Influence of dry-rolled corn processing and increasing dried corn distillers grains plus solubles inclusion for finishing cattle on growth performance and feeding behavior

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ABSTRACT: Sixty-four yearling steers (345 ± 4.2 kg BW) were used to study the effects of degree of dry-rolled corn processing and corn dried distillers grains plus solubles (DDGS) inclusion on feeding and ruminating behavior, G:F, and carcass characteristics. Steers were assigned randomly to 1 of 4 experimental treatments (n = 16 per treatment): 1) coarse-rolled (2.68 mm) corn and 20% DDGS, 2) coarse-rolled corn and 40% DDGS, 3) fine-rolled (1.46 mm) corn and 20% DDGS, and 4) fine-rolled corn and 40% DDGS. Final BW and ADG were not affected by corn processing or DDGS. Dry matter intake (kg/d and % of BW) decreased (P < 0.001) and G:F increased (P < 0.001) with increasing inclusion of DDGS. Meal number increased (P ≤ 0.05) and meal size decreased (P < 0.001) with finer dry-roll corn processing and with increasing inclusion of DDGS. Drinking time decreased (P = 0.03) with finer dry-rolled corn processing and tended to increase (P = 0.06) with increased inclusion of DDGS. Rumination time while standing decreased (P = 0.03) with increased inclusion of DDGS. Increasing inclusion of DDGS from 20 to 40% decreased intake, increased G:F, and altered feeding behavior of finishing steers consuming a 90% concentrate diet without affecting carcass quality. Increasing the degree of dry-roll corn processing did not impact growth performance and did not interact with increasing inclusion of DDGS in finishing diets.

Key words: corn processing, dried distillers grains, feeding behavior, finishing cattle, growth performance

INTRODUCTION

Feed costs represent a large proportion of total costs of beef production. Optimizing utilization of corn grain in combination with corn dry distillers grains plus solubles (DDGS) is critical for maximizing efficiency for finishing cattle. Increased grain processing generally improves the utilization of corn grain (Owens et al., 1997), although this is likely dependent on forage source and level and inclusion of other ingredients in the diet. For example, the inclusion of distillers grains in finishing diets may influence the optimal processing method of corn grain (Corrigan et al., 2009). Less information is available regarding different particle size reduction for dry-rolled corn. Feeding more finely rolled corn increased DMI and ADG when wet corn gluten feed was included in a finishing diet but did not alter G:F (Lowe et al., 2006).

Interactions between feeding behavior, rumen function, and digestibility are largely influenced by dietary composition and feed processing (Gonzalez et al., 2012). We hypothesize that degree of dry-roll corn processing and increasing inclusion of DDGS will influence feeding and ruminating behavior as well as cattle performance. Our objectives were to determine the effect and interaction of degree of dry-roll corn grain processing and increasing inclusion of DDGS on feeding and ruminating behavior, feed efficiency, and carcass quality.

MATERIALS AND METHODS

Animals, Experimental Design, and Dietary Treatments

All procedures with animals were approved by the North Dakota State University (NDSU) Animal Care and Use Committee. Sixty-four steers (345 ± 4.2 kg BW) predominately of Angus, Simmental, and Shorthorn breeding were used in a 2 × 2 factorial arrangement of treatments (degree of dry-roll process-
ing and DDGS inclusion level) and sorted by BW into 3 pens (light, medium, and heavy pens; \( n = 21 \) or \( 22 \) per pen) at the NDSU Beef Cattle Research Complex. Within each pen, steers were assigned randomly to 1 of 4 experimental treatment diets (Table 1; \( n = 5 \) or \( 6 \) steers per treatment within pen; \( n = 16 \) per treatment): 1) coarse-rolled corn and 20% DDGS, 2) coarse-rolled corn and 40% DDGS, 3) fine-rolled corn and 20% DDGS, and 4) fine-rolled corn and 40% DDGS. Diets were formulated to meet or exceed requirements for RDP, MP, vitamins, and minerals (NRC, 1996). Diets were offered for ad libitum intake. Steers were adapted to experimental diets by transitioning from a 60% concentrate diet to the final diets over 21 d. Steers were implanted with 80 mg of trenbolone acetate and 16 mg estradiol (Revalor IS; Merck Animal Health, Whitehouse Station, NJ). One steer was removed from the coarse dry-roll corn processing, 40% DDGS inclusion treatment because it would not consume feed from the Insentec feed troughs (Insentec B. V., Marknesse, The Netherlands).

### Body Weight and Feed Intake Measurements

Steers were weighed before feed delivery for 2 consecutive days at the beginning and ending of the feeding period and every 28 d throughout the feeding period. Average daily gain was calculated by regressing BW on day.

Radio frequency ID tags were placed in the right ear before the experiment. Each pen contained 8 Insentec electronic feeding stations (Inesentec, B. V., Marknesse, The Netherlands) as described by Mader et al. (2009) and Islas et al. (2013) allowing for offering specific dietary treatments and monitoring of individual feed intake and feeding behavior characteristics. Each experimental diet was provided in 2 feeders per pen. Total DMI and feeding behavior traits were summarized (Montanholi et al., 2010) as follows: events (number of bunk visits and meals daily), eating time (minutes; per visit, per meal, and per day), and feed intake (grams; per visit, per meal, and per minute) and these data were summarized as the average of each individual steer starting after dietary adaptation (d 28).

A visit was defined as each time the Insentec system detected a steer at a bunk. A meal was defined as eating periods that might include short breaks separated by intervals not longer than 7 min (Forbes, 1995; Montanholi et al., 2010). Cattle were also monitored for activity (lying, ruminating, drinking, resting while standing, and resting while lying) using visual observation measurements (Maekawa et al., 2002) on a subset of 6 cattle from each treatment for 8-h periods over 3 d to encompass 24 h starting on d 98 of the experiment.

### Feed Analysis

Diet samples were collected weekly. Weekly samples were dried in a 55°C oven and ground to pass a 1-mm screen. Weekly samples were analyzed for DM, ash, N (Kjeldahl method), Ca, and P by standard procedures (AOAC, 1990) and for NDF (assayed with heat stable amylase and sodium sulfite and expressed inclusive of residual ash) and ADF (expressed inclusive of residual ash) concentration by the method of Robertson and Van Soest (1981) using a fiber analyzer (Ankom Technology Corp., Fairport, NY). Percent CP was calculated by multiplying N concentration × 6.25. Samples also were analyzed for ether extract (AOAC, 1990) and for starch (Herrera-

### Table 1. Dietary ingredient and nutrient compositions (% of DM)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Coarse-roll corn</th>
<th>Fine-roll corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse-rolled corn</td>
<td>20.00</td>
<td>40.00</td>
</tr>
<tr>
<td>Fine-rolled corn</td>
<td>40.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Dried corn distillers grains with solubles⁴</td>
<td>20.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Grass–legume hay</td>
<td>5.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Corn silage</td>
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<td>5.00</td>
</tr>
<tr>
<td>Corn condensed distillers solubles</td>
<td>5.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Fine ground corn</td>
<td>2.84</td>
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<tr>
<td>Limestone</td>
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<td>1.90</td>
</tr>
<tr>
<td>Urea</td>
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<tr>
<td>Vitamin premix⁵</td>
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<td>0.05</td>
</tr>
<tr>
<td>Trace mineral premix⁶</td>
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</tr>
<tr>
<td>Monensin premix⁷</td>
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<td>0.02</td>
</tr>
<tr>
<td>Tylosin premix⁸</td>
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<table>
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<tr>
<td>OM</td>
<td>93.8</td>
<td>93.1</td>
</tr>
<tr>
<td>CP</td>
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<tr>
<td>NDF</td>
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<td>29.6</td>
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<tr>
<td>ADF</td>
<td>10.6</td>
<td>10.6</td>
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<tr>
<td>Ether extract</td>
<td>5.28</td>
<td>6.49</td>
</tr>
<tr>
<td>Starch</td>
<td>41.2</td>
<td>29.4</td>
</tr>
</tbody>
</table>

1 Treatments were arranged in a 2 × 2 factorial with degree of dry-roll corn processing (coarse and fine) and dried distillers grains plus solubles inclusion (20 and 40%; DM basis) as the 2 factors (\( n = 15 \) or \( 16 \) per treatment).

2 2.68 ± 0.157 mm (\( n = 4 \) batches of corn).

3 1.46 ± 0.079 mm (\( n = 4 \) batches of corn).

4 Contained 28.6% CP, 11.4% ether extract, 33.5% NDF, 8.37% ADF, and 0.97% S (DM basis).

5 Contained 48,510 kIU/kg vitamin A and 4,630.5 kIU/kg vitamin D.

6 Contained 3.62% Ca, 2.56% Cu, 16% Zn, 6.5% Fe, 4.0% Mn, 1,050 mg/kg I, and 250 mg/kg Co.

7 Contained 176.4 g monensin/kg premix.

8 Contained 88.2 g tylosin/kg premix.

9 Average of weekly samples.
Saldana and Huber, 1989) concentrations. Corn grain samples were taken with each load of grain processed \((n = 4)\). Particle size was analyzed following the procedure of ASAE (1993) with the following modifications: a Tyler Ro-Tap sieve shaker (W. S. Tyler, Mentor, OH) was substituted for the Tyler RX86 sieve shaker. To compensate for differences in sieve shakers, the wing nut supports were raised approximately 2.5 cm from the top of the sieves, allowing the sieves to rock back and forth. Thirteen sieves were used along with a bottom pan. The sieve sizes ranged from 3,360 to 53 μm. Particle size was calculated as the geometric mean diameter using the equations of Baker and Herman (2002). Particle size (mean ± SEM) for the 4 samples each of coarse- and fine-rolled corn was 2.68 ± 0.157 mm and 1.46 ± 0.079 mm, respectively.

**Carcass Characteristics**

Steers were fed until they were visually observed to be finished (approximately 12 mm subcutaneous \([\text{s.c.}]\) fat thickness at the 12th rib) and marketed in 2 groups. The first group (heaviest at d 112) was fed for 112 d \((n = 39; n = 10 \text{ per treatment, except } n = 9 \text{ for the coarse corn processing, } 40\% \text{ DDGS treatment, which had 1 steer removed})\) and the second group was fed for 145 d \((n = 24; n = 6 \text{ per treatment})\) before transport to a commercial slaughter facility. After the first group was sent for slaughter, the remaining cattle were combined into 1 pen for the remainder of the experiment. Hot carcass weight was measured on the day of slaughter and carcass measurements were measured following a 24-h chill. Measurements collected were s.c. fat thickness at the 12th rib, LM area, and marbling score.

**Blood Collection and Plasma Urea-N Analysis**

Blood samples were collected by jugular venipuncture into Vacutainer tubes containing sodium heparin (Becton Dickinson, Rutherford, NJ) on d 28, 56, 84, and 112 before feeding on the same days as BW measurements. Plasma was isolated by centrifugation (Sorvall ST16R; Thermo Fisher Scientific, Waltham, MA) at 3,000 \(\times g\) for 20 min at 4°C and stored at –20°C until analysis. Plasma urea-N was determined using the urease/Berthelot procedure (Chaney and Marbach, 1962; Fawcett and Scott, 1960).

**Statistical Analysis**

Data were analyzed as a completely randomized block (slaughter group) design using the Mixed procedure of SAS (SAS Inst. Inc., Cary, NC) with a \(2 \times 2\) factorial arrangement of treatments. The model included the effects of block (slaughter group), degree of dry roll processing (coarse vs. fine), DDGS inclusion (20 vs. 40% DDGS), and the degree of dry roll processing × DDGS inclusion interaction. For plasma urea-N, data were analyzed as a randomized block (slaughter group) design with repeated measures and tested for the effects of block (slaughter group), day, degree of dry roll processing, DDGS inclusion, degree of dry-roll processing × DDGS inclusion, degree of dry-roll processing × day, DDGS inclusion × day, and degree of dry-roll processing × DDGS inclusion × day using the Mixed procedure of SAS. Appropriate (minimize information criterion) covariance structures were used (Wang and Goonewardene, 2004). The simple covariance structure was used because it had the smallest Akaike information criterion, finite sample corrected Akaike information criterion, and Schwarz’s Bayesian information criterion. Data were considered significant when \(P \leq 0.05\).

**RESULTS**

Initial BW, final BW, and ADG were not affected by dry-roll corn processing or DDGS inclusion (Table 2). Dry matter intake (kg/d and % of BW) was not affected by dry-roll corn processing but decreased \((P < 0.001)\) with increasing DDGS inclusion. Gain:feed was not affected by dry-roll corn processing and increased \((P < 0.001)\) with increasing DDGS inclusion. Hot carcass weight, s.c. fat thickness at the 12th rib, LM area, and marbling score were not affected by dry-roll corn processing or DDGS inclusion.

Number of visits per day was not affected by dry-roll corn processing or DDGS inclusion (Table 3). Number of meals per day increased \((P \leq 0.05)\) with finer dry-roll corn processing and with increased DDGS inclusion. Time eating per visit and per meal was not affected by dry-roll corn processing or DDGS inclusion. Time eating per day was greater \((P = 0.02)\) with finer dry-roll corn processing but was not affected by DDGS inclusion. Eating rate per meal or per minute was less \((P \leq 0.006)\) with finer dry-roll corn processing and with increased DDGS inclusion.

For observational measurements, time eating per day was not affected by dry-roll corn processing or DDGS inclusion (Table 4). Time spent drinking per day decreased \((P = 0.03)\) with finer dry-roll corn processing and tended to increase \((P = 0.06)\) with increased DDGS inclusion.

Total intake time (at both feed and water troughs) was not affected by dry-roll corn processing and tended to increase \((P = 0.06)\) with increased DDGS inclusion. Rumination time while standing was not affected by dry-roll corn processing and decreased \((P = 0.03)\) with increased DDGS inclusion. Rumination time while lying and total rumination time (standing and lying) was not affected by dry-roll corn processing or DDGS inclusion.
Resting time while standing or lying and total resting time (standing and lying) were not affected by dry-roll corn processing or DDGS inclusion.

There were significant dry-roll corn processing × DDGS inclusion (P = 0.02), dry-roll corn processing × day (P = 0.01), and DDGS inclusion × day (P = 0.005) interactions for plasma urea-N concentrations. However, interactions generally occurred because of differences in magnitude of change of urea-N concentrations within treatment over time and not re-ranking of treatments.

Dry-roll corn processing did not influence plasma urea-N concentrations, but increasing DDGS inclusion increased (P < 0.001) plasma urea-N concentrations (Fig. 1).

### DISCUSSION

Feed costs represent a large portion of total costs for cattle feeding operations. Because corn grain and distillers grains typically constitute the largest portion of finishing diets, optimizing use of distillers grains and...
Corn processing methods are important for maximizing efficiency of finishing cattle operations. Although research has generally suggested a greater energy value for distillers grains than for corn, optimal inclusion rates may differ for dry and wet distillers grains (Klopfenstein et al., 2008) and may depend on corn processing (Corrigan et al., 2009). A meta-analysis (Klopfenstein et al., 2008) combining data from 5 different studies examining inclusion levels up to 40% of distillers grains (DM basis) indicated that DMI linearly increased but tended to be quadratic with the greatest intake at 30% inclusion (and decreasing thereafter), ADG responded quadratically with the greatest ADG at 30% inclusion, and G:F responded quadratically with the greatest G:F at 10% inclusion. Our data do not agree with these results as we saw an improvement in G:F when comparing 40 to 20% DDGS, and the response was driven by a lower intake but similar ADG for the 40% DDGS treatment. The reason for the differing results are not clear but might be due to variability in nutrient availability of DDGS due to differences in corn grain source, processing, and drying procedures. Fat level in DDGS as well as other sources of added fat also potentially could impact results.

Our results indicate that decreasing particle size through different degrees of dry rolling did not impact DMI, ADG, or G:F. Research has suggested that DM and starch digestibility generally increase when corn is dry processed to a smaller particle size (Galyean et al., 1979, 1981). However, decreasing particle size via dry processing did not improve ADG or G:F in finishing cattle (Turgeon et al., 1983) or milk production or milk production efficiency
in lactating dairy cows (Ferraretto et al., 2013). The reason that reducing particle size when dry rolling typically does not result in improved performance may be because decreasing particle size increases rate of fermentation in the rumen, which could result in increased incidence of subacute acidosis (Owens et al., 1998). However, inclusion levels for other ingredients in the diet, such as forage or by-products, likely offset the effect of particle size reduction of corn performance and incidence of acidosis. For example, feeding more finely rolled corn increased DMI and ADG when wet corn gluten feed was included in a finishing diet but did not alter G:F (Loe et al., 2006).

Research has suggested that the inclusion of distillers grains in finishing diets may influence the optimal processing method for corn grain (Corrigan et al., 2009). We did not observe any interactions between DDGS inclusion and degree of dry-roll corn processing. Perhaps there was not a great enough difference in particle size between the coarse- and fine-rolled corn used in this experiment in terms of effects on rate of ruminal fermentation and digestion to elicit differential effects depending on DDGS inclusion level. Alternatively, forage NDF levels may have been great enough so that differences in degree of dry-roll corn processing did not result in changes in the incidence of subacute acidosis. This is supported by the fact that estimated effective NDF requirements were met or exceeded by all treatment diets (NRC, 1996).

Less is known about how DDGS inclusion and corn processing influences feeding behavior. Decreasing corn particle size and increasing dietary DDGS increased number of meals and decreased eating rate per meal (meal size) suggesting that cattle are adapting to diets by altering feeding behavior. These adaptations in feeding behavior could be associated with changes in the ruminal environment. Increasing the frequency and distribution of meals throughout the day can moderate ruminal pH (Gonzalez et al., 2012) resulting in a reduced time when ruminal pH is low. Our observational data would also suggest that cattle fed 40% distillers grains spent less time ruminating when standing. This suggests that rumen function may have been altered, which could have been associated with the observed changes in feeding behavior. In other research examining the effects of distillers grains inclusion in finishing diets on feeding behavior, Corrigan et al. (2009) reported an interaction between corn processing type and wet distillers grains plus solubles inclusion level on time spent at the feeder per day, with time spent at the feeder increasing when wet distillers grains plus solubles was fed at 40% compared to 20% of diet DM for cattle fed dry-rolled corn based diets but not for those fed high-moisture or steam-flaked corn-based diets. Research has also suggested that changes in feeding behavior may be associated with changes in feed efficiency in cattle fed the same diet (Golden et al., 2008; Nkrumah et al., 2006; Richardson and Herd, 2004). For example, Montanholi et al. (2010) suggested that more efficient (low residual feed intake) calves consumed smaller meals and had slower eating rates as compared to less efficient calves and also spent less total time at the feeder per day. More research is necessary to better understand how changes in feeding behavior associated with dietary changes impacts cattle performance.

In conclusion, increasing DDGS inclusion from 20 to 40% decreased intake, increased G:F, and altered feeding behavior of finishing steers consuming a 90% concentrate diet without affecting carcass quality. Increasing the degree of dry-roll corn processing did not impact growth performance and did not interact with increasing DDGS inclusion in finishing diets.

LITERATURE CITED


