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Evaluation of Ruminal Dry Matter Disappearance and pH of Dry Corn, High-Moisture Corn, and Rye under *in Vitro* Conditions

Warren Carl Rusche, Zachary Kidd Foster Smith*

South Dakota State University, Brookings, South Dakota, USA
Email: *Zachary.Smith@sdstate.edu

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Abstract

An *in vitro* experiment was conducted to evaluate the effects of grain type on *in vitro* dry matter disappearance (IVDMD) and pH using ruminal fluid and a buffer reagent. Five beef cows were used for ruminal fluid collection and ruminal fluid was pooled prior to use. The cows used for ruminal fluid collection were maintained on a forage-based diet (60:40 forage to concentrate) for 28 d prior to ruminal fluid collection. Three grain types were evaluated: 1) dry corn (89% dry matter; DRC), 2) high-moisture corn (72% dry matter; HMC) and 3) rye (89% dry matter; RYE). Data were analyzed as a completely randomized design. A total of twenty-one replications of each grain type were used for statistical analysis (n = 63 tubes total). IVDMD was greater ($P \leq 0.05$) by 97.1% and 46.4% for RYE compared to DRC and HMC, respectively. Additionally, IVDMD was greater ($P = 0.05$) by 34.6% for HMC compared to DRC. Final pH was decreased ($P \leq 0.05$) for RYE by 12.3% and 2.8% for RYE compared to DRC and HMC, respectively. Also, final pH was decreased ($P = 0.05$) by 9.8% for HMC compared to DRC. These data indicate that corn harvest method (dry vs. high-moisture) influences IVDMD and final pH and that rye has a greater disappearance of dry matter and lower final pH than corn under *in vitro* conditions.

Keywords

Corn, Grain Processing, Ruminal Fermentation, Rye

1. Introduction

Rye grain offers intriguing options as a rotational crop for Midwestern corn and

soybean rotations. Diverse crop rotation combined with livestock enterprises enhances ecosystem services in the face of climate change, consequently identifying crops that can also be used as livestock feed increases the likelihood of system adoption [1]. Diversifying crop rotations, for instance by including winter annual such as cereal rye in maize-soybean system improves yield resilience and increased maize yields over time and across varying growing conditions [2].

However, much less is known regarding feed characteristics and feeding value of rye grain compared to other feed grains. Understanding ruminal degradability by using *in vitro* techniques is important to properly evaluate feedstuffs and predict livestock performance [3]. The objective of this experiment was to quantify IVDMD and pH for rye grain compared to two different forms of corn commonly fed in midwestern US beef cattle diets.

2. Materials and Methods

Animal Care and Used Approval was obtained prior to conduction this experiment from The South Dakota State University Institutional Animal Care and Use Committee (2011-054A).

In vitro Procedure

Five beef cows were used for ruminal fluid collection and ruminal fluid was pooled prior to use. The cows used for ruminal fluid collection were maintained on a forage-based diet (60:40 forage to concentrate) for 28 d prior to ruminal fluid collection. Three grain types were evaluated: 1) dry corn (89% dry matter; DRC), 2) high-moisture corn (72% dry matter; HMC) and 3) rye (89% dry matter; RYE). All samples were dried at 60˚C until no further weight change occurred and ground to 1-mm using a Wiley Mill (Thomas Scientific, Swedesboro, NJ) prior to use. The procedure used was a slight modification to the method described [4]. Briefly, one liter of ruminal fluid will be collected and pooled from rumen fistulated cows (n = 5; average BW = 750 kg) consuming a common diet (60:40 forage to concentrate). Rumen contents were squeezed through four layers of cheesecloth into a pre-warmed thermos. Ruminal fluid was transported back to the laboratory (1.5 km distance) and placed into separatory funnels and placed into a 39˚C water bath and mixed with warmed McDougall's buffer [5]. The ratio of buffer to rumen fluid was 4:1 (v/v). A total of 0.5 g of the appropriate substrate was weighed and placed into 50 mL polypropylene fermentation tubes fitted with a rubber stopper and one-way valve. A volume of 30 mL of the ruminal inoculum was added to each tube. Each tube was flushed with CO_2 and placed into a water bath at 39˚C. All tubes were mixed initially and every 1 hour. Fermentation was terminated after a 7-hour incubation period. At the end of the incubation period, pH was measured using a pH electrode. Fermentation was terminated by the addition of 0.5 mL of 0.2 N HCl and tubes were held under refrigeration at 4˚C. The following day tubes were centrifuged at 1800 x g for 15 min at 4˚C. All remaining solids were filtered with filter papers (Whatman 541, Cytiva, Chicago, IL) and dried at 105˚C for 4 hours. *In vitro* dry matter

disappearance (IVDMD, %) was calculated as: IVDMD, % = 100 × [(initial dry sample weight − (residue-blank))/initial dry sample weight].

3. Results and Discussion

In vitro dry matter disappearance was 97.1% and 46.4% greater ($P \leq 0.05$) for RYE compared to DRC and HMC, respectively, as shown in Figure 1. In addition, IVDMD was 34.6% greater ($P = 0.05$) for HMC compared to DRC. Type of grain also affected final pH, with RYE having lesser final pH values compared to HMC and DRC ($P \leq 0.05$) and HMC less than DRC ($P = 0.05$; 5.61, 5.77, and 6.40 for RYE, HMC and DRC, respectively).

The increased IVDMD for rye grain agrees with other observations where rye grain was more rapidly available in the rumen compared to barley [6] or corn [7]. Differences in degradability between feed grains are related to the molecular structure of the protein matrix surrounding starch granules [6] [7] [8]. Another potential explanation for the increased IVDMD for rye grain is greater concentrations of alkylresorcinols in rye compared to other grain species, which could modify enzyme activity [6] [9]. The IVDMD differences between HMC and DRC observed in the current experiment are also in agreement with previous results demonstrating that fermentation of corn grain enhances DM digestibility compared to dry rolling [10] [11]. Rajtar, Górka, Schwarz and Micek [7] noted that that *in situ* ruminal starch degradability increased with more extensive processing of corn grain. Those researchers also observed that degree of processing did not affect starch digestion in rye, but rye processed to any extent

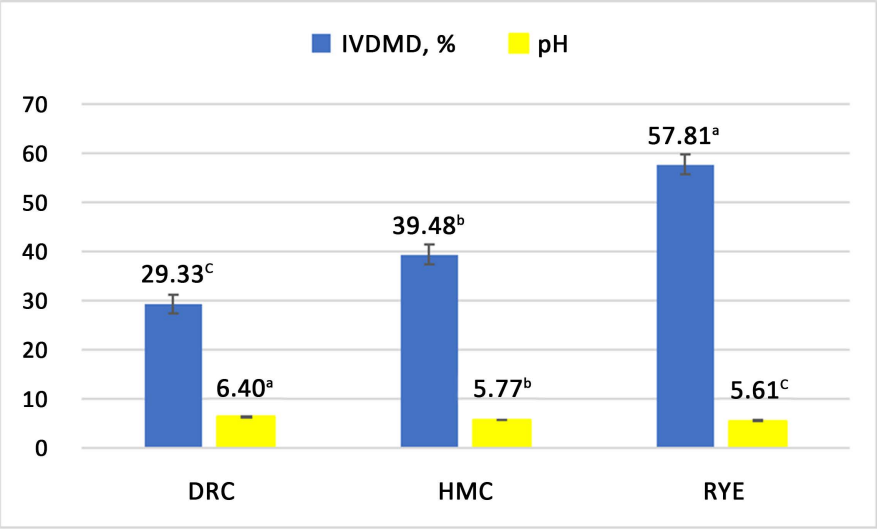

Figure 1. Treatments included: 1) dry corn (89% dry matter; DRC), 2) high-moisture corn (72% dry matter; HMC) and 3) rye (89% dry matter; RYE). Data were analyzed as a completely randomized design. A total of twenty one-replications of each grain type were used for statistical analysis (n = 63 tubes total). Marginal means presented ± the standard error of the mean. Blue Bars = *In vitro* dry matter disappearance (IVDMD) and Yellow Bars = -logc, where c is the hydrogen ion concentration in moles per liter (pH). Measured parameters (IVDMD and pH) with different superscripts (a, b, c) differ ($P \leq 0.05$).

had greater ruminal digestion compared to all processed corn.

Final pH values observed in the current experiment correspond with observed differences in IVDMD. Increased amounts of rapidly degradable starch in the rumen result in greater production of organic acids leading to reductions in ruminal pH [12] [13]. Rumen pH can be influenced by consumption of acidic feedstuffs, such as silages; however, it is the production of fermentation acids in the rumen from starch that has the most profound impact on ruminal pH [12]. Consequently, it is not surprising that RYE had reduced final pH compared to the two corn treatments and that the final pH for HMC was less compared to DRC given the increased IVDMD differences observed in the current experiment. These pH differences agree with those previously observed comparing rye to dry corn [8] and between HMC and DRC [10].

Differences in ruminal digestibility observed in this experiment are useful to explain cattle performance differences when rye is fed in replacement of corn. When dry-rolled rye grain replaced two-thirds or 100% of dry-rolled corn in finishing diets, both intake and gain were reduced compared to lessor inclusions of rye or the dry-rolled corn control [14]. However, when whole rye grain was fed as the sole cereal grain, there was no effect on feed intake [15]. Increased acid load could explain the reductions in voluntary feed intake observed by [14] with greater inclusions of rye grain. In addition, the negative gain and feed efficiency responses to 40% or 60% rye inclusion in finishing beef steer performance in that experiment are consistent with increased incidence of subacute acidosis caused by greater rye grain intake. Chronic subacute acidosis is associated with reduced dry matter intake and live animal performance [16]. The *in vitro* pH observed in the current experiment could be the cause of the reduced dry matter intake and live gain observed earlier [14].

4. Conclusion

In vitro dry matter from rye grain was more digestible compared to either high-moisture or dry-rolled corn, resulting in reduced final pH. Understanding ruminal fermentation characteristics of rye grain is valuable to develop more accurate feeding standards and increase the ability to predict health and cattle performance outcomes.

Data Availability Statement

Data can be made available upon reasonable request to Z.K.S.

Conflict of Interest

The authors declare no conflict of interest.

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