Current strategies to increase nutritive value of corn silage

Luiz Ferraretto[1] and Randy Shaver[2]

[1]Department of Animal Sciences, University of Florida
[2]Department of Dairy Science, University of Wisconsin – Madison

Introduction

High quality whole-plant corn silage (**WPCS**) contributes greatly to supplying the energy, starch and forage NDF needs of high-producing dairy cows, reducing purchased feed costs from expensive grain and byproduct supplements, and generating milk revenues for dairy producers throughout the world. The purpose of this paper is to review selected recent developments and strategies that may influence the nutritive of WPCS.

Corn silage harvest practices

Meta-Analysis

Ferraretto and Shaver (2012) performed a meta-analysis to determine the impact of dry matter (**DM**) content, kernel processing (**PROC**) and theoretical length of cut (**TLOC**) of WPCS 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: ≤ 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 ≥ 3.20 cm TLOC. Data were analyzed using Proc Mixed in SAS with WPCS treatments as Fixed effects and trial as a Random effect.

Milk yield was decreased by 2 kg/d per cow 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 WPCS. 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 WPCS had minimal impact on any of the parameters evaluated. Starch digestibility and

lactation performance were reduced for dairy cows fed diets containing WPCS with >40% DM or WPCS with insufficient kernel processing.

An interaction was observed between DM content and kernel processing for TTSD. Kernel processing increased TTSD for diets containing WPCS 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 WPCS 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

Vanderwerff et al. (2015) evaluated in a feeding trial: 1) the response to corn shredlage (**SHRD**) in a brown midrib (**BMR**) WPCS hybrid, and 2) whether the greater TLOC setting on the SPFH for the harvest of SHRD increased the peNDF content of the WPCS.

A BMR WPCS hybrid (F2F627; Mycogen Seeds) was harvested in September 2013 with a Claas 940 SPFH equipped with either a Claas conventional processor or a SHRD processor on the same day at 50% kernel milk line stage of maturity. The conventional processor was set for a 2-mm roll gap and 40% roll speed differential with the SPFH set for a 19-mm TLOC for harvest of the conventionally-processed corn silage (**KP**). Harvest of the SHRD was done with the SHRD processor set at a 2-mm roll gap and 32% roll speed differential with the SPFH set for a 26-mm TLOC. The KP and SHRD were stored in separate silo bags until the bags were opened to begin the feeding trial in January, 2014.

Mid-lactation Holstein cows were used in a 16-week continuous-lactation experiment in our university dairy herd with 15 replicated pens of 8 cows each. The respective treatment TMR contained 45% (DM basis) from either SHRD or KP. Both TMR treatments (SHRD and KP) contained 10% alfalfa silage and 45% (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 monensin. Additionally, a third treatment TMR (**KPH**) was included in the experiment to focus on the peNDF question. This ration was formulated with 35% KP, 10%

alfalfa silage, 10% chopped hay, and 45% (DM basis) of the same concentrate ingredients adjusted in proportions in the mix to balance dietary crude protein and starch concentrations across the three treatments.

The SHRD and KP were similar in average DM (39%) content and pH (3.9). Corn silage processing scores on feed-out samples averaged 72% for SHRD and 68% for KP with less variation observed for SHRD over the duration of the experiment. The sample range (difference between maximum and minimum samples) was 10%-units for SHRD and 21%-units for KP. For SHRD, all processing scores were above 65%. However, for KP 43% of the samples obtained on a weekly basis throughout the feeding trial were at or below a processing score of 65%.

The proportion of coarse stover particles was greater for SHRD than KP for samples collected during feed-out from the silo bags throughout the feeding trial (18% versus 7% as-fed particles retained on the top screen of the shaker box). For the TMR fed throughout the trial, the proportion of as-fed particles on the top screen of the shaker box was greater for SHRD than KP or KPH. Our measurements of weigh-backs during the trial indicated minimal sorting and no differences in sorting among the three treatments.

Averaged over the treatment period, milk yield was 1.5 kg/day per cow greater for SHRD than KP in 6 out of the 14 weeks, with the SHRD cows averaging 51.3 kg/d; feed efficiency was similar for the two treatments. Milk yield was 3.4 kg/d per cow lower and feed efficiency was reduced for KPH compared to KP.

Milk fat content was greater for KPH (3.7%) than KP or SHRD (3.3%). Rumination activity measured using the SCR rumination collars averaged 8.4 hours per day and was not different among the treatments. Using milk fat content and rumination activity data to assess peNDF suggests that the peNDF content of SHRD was not improved despite its longer TLOC and increased percentage of as-fed particles on the top screen of the shaker box compared to KP. Milk fat yield was not statistically different among the treatments, but was numerically greatest for KPH and lowest for KP. Similar to the milk yield differences, milk protein and lactose yields were greatest for SHRD and lowest for KPH. Body condition score (3.1 on average) and body-weight change (0.6 kg/d per cow on average) were similar among the three treatments.

Total-tract DM and organic matter (**OM**) digestibility were greater for cows fed KP and SHRD than for cows fed KPH. Total-tract NDF digestibility (**TTNDFD**) tended to be greatest

for KPH and lowest for SHRD. Lower TTNDFD for SHRD may be related to increased dietary starch content for SHRD compared to KPH and increased kernel processing and ruminal starch digestibility for SHRD compared to KP and KPH. The ruminal in situ starch digestibility was greater for SHRD than KP (88.3 vs. 76.0%, respectively). Total-tract starch digestibility was greater for SHRD than KP. Differences in total-tract starch digestibility between SHRD and KP were, however, biologically small (0.5%-units) and starch digestibility was near 100% for all treatments. Small differences in total-tract starch digestibility along with much larger differences ruminally may be explained by post-ruminal compensatory digestion of starch. Nearly complete digestion of starch in the total-tract may be explained by the nearly 6 month lag between ensiling and the midpoint of the feeding trial.

Silage Fermentation

Hoffman et al. (2011) reported that ensiling high-moisture corn (**HMC**) for 240 d 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. A reduction in zein protein over the ensiling period for HMC was observed when measured by high-performance liquid chromatography (Hoffman et al., 2011). Ammonia-N content increased, however, as high-performance liquid chromatography zein protein subunits in HMC decreased (Hoffman et al., 2011), and ammonia-N was used in combination with mean particle size for modeling the effects of corn maturity, moisture content and extent of silage fermentation on ruminal and total-tract starch digestibilities for HMC at feed out (Hoffman et al., 2012a, b). Ferraretto et al. (2014), using a data set comprised of 6,131 HMC samples (55 to 80% DM) obtained from a commercial feed analysis laboratory, reported that ammonia-N was positively related to ruminal in vitro starch digestibility at7 h (**ivStarchD**; $R^2 = 0.61$) and combined, ammonia-N, DM, soluble-CP and pH provided a good prediction of ivStarchD (adjusted $R^2 = 0.70$).

In WPCS fermented for 0, 45, 90, 180, 270, and 360 d, ammonia-N and soluble-CP contents and ivStarch increased over time and soluble CP, but not ammonia-N, was highly correlated with ivStarchD ($R^2 = 0.78$ versus 0.24; Der Bedrosian et al., 2012). Young et al. (2012) and Windle et al. (2014) reported that increases in WPCS ammonia-N and soluble-CP

contents were accompanied by increases in ivStarchD in response to increased time of ensiling and exogenous protease addition.

Ferraretto et al. (2015b) evaluated the interaction between hybrid type and ensiling time on a study where 8 WPCS hybrids (4 BMR and 4 leafy) were ensiled for 0, 30, 120 and 240 d. Fermentation profile, ammonia-N and soluble-CP contents, and ivStarchD were similar for the 2 hybrid types and there was no hybrid type × time of ensiling interaction detected. Increases in WPCS ammonia-N and soluble-CP contents were accompanied by increases in ivStarchD in response to increased time of ensiling. Positive relationships between ivStarchD and ammonia-N ($R^2 = 0.67$) and soluble-CP ($R^2 = 0.55$) were observed. Ammonia-N and soluble-CP were both good indicators of ivStarchD in WPCS in this study. It appears that ammonia-N and soluble-CP can be used in models to predict starch digestibility for WPCS as has been done for HMC, however, more research is needed especially with regard to combining the particle size of the kernels in WPCS along with these N measures into predictive models.

The effects of ensiling time and exogenous protease addition on fermentation profile, N fractions and ivStarchD in WPCS of various hybrids, maturities and chop lengths were evaluated by Ferraretto et al. (2015a). Extended time in storage increased ammonia-N, soluble CP and ivStarchD in WPCS of various hybrids, maturities and chop lengths. However, contrary to our hypothesis, extended ensiling time did not attenuate the negative effects of kernel vitreousness and maturity at harvest on ivStarchD. Exogenous protease attenuated but did not overcome negative effects of maturity on WPCS ivStarchD.

Corn silage hybrid types

Ferraretto and Shaver (2015) performed a meta-analysis to evaluate the effects of WPCS hybrid type on digestion, rumen fermentation and lactation performance by dairy cows using a dataset of 162 treatment means from 48 peer-reviewed articles published 1995-2014. Categories for hybrids differing in grain and stalk characteristics, respectively, were: conventional dent (**CONG**), nutridense (**ND**), high oil (**OIL**), and waxy (**WAXY**); conventional, dual-purpose, isogenic or low-normal fiber digestibility (**CONS**), brown midrib (**BMR**), high fiber digestibility (**HFD**), and leafy (**LFY**). Genetically-modified (**GM**) hybrids were compared

with their genetically similar non-biotech counterpart (**ISO**). Data were analyzed using Proc Mixed in SAS with hybrid as fixed and trial as random effects.

Silage nutrient composition was similar, except for lower CP and ether extract for CONG than ND and OIL. Milk fat content and yield and protein content were lowest for OIL. Intake, milk production and total tract nutrient digestibilities were unaffected by grain hybrid type. Except for lower lignin for BMR, and a trend for lower starch for HFD than CONS, silage nutrient composition was similar among hybrids of different stalk type.

Dry matter intake, milk yield, and protein yield were 1.1, 1.5, and 0.05 kg/d per cow, respectively, greater for BMR than CONS and LFY on average. Total tract NDF digestibility was greater and starch digestibility reduced for BMR and HFD compared to CON or LFY. No differences in lactation performance were observed for GM compared to ISO. Research does not suggest any cause for concern about feeding WPCS produced from genetically-modified seed corn when the traits make agronomic and economic sense to the grower.

Except for negative effects of OIL on milk fat and protein percentages, differences were minimal among WPCS hybrids differing in grain type. Except for positive effects of BMR on DMI and milk and protein yields, differences were minimal among WPCS hybrids differing in stalk type. However, reduced ruminal and total tract starch digestibilities for BMR merit further study.

References

Der Bedrosian, M. C., L. Kung, Jr., and K. E. Nestor, Jr. 2012. The effects of hybrid, maturity and length of storage on the composition and nutritive value of corn silage. J. Dairy Sci. 95:5115-5126.

Ferraretto, L.F., P.M. Crump, and R.D. Shaver. 2015a. Effect of ensiling time and exogenous protease addition to whole-plant corn silage of various hybrids, maturities and chop lengths on nitrogen fractions and ruminal in vitro starch digestibility. J. Dairy Sci. *In press*.

Ferraretto, L.F., and R.D. Shaver. 2015. Impact of whole-plant corn silage hybrid type on intake, digestion, ruminal fermentation and lactation performance by dairy cows through a meta-analysis. J. Dairy Sci. 98:2662-2675.

Ferraretto, L.F., and R.D. Shaver. 2012. Meta-analysis: Impact of corn silage harvest practices on intake, digestion and milk production by dairy cows. The Prof. Anim. Sci. 28:141-149.

Ferraretto, L.F., R.D. Shaver, S. Massie, R Singo, D.M. Taysom and J.P. Brouillette. 2015b. Effect of ensiling time and hybrid type on fermentation profile, nitrogen fractions and ruminal in vitro starch and NDF digestibility in whole-plant corn silages. The Prof. Anim. Sci. 31:146-152.

Ferraretto, L.F., K. Taysom, D.M. Taysom, R.D. Shaver, and P.C. Hoffman. 2014. Relationships between dry matter content, ensiling, ammonia-nitrogen and ruminal in vitro starch digestibility in high-moisture corn samples. J. Dairy Sci. 97:3221-3227.

Hoffman, P.C., N.M. Esser, R.D. Shaver, W.K. Coblentz, M.P. Scott, A.L. Bodnar, R.J. Schmidt and R.C. Charley. 2011. Influence of ensiling time and inoculation on alteration of the starch-protein matrix in high moisture corn. J. Dairy Sci. 94:2465-2474.

Hoffman , P.C., D.R. Mertens, J. Larson, W.K. Coblentz and R.D. Shaver. 2012a. A Query for Effective Mean Particle Size of Dry and High Moisture Corns. J. Dairy Sci. 95: 3467-3477.

Hoffman, P.C., R. Shaver, and D. Mertens. 2012b. Feed Grain 2.0 Evaluation System. Accessed July 12, 2012. http://www.uwex.edu/ces/dairynutrition/documents/FeedGrainV2.0b.xlsx

Vanderwerff, L.M., L.F. Ferraretto, and R.D. Shaver. 2015. Brown midrib corn shredlage in diets for high-producing dairy cows. J. Dairy Sci. 98:5642-5652.

Windle, M.C., N. Walker, and L. Kung Jr. 2014. Effects of an exogenous protease on the fermentation and nutritive value of corn silage harvested at different dry matter contents and ensiled for various lengths of time. J. Dairy Sci. 97:3053-3060.

Young, K. M., J. M. Lim, M. C. Der Bedrosian, and L. Kung Jr. 2012. Effect of exogenous protease enzymes on the fermentation and nutritive value of corn silage. J. Dairy Sci. 95:6687-6694.

NOTES