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Summary

Using the mobile bag technique, five commercially available corn hybrids harvested as either dry-rolled or high-moisture corn were evaluated for site and extent of DM and starch digestion. Total-tract DM digestibility was improved 7 to 16 percentage units, and total-tract starch digestibility was improved 9 to 18 percentage units among hybrids when processed as high-moisture corn compared to dry-rolled corn. The results of this trial suggest that hybrid and processing method interact and can influence DM and starch digestibility.

Introduction

Macken et al. (*2003 Nebraska Beef Report*, pp. 32-34), found corn hybrids which contain more floury endosperm were more efficiently used by finishing cattle when dry-rolled, although harder endosperm hybrids were improved more than floury hybrids when processed as high-moisture corn. A more recent study (*2006 Nebraska Beef Report*, pp. 38-39) using three hybrids processed as either dry-rolled (DRC) or high-moisture corn (HMC) found that hybrid differences as well as processing method impact nutrient digestion. Our objective for this study was to evaluate corn hybrid, processing method, and interactions between these factors on-site and extent of DM and starch digestion, using five hybrids as DRC or HMC.

Procedure

Corn Production and Sampling

Five commercially available corn hybrids were selected based on a range of kernel characteristics, including hardness and kernel weight, from previous research conducted in 2004-2005 (*2006 Nebraska Beef Report*, pp. 45-47). Corn hybrids were grown and stored for a concurrent finishing trial (procedure detailed in *Nebraska Beef Report 2008*, pp. 54-56). Each sample for this trial was a composite of the first six weekly samples from the finishing trial.

Sample Preparation

Each sample was ground through a Wiley Mill with a 6.35 mm screen to simulate mastication. Dry-rolled corn samples were directly ground and high-moisture samples were freeze ground using dry ice. A 2 g sample (DM) of each ground sample was placed in a Dacron bag for incubation. For ruminal digestibility, each sample was replicated four times in two ruminally and duodenally fistulated Holstein steers. Each sample was replicated six times in each steer to determine post-ruminal and total-tract digestibility. Bags were heat sealed prior to incubation.

All bags were ruminally incubated for 22 hours, based on a 75% mean retention time for a 3.44%/hour passage rate. Following ruminal incubation, post-ruminal bags were exposed to a simulated abomasal digestion utilizing pepsin and hydrochloric acid. Post-ruminal bags were rolled and placed in the duodenal fistula one at a time beginning at approximately 1700 hour. Bags were inserted every 5 minutes allowing for the movement of the previous bags into the intestines to avoid compaction. Eight bags were incubated per day, within a 4-day sampling week, and were collected in the feces, usually within 24 hour post-insertion. Bags not collected within 48 hours post-insertion were treated as missing data.

Lab Analysis

At the conclusion of the trial, bags were machine washed with five 3-minute cycles and placed in a 60°C forced air oven for 48 hours. Bags were then composited within animal and sample across days in order to run starch analysis. Using the Megazyme® procedure, starch concentration was determined in the original samples and composites, and used to determine starch digestibility.

Statistical Analysis

Data were analyzed using the MIXED procedure of SAS (SAS 9.1, SAS Inst., Cary, N.C.) with the model including the effects of hybrid, processing method, and hybrid*processing method interaction with day and steer as random variables. At the conclusion of this trial and the finishing trial, correlations were determined between digestibilities and G:F as well as kernel characteristics.

We designed an index utilizing the Stenvert measurements of grind time and rpm to simplify the analysis of hard vs soft endosperm types. This index was derived by taking the drop in RPM from 3,600 (beginning RPM) and multiplying this by the grind time. By doing this calculation we were able to have a measurement similar to an "area under the curve" measurement. This measurement would be useful to identify the magnitude of kernel hardness based on drop in RPM and grind time.

(Continued on next page)

Table 1. Effect of hybrid and processing method on DM and starch digestibility.

Treatment	H-9485Bt DRC	H-9485Bt HMC	H-8562 DRC	H-8562 HMC	33P67 DRC	33P67 HMC	H-9230Bt DRC	H-9230Bt HMC	H-8803Bt DRC	H-8803Bt HMC	P-value[a]
Ruminal DMD[b]	40.98[d]	49.79[e]	40.18[d]	63.37[g]	38.33[d]	57.48[d]	37.88[d]	68.02[g]	38.40[d]	65.08[g]	<0.01
Ruminal SD[c]	37.21[g]	52.65[f]	35.63[g]	71.11[d]	36.65[g]	60.80[ef]	38.43[g]	76.08[d]	35.39[g]	68.79[de]	<0.01
Post-ruminal DMD	62.10	68.51	62.89	67.55	52.17	62.35	56.60	61.31	54.21	66.42	0.28
Post-ruminal SD	66.69[g]	82.64[e]	65.36[gh]	91.11[d]	53.59[i]	76.88[f]	56.62[ij]	86.51[de]	60.23[hi]	88.45[d]	<0.01
Total-tract DMD	77.27[fg]	84.13[h]	77.89[g]	88.40[i]	69.83[d]	83.65[h]	72.75[de]	88.21[i]	70.76[d]	83.31[i]	<0.01
Total-tract SD	79.82[f]	92.91[e]	79.79[f]	98.08[d]	70.75[h]	91.40[e]	74.41[g]	97.84[d]	73.89[gh]	97.15[d]	<0.01

[a]Protected F-statistic for the hybrid*processing interaction effect.
[b] DMD = Dry matter digestibility.
[c] SD = Starch digestibility.
[d,e,f,g,h,i,j]Means with unlike superscripts within a column differ $P < 0.05$.

Results

Digestibility

A significant interaction was observed between hybrid and processing for ruminal, post-ruminal, and total-tract starch, as well as ruminal and total-tract DMD, therefore only simple effects will be presented for all variables (Table 1). No interaction between hybrid and processing method for post-ruminal DMD was observed. One interesting observation was, with the exception of post-ruminal DMD, the observed improvement in digestibility for high-moisture corn compared to dry-rolled corn decreased as the feedstuff traveled through the digestive tract. Ruminal DMD was greatest for hybrid H-9230Bt fed as HMC and was lowest for the same hybrid fed as dry-rolled corn (DRC). A range of 9 (40.98 vs. 49.79) to 30 (37.88% vs. 68.02%) percentage unit improvement in ruminal DMD was seen within hybrids when processed as HMC vs. DRC.

For ruminal starch digestibility H-9230Bt HMC (76.1%) was the most digestible with H-8803Bt DRC (35.4%) being the least digestible. The greatest change in digestibility among hybrids when processed as HMC compared to DRC was 37.7 percentage units (38.4% vs. 76.1%). The smallest change for ruminal starch digestibility between HMC and DRC among hybrids was 15.5 percentage units (37.2% vs. 52.7%).

Post-ruminal DMD was significantly increased ($P < 0.01$) when hybrids were processed as high-moisture corn compared to dry-rolled corn (65.30% vs. 57.74%). Hybrids were significantly ($P < 0.01$) different in post-ruminal DMD with hybrids H-8562 (65.22%) and 33P67 (65.30%) being the most digestible, H-9485Bt (57.26%) the least digestible, and H-8803Bt (60.32%) and H-9230Bt (58.96%) being intermediate.

Hybrid H-8562 HMC (91.1%) had the greatest extent of digestion for starch entering the small intestine, while 33P67 DRC (53.6%) exhibited the least extensive post-ruminal starch digestion. HMC improved digestion of starch entering the small intestine by 15.9 (66.7% vs. 82.6%) to 29.9 (56.6% vs. 86.5%) percentage units compared to DRC among hybrids.

The greatest extent of DM digestion, throughout the digestive tract, was observed for H-8562 HMC (88.4%), with 33P67 DRC (69.8%) exhibiting the least amount of DM digestion. DRC samples, among hybrids, were less digestible for DM compared to those hybrids processed as HMC as shown in Table 1.

Total-tract starch digestibility was lowest for 33P67 DRC (70.8%) and highest for H-8562 HMC (98.1%). When hybrids were processed as HMC, starch was more digested throughout the entire digestive tract compared to being processed as DRC as shown in Table 1. Comparing these results with previous mobile bag research using some of these same hybrids (*2006 Nebraska Beef Report*, pp. 38-39), our findings are similar though the numbers are slightly lower than those previously reported. Both studies included hybrids H-8562, H-9230Bt, and 33P67, and in both studies similar patterns of digestibility were seen, with H-8562 being generally the most digestible, 33P67 the least digestible, and H-9230Bt intermediate. However, in the previous study processing and hybrid interactions were only found for post-ruminal and total-tract DM digestibility, where we found an interaction for all digestibilities except post-ruminal DM digestibility.

Table 2. Correlations between G:F and DM and starch digestion.

Variable	Across Processing r	Across Processing P-value	Within HMC r	Within HMC P-value	Within DRC r	Within DRC P-value
Rum. DMD[a]	0.78	<0.01	-0.12	0.85	0.33	0.58
Rum. SD[b]	0.80	<0.01	-0.10	0.99	0.35	0.57
PR DMD[c]	0.78	<0.01	0.75	0.14	0.25	0.68
PR SD[c]	0.86	<0.01	0.70	0.19	-0.05	0.95
TT DMD[d]	0.86	<0.01	0.39	0.53	0.31	0.61
TT SD[d]	0.86	<0.01	0.49	0.41	0.12	0.85

[a]DMD = DM digestibility
[b]SD = Starch digestibility
[c]PR = Post-ruminal
[d]TT = Total-tract

Correlation with G:F

Correlations between this study and the concurrent finishing study (*2008 Nebraska Beef Report*, pp. 54-56) were determined in order to evaluate the relationship of digestibility to G:F. Table 2 outlines the correlation coefficients, and corresponding P - values, of DM and starch digestibility with G:F. The table contains the correlations for all treatments, as well as hybrids within processing methods. Significant ($P < 0.01$) correlations were found between feed efficiency and DM and starch digestibilities. The strongest relationships to G:F were observed for post-ruminal starch, total-tract starch and total-tract DM (r = 0.86 for all) digestibility. The lowest, though still high, were observed for ruminal starch (r = 0.80), ruminal and post-ruminal dry matter digestibility (r = 0.78 for both). If the treatments were separated by processing method, we no longer detected any significant relationships between G:F and DM or starch digestibility. Within HMC only, the highest correlation was observed with post-ruminal dry matter digestibility (r = 0.75). No high correlations were observed between G:F and DM or starch digestibility within DRC only.

Correlations with kernel characteristics

Correlations with kernel characteristics were analyzed for DRC and HMC independently. Within DRC, ruminal (r = 0.90) and total-tract (r = 0.89) DM digestibility (DMD) were correlated with kernel weight ($P = 0.04$ for each). Post-ruminal DMD was strongly related (r = 0.86, $P = 0.06$) to kernel weight as well. Our hardness index correlated negatively with ruminal (r = -0.83, $P = 0.09$), post-ruminal (r = -0.81, $P = 0.10$) and total-tract (r = -0.80, $P = 0.11$) DMD . These negative relationships indicated that harder kernels decreased DMD.

Within HMC, the relationships between kernel characteristics and DMD changed dramatically. Kernel weight was not a significant indicator of digestibility, though the relationships between ruminal (r = -0.61, $P = 0.27$) and post-ruminal (r = 0.56, $P = 0.32$) DMD were relatively high. Post-ruminal DMD was highly correlated ($P = 0.03$) with the hardness index, and the relationship was very high (r = -0.92). Interestingly, neither ruminal or total-tract DMD were correlated to the hardness index ($P = 0.74$ and $P = 0.72$ respectively).

In conclusion corn hybrid interacted with processing method for DM and starch digestion. Also, high correlations between G:F and DMD exist, and are affected by processing method more than corn hybrid. We can also conclude kernel weight and kernel hardness can be used to predict DMD for DRC, however those relationships are lower for HMC. Our results also suggest some hybrids are more digestible as HMC, while some hybrids show much less response in digestibility as HMC.

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