What's New with Corn Silage for Dairy Cattle?

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Summary

High quality corn silage contributes greatly to supplying the energy, starch, and forage neutral detergent fiber **(NDF)** needs of high-producing dairy cows, reducing purchased feed costs from expensive grain and byproduct supplements, and generating milk revenue for dairy producers. Transgenic corn hybrids have become common for corn silage production, and extensive research does not suggest any cause for concern about feeding corn silage produced from genetically modified seed corn when the traits make agronomic and economic sense to the grower. Commercial transgenic corn hybrids specific for improving the nutritional quality and feeding value of corn silage are not available, but in the future they could enhance progress for improving the digestibility of NDF and potentially circumvent major nutritional limitations to the feeding of high corn silage diets to dairy cows. Results from a meta-analysis indicate that starch digestibility and lactation performance were reduced for dairy cows fed diets containing corn silage with >40% dry matter **(DM)** or corn silage with insufficient kernel processing. Kernel processing corn silage to improve starch digestibility was effective across a wide range of DM contents and theoretical lengths of cut but did not overcome adverse effects of very high DM content on total-tract starch digestibility and was ineffective at very long theoretical lengths of cut. Results of a feeding trial with corn shredlage suggest potential for this method of corn silage harvest. Analysis of commercial forage testing laboratory datasets revealed extensive variation in the ammonia nitrogen content of corn silage that appeared to be unrelated to the DM content of corn silage, and presumably the results more closely related to the length of silage fermentation prior to on-farm sampling. Research is needed to determine the effectiveness of ammonia nitrogen content in combination with some measure of particle size for predicting corn silage starch digestibility parameters as has been done for high-moisture corn.

Introduction

We combined survey data from 14 selected Wisconsin high-producing dairy herds collected in 2004, 2007, and 2010 to summarize their forage feeding practices (Shaver and Kaiser, 2011). Forage comprised 50 to 60% of total mixed ration **(TMR)** DM with up to 24% NDF from forage in TMR DM. Corn silage comprised 40 to 70% of the forage DM. We calculated that the following percentages of dietary nutrients were provided by forage: NDF (75%), physically-effective NDF (**peNDF**; 85%), crude protein (**CP**; 45%), starch (40%), non-fiber carbohydrates (55%), and energy (50%). Corn silage comprised from 40 up to 70% of the forage DM. Corn silage contributed more than alfalfa with regard to dietary starch, while alfalfa contributed more than corn silage with regard to dietary CP. Both contributions are important for reducing feed costs at this time, as both corn grain and protein supplements are relatively expensive.

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The estimated milk from forage (corn silage, alfalfa silage, and alfalfa hay) was about 60 lb/cow/day on a dietary energy basis after apportioning the cow's energy needs to support maintenance and body weight **(BW)** gain to forage or concentrate according to dietary forage to concentrate ratio. On average, the estimated milk per ton of forage DM was about 3,000 lb, or $600 of gross milk revenue per ton of forage DM consumed by cows in these survey herds at a $20/cwt milk price.

Although high milk production is often attributed to high concentrate feeding, clearly these top-producing Wisconsin dairy herds rely heavily upon forages not only for fiber, but also for protein, starch, and energy contributions which have become more important during this period of high concentrate prices. Furthermore, the amount of milk produced from forage in these top-producing herds contributes significantly to their total production, resulting in high milk revenue being generated per ton of forage DM, which underscores the importance of managing the forage production, harvest, and storage process to achieve high forage quality. The purpose of this paper is to review selected recent developments and considerations for corn silage.

Transgenics

Biotech corn continues to become more prevalent for the production of not only grain but also corn silage, with the trend toward multiple or stacked traits for herbicide tolerance and pest protection (Hartnell, 2010). Of the 13 peer-reviewed journal lactation trials comparing transgenic to conventional corn silages summarized by Hartnell (2010), only one reported any significant difference between treatments and that was only for greater milk protein content for the transgenic over the conventional corn silage. Brouk et al. (2011) added to the list of no-significant-difference lactation trials with a comparison of transgenic to non-transgenic, near-isogenic corn silages. Based on the evidence to date, dairy producers and nutritionists should not be concerned about feeding corn silage produced from genetically modified seed corn when the traits make agronomic and economic sense to the grower.

Commercial transgenic corn hybrids specific for improving the nutritional quality and feeding value of corn silage for dairy cattle are not available. This is unfortunate since progress for improving in vitro digestibility of NDF (**ivNDFD**; % of NDF) through conventional corn breeding techniques has been minimal based on data from the University of Wisconsin Agronomy Department's annual commercial corn silage hybrid evaluation trials conducted from 1996 through 2010 (**UWAT**; Jung and Lauer, 2011). Reduced lignin content and corresponding increases in ivNDFD, DM intake **(DMI)**, and lactation performance has consistently been observed though for brown midrib (bm3) mutant corn hybrids (Gencoglu et al., 2008). In UWAT, the ivNDFD increase for bm3 hybrids above the overall trial average ranged from 6 to 11%-units across the 15 years. However, starch concentrations were reduced below the overall trial average by 1 to 3%-units in about half of the years and 4 to 7%-units in the others. Leafy-type hybrids have achieved some popularity for corn silage production in the dairy industry. In UWAT, the ivNDFD for leafy-type hybrids varied by 2%-units both above and below the overall trial average, and their starch concentrations were lower than the overall trial average by about 3%-units, ranging from 1 to 8%-unit reductions across the 15 years. Lack of consistent improvements in ivNDFD and reduced starch limited milk per ton potential for the leafy-type hybrids in UWAT (Lauer et al., 2009). While milk per ton estimates were consistently well above the overall trial average for bm3 hybrids, whole-plant DM yield per acre and starch content limited their milk per acre potential in UWAT (Lauer et al., 2009).

Jung et al. (2011) reported similar milk production responses for either altered lignin cross-linking through reduced-ferulate mutant lines or reduced lignin content through bm3 mutant lines compared to near-isogenic control lines of each type, with all lines harvested and fed as whole-plant corn silage. These authors suggested that combining both mutations in the same corn line may allow for greater improvements in animal performance since the genes and modes of action (ferulate cross-linking vs. lignin content) involved are different. Use of transgenic technology could hasten the inclusion of this and other nutritional traits in corn for silage production. There have been reports (Piquemal et al., 2002; He et al., 2003) on transgenic bm3 plants with reduced lignin and increased fiber digestibility, but this has not led to the availability of commercial transgenic bm3 hybrids. Interestingly, a transgenic reduced-lignin alfalfa variety is being pursued commercially (Mertens and McCaslin, 2008; Weakley et al., 2008). Other areas with potential for improving the nutritional quality and feeding value of corn grain and silage for dairy cows with transgenics could include increased oleic with reduced linoleic acids to minimize milk fat depression with high corn silage diets (He et al., 2012), increased protein and lysine contents to reduce supplemental needs to meet cow requirements (NRC, 2001), and altered kernel endosperm properties to improve starch digestion (Lebaka et al., 2007; Lopes et al., 2009). Although the importance of the corn genetic aspect of the latter area is tempered for corn silage because the kernel should be less mature than black layer at harvest (Ferraretto and Shaver, 2012), processing of the kernel during harvest increases starch digestibility (Ferraretto and Shaver, 2012), and starch digestibility increases over time of storage in the silo through fermentation and proteolysis of the starch-protein matrix (Benton et al., 2005; Hoffman et al., 2011; Young et al., 2011).

Corn Silage Harvest Practices

Meta-analysis

Ferraretto and Shaver (2012) performed a meta-analysis to determine the impact of DM content, kernel processing (**PROC**), and theoretical length of cut **(TLOC)** of corn silage on intake, digestion, and milk production by dairy cows. The dataset was comprised of 106 treatment means from 24 peer-reviewed journal articles from 2000 to 2011. Categories for DM content at silo removal and PROC and TLOC at harvest were: d" 28% **(VLDM)**, >28% to 32% **(LDM)**, >32% to 36% (**MDM**), >36% to 40% (**HDM**), and >40% **(VHDM)** DM; 1 to 3 or 4 to 8 mm roll clearance or unprocessed; 0.48 to 0.64, 0.93 to 1.11, 1.27 to 1.59, 1.90 to 1.95, 2.54 to 2.86, and e" 3.20 cm TLOC. Data were analyzed using Proc Mixed in SAS with whole plant corn silage **(WPCS)** treatments as fixed effects and trial as a random effect.

Milk yield was decreased by 4.4 lb/cow/day for VHDM. Fat-corrected milk **(FCM)** yield decreased as DM content increased. Total-tract digestibility of dietary starch **(TTSD)** was reduced for VHDM compared to HDM and LDM. Processing (1 to 3 mm) increased TTSD compared to 4 to 8 mm PROC and unprocessed corn silage. Milk yield tended to be 1.8 kg/cow/d greater, on average, for PROC (1 to 3 mm) and unprocessed WPCS than 4 to 8 mm PROC. The TLOC of corn silage had minimal impact on any of the parameters evaluated. Starch digestibility and lactation performance were reduced for dairy cows fed diets containing corn silage with >40% DM or corn silage with insufficient kernel processing.

An interaction was observed between DM content and kernel processing for TTSD. Kernel processing increased TTSD for diets containing corn silage with 32 to 40% DM. Also, an interaction was observed between TLOC and kernel processing for TTSD. Kernel processing increased diet TTSD when TLOC was 0.93 to 2.86 cm. Kernel processing corn silage to improve starch digestibility was effective across a wide range of DM contents and TLOC but did not overcome adverse effects of very high DM content on TTSD and was ineffective at very long TLOC.

Corn shredlage

Garnering much recent interest by dairy producers and their nutritionists has been a new method of harvesting whole-plant corn for silage. The resultant product has been called corn shredlage by the developer of the process (Shredlage™, LLC; http://www.shredlage.com/) and the manufacturer of the new processing rolls used in the process (Scherer Corrugating & Machine, Inc., Tea, SD; http://scherercorrugating.com/).

Although it is a recent development with limited information available, we conducted a feeding trial with corn shredlage fed to lactating dairy cows at the UW Blaine Arlington Dairy during Oct. – Dec., 2011 following a September, 2011 harvest at UW Arlington Agricultural Research Station (**AARS**). Corn shredlage is silage produced from whole-plant corn that has been harvested with a commercially-available self-propelled forage harvester (**SPFH**) fitted with aftermarket cross-grooved crop processing rolls and the SPFH set for a longer TLOC than commonly used. At the time of writing this article, these rolls have only been adapted on Claas SPFH, although the manufacturer has indicated that kits are also being developed for John Deere SPFH.

Compared to normal processed corn silage harvested with the chopper set at 19 mm TLOC, the most obvious difference for corn shredlage harvested with the SPFH set at 30 mm TLOC is a greater proportion of coarse stover particles in the shredlage. When fed in rations for lactating dairy cows, this can increase the peNDF content of the ration, which is important for proper rumen function, cow health, and milk fat content. The cross-grooved rolls used for producing corn shredlage may cause greater damage to the coarse stover particles and allow for greater digestibility of the NDF, but this has yet to be evaluated. With proper roll gap settings for both types of crop processing, rolls differences in kernel and cob breakage would not be expected, but this has not been compared in detail to our knowledge.

A 20 acre field at UW AARS planted with a dual-purpose hybrid was used for the study. One day apart in early September, 2011, half the field was harvested as corn shredlage (**SHRD**) and the other half harvested as normal processed corn silage (**KPCS**). The SHRD and KPCS were stored in separate side by side 10' diameter by 200' long silo bags and allowed to ferment for one month before commencing the dairy feeding trial. For harvest of the SHRD, a SPFH equipped with the new shredlage processing rolls was set for a 30 mm TLOC by removing half of the knives and the processor roll gap set at 2.5 mm. The SHRD harvest was done by a custom operator (Kutz Farms, Jefferson, WI) and SPFH was set up by Shredlage™ LLC and Scherer representatives. Some forage harvester manufacturers recommend not removing knives when harvesting whole-plant corn silage. The very long particle-size that results from removing knives can put added stress on SPFH components, like the cutter-head and blower. Careful consideration concerning SPFH wear and longevity should be made by the SPFH operator before knives are removed when harvesting whole-plant corn silage, no matter what type of processor is used. Harvest of the KPCS was done using the UW AARS SPFH set for a 19 mm TLOC and equipped with conventional processing rolls. The processor roll gap was not altered from that normally used by UW AARS for harvest of corn silage for the UW Dairy. The exact roll gap was undetermined, but appeared to be greater than 3 mm based on kernel processing results. For samples collected at harvest, the corn silage processing score (**CSPS**; % of starch passing through a 4.75 mm screen) was 60.3% ± 3.9 for KPCS and 75.0% ± 3.3 for SHRD.

The SHRD and KPCS were similar in DM (35.0% ± 1.9 versus 34.7% ± 1.4) and starch (37.6% ± 5.2 versus 38.7% ± 4.9) concentrations, pH (3.59 ± 0.05 versus 3.61 ± 0.03), and silo bag packing density (17.5 versus 17.2 lb DM per cu. ft.). The proportion of coarse particles was greater for SHRD than KPCS for samples collected during feed-out from the silo bags throughout the feeding trial (31.5 versus 5.6% retained on the 19 mm screen of the Penn State Separator Box). For the TMR fed throughout the trial, the proportion of coarse particles was greater for TMR prepared with SHRD than KPCS (15.6 versus 3.5% retained on the 19 mm screen of the Penn State Separator Box). Our measurements of weigh-backs during the trial did not reveal feed sorting for either treatment.

Fourteen 8-cow pens, balanced by breed, parity, and days in milk (**DIM**), were randomly assigned to either the SHRD or KPCS treatment TMR (7 pens and 56 cows per treatment). At the start of the feeding, SHRD and KPCS cows were 114 ± 35 and 117 ± 36 DIM, respectively. All pens were fed a 50:50 mixture (DM basis) of the two forages in the TMR for a 2-week covariate adjustment, followed by an 8-week treatment period whereby pens received their respective treatment containing 50% (DM basis) of the TMR from either SHRD or KPCS. Both TMR treatments contained 10% alfalfa silage and 40% (DM basis) of the same concentrate mix comprised of dry ground shelled corn, corn gluten feed, solvent and expeller soybean meal, rumen-inert fat, minerals, vitamins, and Rumensin® (Elanco Animal Health, Indianapolis, IN). Statistical analysis of the data was done using pen as the experimental unit.

The DMI tended ($P < 0.08$) to be 1.5 lb/cow/day greater for SHRD than KPCS, while milk yield (96.1 vs. 94.2 lb/cow/day for SHRD vs. KPCS), and feed efficiency (1.72 vs. 1.73 lb milk/lb DMI for SHRD vs. KPCS) were similar ($P >$ 0.10). Yield of 3.5% FCM tended ($P < 0.08$) to be greater for SHRD than KPCS (100.1 vs. 97.9 lb/cow/day for SHRD vs. KPCS). A week by treatment interaction was detected ($P < 0.03$); there was no difference between the treatments at week 2, FCM yield tended ($P < 0.10$) to be greater for SHRD compared to KPCS at weeks 4 and 6, and FCM yield was ($P < 0.01$) 4.4 lb/cow/day greater for SHRD than KPCS at week 8. Milk fat, protein, and urea-nitrogen contents were unaffected ($P >$ 0.10) by treatment and averaged 3.72%, 3.20%, and 13.8 mg/dL, respectively. Body weight (1562 lb, on average) and condition score (3.04, on average) and BW change (0.66 lb/cow/day) were similar ($P > 0.10$) for the 2 treatments.

To the extent that the stover particle length can be increased while maintaining adequate kernel processing, the use of corn shredlage may allow for the feeding of higher forage diets. Assess particle size of corn shredlage as an indicator of peNDF and CSPS of corn shredlage as an indicator of starch digestibility to determine what ration adjustments may be warranted. More data are needed regarding NDF digestibility for corn shredlage and the relative peNDF for corn shredlage compared to hay-crop silage, whole cottonseed, and chopped hay or straw, to allow for better decisions on how best to utilize corn shredlage in dairy cattle diets.

Corn Silage Fermentation and Starch Digestibility

Highly vitreous corn types contain greater concentrations of prolamin proteins than floury or opaque corn types (Larson and Hoffman, 2008). Starch granules in the corn endosperm are surrounded by hydrophobic prolamin proteins which are slowly degraded (McAllister et al., 1993). Hoffman et al. (2011) reported that ensiling high-moisture corn **(HMC)** for 240 days reduced zein protein subunits that cross-link starch granules and suggested that the starch-protein matrix was degraded by proteolytic activity over an extended ensiling period. This could explain reports of greater ruminal in situ starch degradability for HMC with greater moisture contents and duration of silage fermentation (Benton et al., 2005). Newbold et al. (2006) reported that ruminal in situ starch and crude protein degradabilities increased for corn silage as the length of silage storage time increased. Increased corn silage in vitro starch digestibility with greater length of silage storage time was reported by Hallada et al. (2008) and Der Bedrosian et al. (2010).

The Larson and Hoffman (2008) turbidity assay determination of total zein protein content did not detect a reduction in zein protein subunits over the ensiling period for HMC as measured by high-performance liquid chromatography (**HPLC**; Hoffman et al., 2011). Ammonia content increased, however, as HPLC zein protein subunits in HMC decreased (Hoffman et al., 2011). Ammonia nitrogen has been suggested in combination with mean particle size for modeling the effects of corn maturity, moisture content, and length of silage fermentation time on ruminal and total-tract starch digestibilities and rate of ruminal starch degradation for HMC at feed out (Hoffman et al., 2012). Young et al. (2011) reported that the addition of protease enzymes and greater length of the ensiling period increased ammonia nitrogen content and ruminal in vitro starch digestibility of corn silage. The DairyOne (Ithaca, NY) on-line data base (http://www.dairyone.com/) reveals that for over 12,000 corn silage samples analyzed from May 2000 through April 2011, ammonia nitrogen, averaged 7.1% of total nitrogen with a normal range from 3.0 to 11.1%. In our analysis of a dataset provided by Dairyland Labs (Arcadia, WI) with over 1,900 corn silage samples, ammonia nitrogen averaged 5.7% of total nitrogen with a normal range from 2.7 to 10.7%. Additionally, in our analysis of a dataset provided by Cumberland Valley Analytical Services (Maugansville, MD) with about 44,000 corn silage samples from May 2007 through February 2012, ammonia nitrogen averaged 9.6% of total nitrogen, with a normal range from 7.8 to 11.4%. Corn silage DM content explained almost none of the ammonia nitrogen variation in either dataset, which may not be too surprising since length of silage fermentation prior to on-farm sampling was unknown and could have ranged from less than a few weeks to over a year in storage. Research is needed to determine the effectiveness of ammonia nitrogen content in combination with some measure of particle size, possibly processing score (Ferreira and Mertens, 2005), for predicting corn silage starch digestibility parameters.

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