results with a larger-scale feedlot study. Further, additional research should be performed to evaluate how feeding wheat in combination with modified distillers grains with solubles affects feedlot performance of lightweight feedlot cattle. This could prove important as lightweight calves be less adapted to consuming grain and would consume finishing diets for a longer period of time compared to the steers in the current study.

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