Opportunities to Improve Starch Digestibility on Dairy Farms

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November 2012

Corn that is harvested and stored either as whole-plant corn silage or high moisture corn goes through fermentation while in the silo. After two to four weeks in storage, bacteria have converted the sugars to primarily lactic acid and the pH decline is nearly complete. At that point, the ensiled feeds are ready to be fed to cattle. However, research indicates that the digestibility of starch in these feeds continues to increase even after several months in the silo. If that is the case, would farms be better off to let ensiled feeds in storage longer before feeding to cattle?

University of Wisconsin-Extension county-based agriculture agents conducted a field study to evaluate changes in starch digestibility over the winter months on commercial dairy farms. Thirty farms from across the state of Wisconsin participated in the project. Corn silage, high moisture corn, and dry corn samples were collected from these farms. Feed samples were analyzed for dry matter (**DM**) and starch content, particle size, and 7-hour ruminal in-vitro starch digestibility (**ivStarchD**). A manure sample was also collected from each farm. The manure was gathered by obtaining rectal grab fecal samples, and the analyzed sample was a composite of manure from ten cows within the herd that were between 45 and 120 days in milk. The manure samples were analyzed for starch content, and total tract starch digestibility was estimated as well. Feed and manure samples were collected from these thirty farms in November 2011 and then again in April 2012.

Laboratory analysis was done by Rock River Laboratory, Inc. in Watertown, Wisconsin. Total tract starch digestibility (**TTSD**) was determined using the following equation: TTSD % = (100 * (0.9997 – 0.0125 * fecal starch, % DM)); $R^2 = 0.94$ (Ferraretto and Shaver, 2012, The Professional Animal Scientist, In press).

Farms in the study milked 223 ±206 cows, and herd size ranged from 38 to 1000 milking cows. Bulk tank milk yield was 72 ±12 per cow and ranged from 45 to 93 pounds per cow per day across the herds. Our goal was to include farms that planned to feed 2011 corn silage in the fall and that would still be feeding that silage in the spring. Farms were invited to participate in the project by their local county based agriculture agent. Participating farms were located in the following Wisconsin counties: Buffalo, Calumet, Chippewa, Clark, Fond du Lac, Jackson, Monroe, Oconto, Outagamie, Price, Shawano, Sheboygan, and Waupaca.

Trial results for corn silage are presented in Tables 1a (fall samples) and 1b (spring samples). Corn silage ivStarchD was about 7 percentage units greater on average for the spring compared to the fall sampling period *(Figure 1)*. While this was not a controlled experiment evaluating exactly the same corn silages after short and long ensiling periods, these field trial results suggest that the digestibility of starch in corn silage fed on dairy farms in Wisconsin does increase as we go from fall to spring feed-out from silos. This observation is in agreement with the results of controlled experiments that evaluated length of silo fermentation effects on starch digestibility for corn silage (Young et al., 2012) and high-moisture corn (Benton et al., 2005; Hoffman et al., 2011). Hoffman et al. (2011) reported that ensiling for 240 days reduced zein protein subunits that cross-link starch granules and suggested that the starch-protein matrix was degraded by proteolysis over an extended ensiling period. This would explain observations of increased starch digestibility with increasing silo fermentation time.

Table 1a
Corn Silage
Fall 2011

	n	Average	Standard Deviation	Minimum	Maximum
Dry Matter %	30	35.0	4.5	28.8	49.5
Corn Silage Processing Score %	30	57.0	11.1	34.9	74.4
Starch %	30	34.7	5.4	16.0	44.1
7-hour Starch Digestibility %	30	83.7	7.5	58.1	93.9

Table 1b
Corn Silage
Spring 2012

	n	Average	Standard Deviation	Minimum	Maximum
Dry Matter %	35	36.2	5.1	28.1	50.5
Corn Silage Processing Score %	35	61.1	12.4	38.6	88.7
Starch %	35	34.1	4.8	23.9	41.9
7-hour Starch Digestibility %	35	90.3	3.7	82.5	96.2

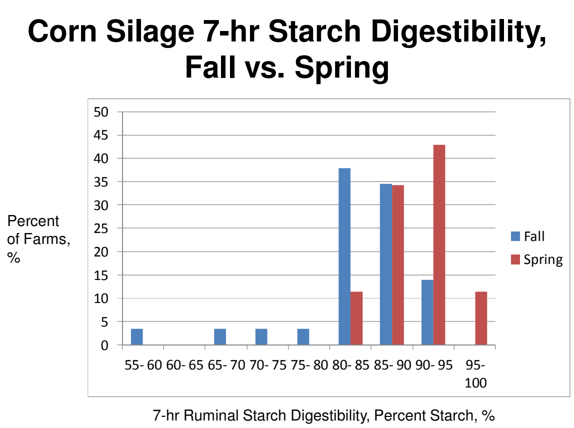

Figure 1: Corn silage starch digestibility improved about seven percentage points from the fall to spring collected samples.

The average corn silage DM and starch contents were very similar for the fall and spring collected samples. Average corn silage starch contents were above 34 percent (DM basis) and indicative of a high proportion of grain in many of these samples. The range in corn silage DM content was above 20 percentage units for both sampling periods, which suggests that better control of maturity at harvest could be an opportunity for improvement of starch digestibility among these farms. Specifically, harvest of corn silage with 40 percent or greater DM content can reduce starch digestibility (Ferraretto and Shaver, 2012), and about 20 percent of the samples were at or above 40 percent DM *(Figure2).*

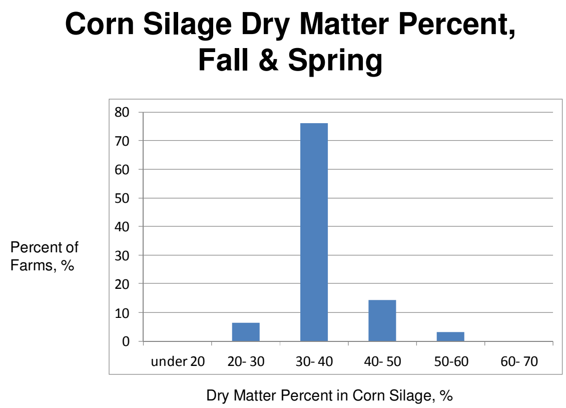

Figure 2: Corn silage harvested with 40 percent or greater DM content can reduce starch digestibility. More than 20 percent of samples were at or above 40 percent DM.

The kernel processing score (KPS) was also similar for the fall and spring collected samples. Ferreira and Mertens (2005) reported on the KPS procedure for determining degree of kernel damage in corn silage (percent of starch passing through a 4.75 mm screen) which they found was related to ruminal in vitro starch digestibility. Values for corn silage KPS of equal to or greater than 70 percent, 50 to 69 percent, and less than 50 percent are thought to be indicative of excellent, adequate and poor kernel processing, respectively. Even though average corn silage KPS measurements for the trial were in the adequate category at 57 percent for the fall samples and 61percent for samples collected in spring, about 25 percent of the samples fell in the poorly processed category *(Figure 3)*. This indicates that greater kernel processing at harvest is also an opportunity for improvement among these farms.

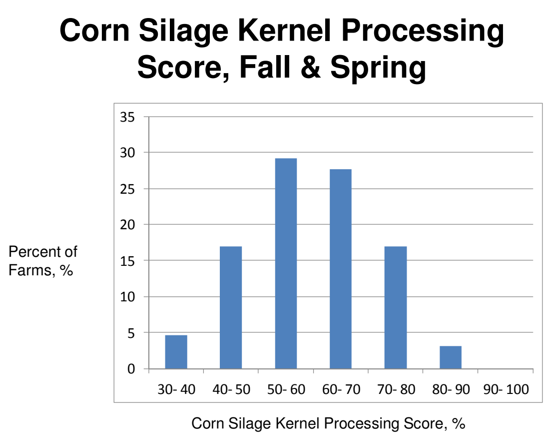

Figure 3: Corn silage kernel processing is evaluated on a scale, where 70 percent or greater is excellent, 50 to 69 percent is adequate, and less than 50 percent is poorly processed feed. On average, the samples fell in the adequately processed category, but almost a quarter of the samples were considered poorly processed.

Trial results for high moisture corn are presented in Tables 2a (fall samples) and 2b (spring samples). Unlike corn silage, the ivStarchD measurements were similar for the fall and spring collected samples. This was unexpected based on controlled research trials (Benton et al., 2005; Hoffman et al., 2011) that have been done in the past. However, in a field trial setting, the silo fermentation for high moisture corn may be slowed by cold ambient temperatures at harvest and during storage, and the fermentation process may not speed up until ambient temperatures rise in later spring to early summer. Therefore, between November and April, when our samples were collected, silo fermentation may have been insufficient to result in an increase in starch digestibility. The high moisture corn samples, on average, were relatively dry at 72 percent for fall samples and 75 percent DM for spring collected samples. High DM content can limit the extent of silo fermentation. It is possible that with greater moisture contents, warmer ambient temperatures at harvest, and sampling later in the spring or early summer, increases in starch digestibility may have been detected. Approximately 45 percent of the high moisture corn samples contained more than 74 percent DM *(Figure4)*. Starch digestibility is reduced with increasing DM content in high moisture corn (Hoffman and Shaver, 2009). Our results imply that better control of harvest moistures could be an opportunity for improvement among these farms. In addition, approximately 35 percent of the high moisture corn samples were found to have a mean particle size greater than 2000 microns *(Figure 5)*. Starch digestibility is reduced with increased corn particle size (Hoffman et al., 2012), so more kernel processing could also be a way to improve starch digestibility among these farms.

Table 2a
High Moisture Corn
Fall 2011

	n	Average	Standard Deviation	Minimum	Maximum
Dry Matter %	19	72.0	7.2	51.4	81.4
Particle Size, microns	19	1725	562	780	2710
Starch %	19	72.1	6.2	56.9	81.8
7-hour Starch Digestibility %	19	75.7	8.2	65.4	89.6

Table 2b
High Moisture Corn
Spring 2012

	n	Average	Standard Deviation	Minimum	Maximum
Dry Matter %	23	74.8	5.9	60.1	86.6
Particle Size, microns	23	1548	626	539	2684
Starch %	23	68.3	9.3	48.3	79.1
7-hour Starch Digestibility %	23	74.5	7.2	61.6	85.8

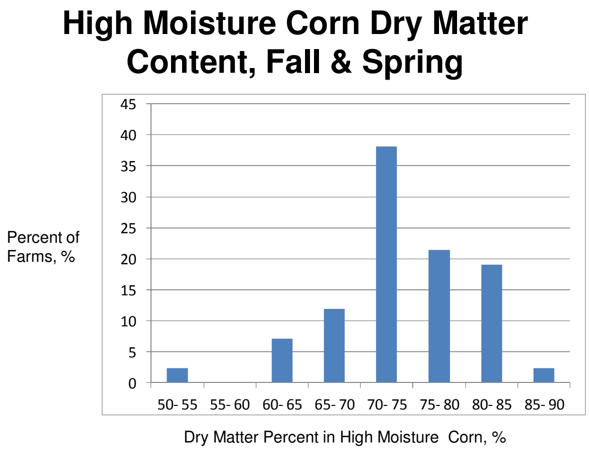

Figure 4: Fermentation and starch digestibility of high moisture corn silage decrease as dry matter content increases. Almost 45 percent of samples had a dry matter content of 75 percent or more.

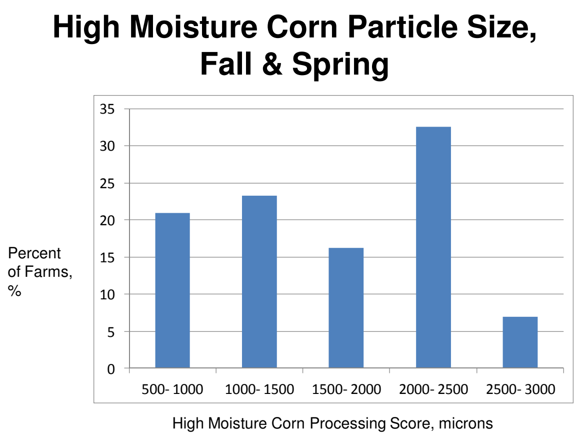

Figure 5: Starch digestibility is reduced with increased corn particle size. About one third of the samples had a particle size score greater than 2,000 microns, which negatively affects starch digestibility.

Only a few farms had dry corn available for sampling and analysis. These results are presented in Table 3. As recommended (Hoffman et al., 2012), the dry corn was fine ground to improve starch digestibility (550 ± 61 micron mean particle size).

Table 3
Dry Corn
Fall 2011 & Spring 2012

	n	Average	Standard Deviation	Minimum	Maximum
Dry Matter %	9	84.1	4.0	76.4	90.0
Particle Size, microns	8	550	61	461	635
Starch %	5	74.9	2.4	70.6	76.5
7-hour Starch Digestibility %	9	73.5	4.1	68.6	81.5

Trial results for the fecal samples are presented in Tables 4a (fall samples) and 4b (spring samples). Dr. James Ferguson (Ferguson, 2003; University of Pennsylvania School of Veterinary Medicine, New Bolton Center) recommends that fecal starch be less than five percent (DM basis). On average, project farms were below this threshold at 3.3 percent and 4.1percent fecal starch (DM basis) for fall and spring collected samples, respectively. However, a quarter of the samples were above 5 percent fecal starch with sample maxima of 15 percent to 20 percent (DM basis; Figure 6), resulting in calculated total-tract starch digestibility minima of 76 percent to 81 percent. While these farms had room for improvement, most farms achieved high total-tract starch digestibility with an average of 95 percent across farms and sampling periods and maxima of 99 percent.

Table 4a
Fecal Samples
Fall 2011

	n	Average	Standard Deviation	Minimum	Maximum
Starch %	29	3.3	3.0	0.4	15.2
Total Tract Starch Digestibility %	29	95.9	3.7	80.9	99.5

Table 4b
Fecal Samples
Spring 2012

	n	Average	Standard Deviation	Minimum	Maximum
Starch %	30	4.1	4.0	0.6	19.6
Total Tract Starch Digestibility %	30	94.9	5.0	75.5	99.2

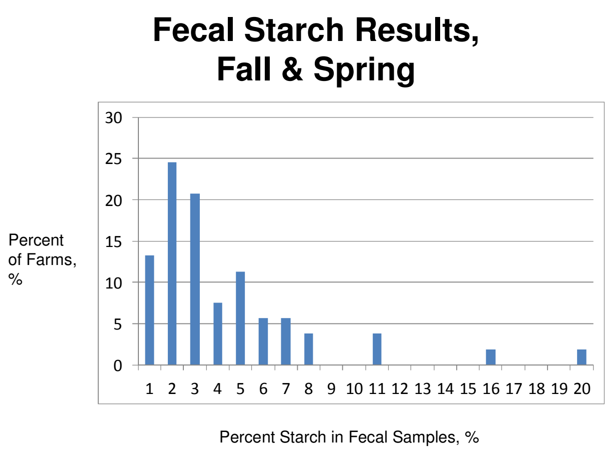

Figure 6: A reasonable goal for fecal starch content is less than five percent. Three quarters of the samples were under that threshold.

Fecal starch contents and calculated total-tract starch digestibilities were similar for fall and spring collected samples. Differences in corn silage ruminal ivStarchD observed between the sampling periods were not likely great enough to be detected through the fecal starch approach. Differences in post-ruminal starch digestion, dry matter intake, and rations may explain the lack of difference in fecal starch between the two sampling periods.

Dr. Ferguson has estimated that for each one percentage unit increase in fecal starch above five percent (DM basis), a decline in milk yield of about one pound per cow per day can be expected. Excess starch in the manure means not only decreased milk production but also money wasted on feed that is not being digested. Since milk yield losses can be significant, it is wise for farms to look for ways to improve starch digestibility of their ration. With fermented feeds, especially corn silage, our data shows that extra time in storage can make quite a difference in starch digestibility. For this reason, farms would be benefited by leaving feed in storage longer before feed out. However, for farms that are unable to produce and/or store enough feed to do this, other small changes can yield improved starch digestibility results. This includes harvesting corn silage and high moisture corn at a lower DM percent and greater kernel processing at harvest. To get a grasp on starch digestibility, it would be useful for a farm to conduct their own fecal sampling. Easy to do and relatively inexpensive, a fecal sample could tell let you know how your starch digestibility stacks up and if changes to the ration, harvesting or corn processing are needed.

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