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Development of a Berry Processing Score for Sorghum Silage and Assessment of Processing Effects on Sorghum Silage Starch Digestibility

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Summary
The objectives of this study were to develop a berry processing score (BPS) for sorghum silage, similar to the kernel processing score currently used for corn silage, and to evaluate the effects of processing on starch digestibility. Sorghum silage samples were collected from commercial farms in Kansas and randomly assigned to 1 of 4 processing levels differing in roll gap spacing: unprocessed (UNP), 1.5 (1.5P), 1.0 (1.0P), or 0.5 (0.5P) mm. Differences in BPS and starch digestibility were found–as the roll gap decreased, both BPS and starch digestibility increased. Thus, by processing sorghum silage during harvest and measuring the extent of processing, sorghum silage starch digestibility can be greatly enhanced. Sorghum silage may serve as a viable alternative to corn silage in the diets of lactating dairy cows in areas of the country where corn silage is a high-risk forage crop due to lack of water.

Introduction
Sorghum has become an increasingly important forage crop for dairy producers, particularly in the Midwestern and plains regions of the United States that routinely experience conditions of insufficient water. When compared to corn silage, sorghum silage uses 30–50% less water, making sorghum more heat- and drought-tolerant. This is especially important in areas where irrigation is limited and where elevated temperatures combined with drought are common.

Sorghum silage has long been known to have reduced whole-plant digestibility compared to corn silage, and therefore milk yield often decreases when sorghum silage is fed. A primary reason for reduced digestibility is that the starch contained within the berry is extremely dense, hard, and resistant to digestion. The protein matrix binds starch more tightly in sorghum than in corn, leading to lower digestibility and milk yield when feeding sorghum.

Kernel processing via on-board kernel processors has been used extensively in the harvest of corn silage, in an effort to better expose the starch within grain (increase surface area), and ultimately increase total tract starch digestibility for the dairy cow.

Ten years ago, a method was established to determine the degree of kernel processing, or breakage, in whole plant corn harvested as silage. However, no such method has been developed for sorghum silage. Therefore, the objectives of this study were to develop a similar scoring system for sorghum silage and to evaluate its relationship with starch digestibility.

Experimental Procedures

A total of 72 samples were collected from 6 commercial dairy farms in Kansas. Upon arrival at the Kansas State University Grain Science and Industry grain processing laboratory, samples were either left unprocessed and used as the control, or run through a 9 × 6 inch roller mill using a roll gap setting of 1.5 mm, 1.0 mm, or 0.5 mm. The 12 samples from each farm were split into 4 treatments based on the level of processing: unprocessed (UNP), 1.5 mm processed (1.5P), 1.0 mm processed (1.0P), and 0.5 mm processed (0.5P). This resulted in 3 samples for each treatment from each farm in the study. One sample was analyzed to determine 7-hour *in situ* starch digestibility as an estimate of ruminal starch digestibility. Remaining samples were dried in a forced-air oven at 55°C for 72 hours to ensure complete removal of moisture, resulting in samples weighing ~100 g on a DM basis. Dry samples were separated for 10 minutes using a Ro-Tap 3-dimensional separator (W. S. Tylor, Mentor, OH) fitted with screens containing square apertures of 9.50, 6.70, 4.75, 4.00, 3.35, 2.80, 2.36, 1.70, 1.18, and 0.6 mm (in addition to a pan). Following separation of the sorghum silage samples, samples were divided into material retained above and below the 1.7 mm screen. Samples were then analyzed for starch content at Rock River Laboratories (Watertown, WI) to determine the percent of total starch passing through the 1.7 mm screen to determine the BPS for each sample. A BPS was calculated as follows:

BPS = (Starch passing through 1.7 mm screen (g) / Total sample starch (g)) × 100

Results and Discussion

As shown in Figure 1, BPS increased as the level of processing increased (26.28, 34.64, 40.30, and 55.05 ± 0.04% for UNP, 1.5P, 1.0P, and 0.5P, respectively; $P < 0.001$). The unprocessed sample represents sorghum silage as it was collected from on-farm silage bunkers and indicates that processing of the sorghum berries could be greatly improved in the field. While BPS was improved when processed at either 1.5 or 1.0 mm compared to UNP, berry particle size could be reduced even further when processed at a roll gap spacing of 0.5 mm to enhance starch digestibility. Applying this to a forage harvester in the field will no doubt be more difficult when considering the amount of silage material that must pass through the processing unit.

As a result of the increased BPS, 7-h *in situ* starch digestibility also increased as the level of processing increased ($P < 0.01$) because of the reduced particle size of the starch present in the sorghum berries (Figure 2). Seven-hour *in situ* starch digestibility was lowest for UNP (50.54 ± 4.94%), intermediate for 1.5P and 1.0P (66.76 and 68.95 ± 4.94%) and greatest for 0.5P (82.07 ± 4.94%). These data are in agreement with previous research showing that processing increases the rate of starch digestion with the effects being greater for grains with more vitreous endosperm, such as sorghum. While little work has been conducted with sorghum silage, to our knowledge, similar results have been found when processing corn silage, where processing during harvest reduced the kernel particle size and increased total-tract starch digestibility. Improving starch digestibility via processing not only will affect milk production, but also ruminal pH and fiber digestibility, and the type, amount, and absorption of fuels (e.g. acetate, propionate, lactate, and glucose) available to the cow.

Based on the results for BPS and its relationship with greater 7-hour *in situ* starch digestibility (Figure 3; $R^2 = 0.43$), we recommend that for sorghum silage samples to be considered adequately processed, $\geq$ 50% of the starch should pass through the 1.7 mm screen. As shown in Figure 2, 7-hour *in situ* starch digestibility can exceed 80% when processed at 0.5 mm. A common goal recommended for 7-h *in situ* starch digestibility is ~85%. Therefore, the current data shows that sorghum starch can become quite digestible–similar to starch digestibility in corn–when adequately processed. When < 30% of the starch is able to pass through the 1.7 mm screen, these samples should be considered poorly processed and will have poor digestibility (~50%) in the rumen of the dairy cow (Figure 2). This confirms producers' and nutritionists' concerns about the reduction in starch digestibility observed when replacing a portion of the corn silage in the diet with sorghum silage. When BPS is between 30 and 50%, samples should be considered intermediately processed. Seven-hour *in situ* starch digestibility was greater for 1.5P and 1.0P compared to UNP, but still lower than 0.5P. Therefore, sorghum silage should be harvested using a sorghum silage processor with the roll gap spacing set as tightly as possible, approximately 0.5 mm.

Conclusions

From these data, we were able to develop a method to calculate a BPS for sorghum silage samples measured as the percent of starch passing through a 1.7-mm screen. The development of a BPS for sorghum silage will give the industry a standard by which to measure the degree of processing in sorghum silage. Data also showed that 7-hour *in situ* starch digestibility was increased as BPS increased. Therefore, by increasing the level of processing in sorghum silage, we may be able to enhance starch digestibility sufficiently to allow sorghum silage to replace at least a portion of corn silage in the diet without the commonly-seen decrease in starch digestibility, and therefore milk production. This may be especially important in areas of the country that are at increased risk of drought-like conditions and may have limited access to water during the growing season.

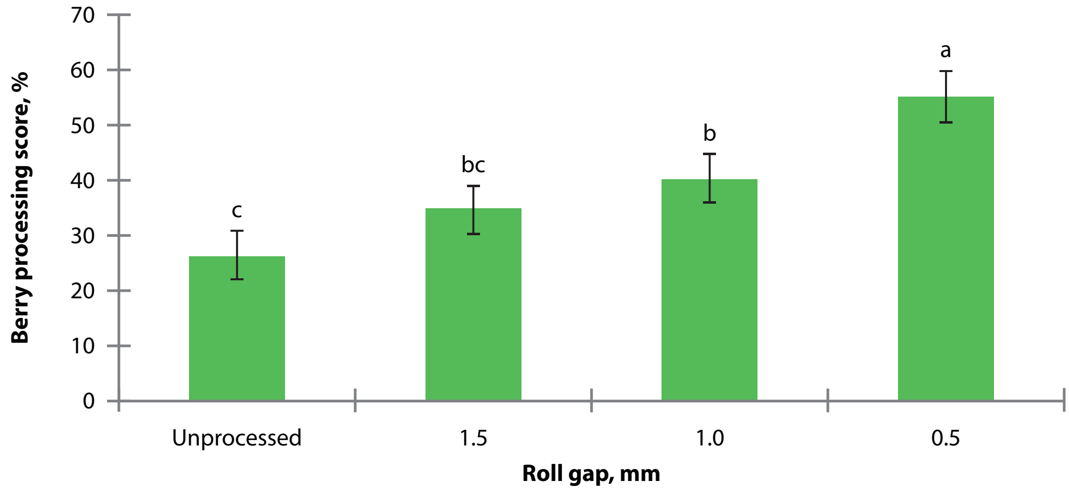

Figure 1. Berry processing score (BPS) by roll gap spacing (unprocessed, 1.5, 1.0, or 0.5 mm) measured as a percent of total starch passing through the 1.7 mm screen. Treatment effect: $P < 0.001$, unprocessed vs. processed (1.5, 1.0, and 0.5 mm); $P < 0.001$; linear, $P < 0.001$.

[a,b,c]Means differ ($P < 0.05$).

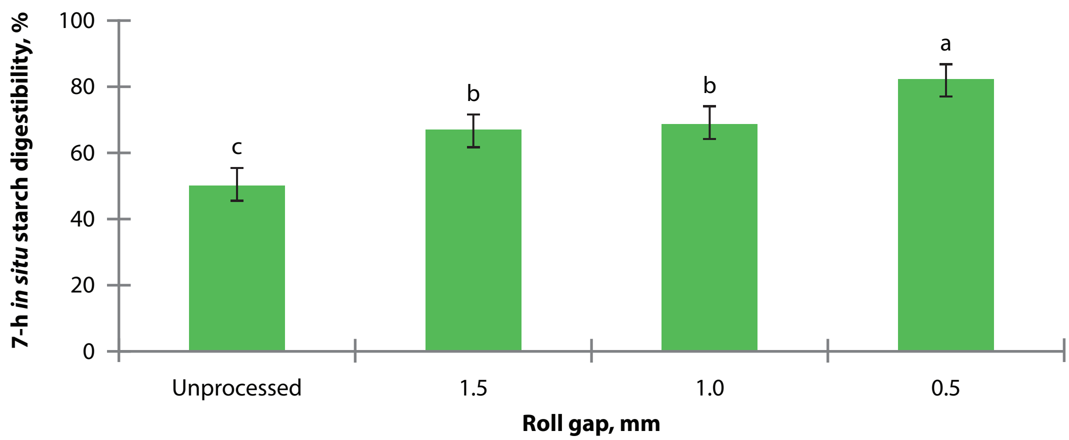

Figure 2. Least squares means for 7-h *in situ* starch digestibility by roll gap spacing (unprocessed, 1.5, 1.0, or 0.5 mm). Treatment effect: $P < 0.01$, unprocessed vs. processed (1.5, 1.0, and 0.5 mm); $P < 0.01$; linear, $P = 0.04$.

[a,b,c]Means differ ($P < 0.05$).

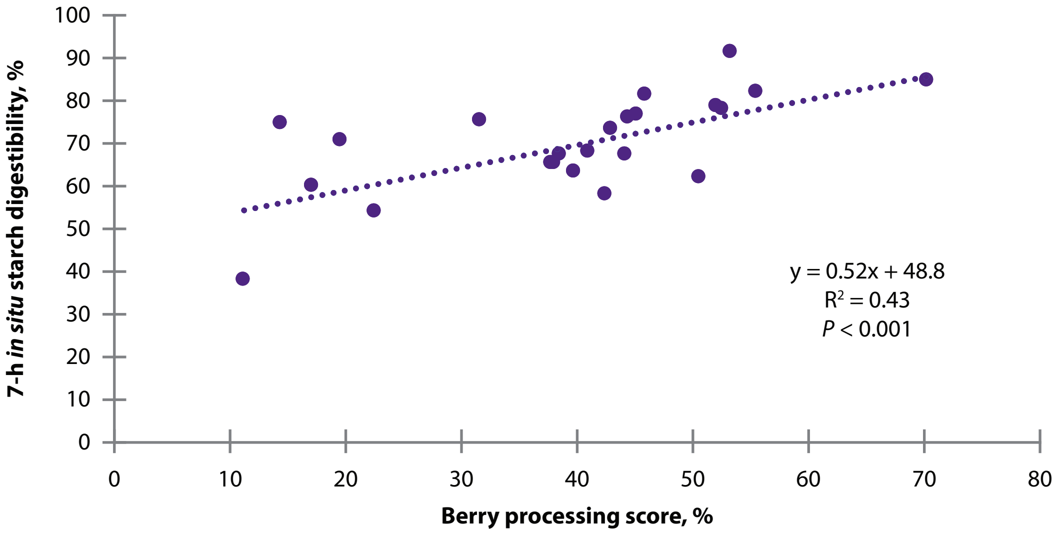

Figure 3. Relationship between 7-h *in situ* starch digestibility and berry processing score (BPS). Berry processing score was defined as the percent of starch passing through the 1.7 mm screen.