Impact of Vitreousness, Processing, and Chop Length on the Utilization of Corn Silage by Dairy Cows

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Vitreousness

Flint corn has a greater proportion of vitreous endosperm than dent corn (Philippeau et al, 1999). Philippeau and Michalet-Doureau (1997) observed that increased kernel vitreousness was associated with decreased ruminal starch degradation. Increased kernel vitreousness may explain the reduction in total-tract starch digestibility observed for mature whole-plant corn silage (**WPCS**; Bal et al., 1997; Johnson et al., 2002), the variation in the starch digestibility response to kernel processing of WPCS (Bal et al., 2000b; Dhiman et al., 2000; Johnson et al., 2002), and differences between corn hybrids grown for WPCS production in ruminal (Bal et al., 2000c) and total-tract starch digestibility (Bal et al., 2000a; Johnson et al., 2002).

Correa et al. (2002) studied 14 USA and 5 Brazilian commercially available corn hybrids cultivated in their respective countries. The USA hybrids were predominantly dent-endosperm cultivars, while the Brazilian hybrids were flint or predominantly-flint endosperm cultivars. Starting at the early-dent stage of maturity, the middle portion of nine ears of the USA hybrids was evaluated twice a week and harvested at three maturity stages; one-half milk line (HM), black layer (BL), and 21 d after BL (mature; MT). Brazilian hybrids were harvested only at the mature stage of growth. Corn vitreousness was determined by manual dissection of the kernels (Dombrink-Kurtzman and Bietz, 1993). Kernel density was determined using a picnometer. Ruminal in situ degradations of 4-mm Wiley-mill grind corn kernel DM and starch were determined in three lactating Holstein cows fitted with ruminal cannulae. Three USA dent hybrids at the MT stage of maturity and three Brazilian flint hybrids were selected to represent the lowest, mid-point, and highest vitreous hybrids from each country for ruminal in situ incubations. Ruminal in situ degradation of two USA hybrids, the one with least and the one with greatest average kernel vitreousness, was also evaluated at the three maturity stages.

Kernels from commercial Brazilian flint hybrids had greater vitreousness and density than commercial dent hybrids from Midwest USA. Vitreousness of the five Brazilian flint hybrids at MT averaged 73.1% (range of 64.2% to 80.0%), while vitreousness of the 14 USA dent hybrids at MT averaged 48.2% (range of 34.9% to 62.3%). Density of the five Brazilian flint hybrids at MT averaged 1.268 g/cm^3 (range of 1.218 to 1.292 g/cm^3), while density of the 14 USA dent hybrids at MT averaged 1.201 g/cm^3 (range of 1.169 to 1.235 g/cm^3). Kernel hardness is an index of the relative proportion of vitreous to floury endosperm. The direct laboratory measurement of vitreousness is labor intensive, while determining grain density with a picnometer is less so. Since hardness is the major factor determining density, density may be a good indirect measure of vitreousness (Philippeau et al., 1999). The correlation between density and vitreousness was 0.87 (P<0.001), which suggests that density may be a reliable tool for screening large corn data sets for vitreousness.

For the 14 USA dent hybrids, days from planting to harvest was 139 $\pm$ 4.5 (mean $\pm$ S.D.) d at HM, 155 $\pm$ 5.3 d at BL, and 176 $\pm$ 5.8 d at MT (Figure 1). Within each maturity stage, the highest vitreousness measurements were on the earlier maturing (fewer days from planting to harvest) hybrids. Within the USA dent hybrids, kernel DM, vitreousness and density increased (P < 0.001) with advancing maturity (Table 1). Philippeau and Michalet-Doureau (1997) reported that vitreousness of a dent corn hybrid increased with advancing maturity.

The correlation between vitreousness and ruminal starch availability was -0.93 (P < 0.001; Figure 2; 12 in situ comparisons). Philippeau and Michalet-Doureau (1997) observed a value of -0.86 for the same correlation. Vitreousness was correlated with the starch A fraction (-0.91; P < 0.001) and the fractional rate of starch degradation (-0.66; P < 0.001). The mean vitreousness across maturity stages for the high vitreousness USA dent hybrid (HVH) was 55.2% of the endosperm; 49.8% at HM, 55.8% at BL, and 60.0% at MT. For the low vitreousness USA dent hybrid (LVH), the mean value was 36.3%; 33.0% at HM, 35.1% at BL, and 40.8% at MT. Previous research on kernel vitreousness usually compared flint corn with dent corn, and found a negative impact of increased kernel vitreousness on ruminal starch degradation (Philippeau and Michalet-Doureau,1997; Philippeau et al, 1999). We compared two dent corn hybrids differing in kernel vitreousness and found greater ruminal starch availability for LVH (Figure 3; six in situ comparisons). These data suggest that, in dent corn populations, vitreousness may be a useful parameter to select corn hybrids for high ruminal starch availability. Ruminal starch availability showed a decline after the BL stage of maturity and this decline was more accentuated for HVH than LVH (Figure 3; quadratic regression r^2= 0.69 HVH vs. 0.15 for LVH), suggesting that ruminal availability of higher vitreousness kernels may be more affected by advancing of maturity. Corn hybrids of high vitreousness may have a greater decrease in starch digestibility in response to delayed harvest than hybrids with low vitreousness (Johnson et al., 2002).

Processing and Chop Length

Increased use of WPCS harvesters fitted with on-board processors (roller mills) and interest in forage and TMR particle size has fueled recent research evaluating the effects of WPCS processing and chop length on lactation performance by dairy cows. The results of WPCS processing trials have been mixed. Bal et al. (2000b) reported a 1.2 kg/d increase in milk production and a 4.2 percentage-unit increase in total-tract starch digestion for diets containing processed vs. unprocessed WPCS. In contrast, Dhiman et al. (2000) found no advantage to processing WPCS on milk production or starch digestibility by dairy cows in two of three studies. The results of WPCS chop length experiments are more consistent showing no or minimal improvements in lactation performance by dairy cows (Bal et al., 2000b; Clark and Armentano, 2000; Schwab et al., 2002).

Oba and Allen (1999) reported a 2.8 kg/d increase in milk yield and 2.2 percentage unit increase in total-tract neutral detergent fiber (**NDF**) digestibility for dairy cows fed diets containing unprocessed brown midrib (***bm3***) WPCS vs. its unprocessed isogenic control. The *bm3* hybrid for WPCS production has gained popularity among some dairy producers in North America. Some industry representatives and consultants have recommended, in the absence of controlled trials, that processed *bm3* WPCS should be chopped longer than processed conventional WPCS hybrids in order to maintain effective fiber.

Our lab (Bal et al., 2000b; Schwab et al., 2002) has published the results of experiments that evaluated the effects of processing and chop length for conventional and *bm3* WPCS on intake, digestion, and milk production by dairy cows. The results of these trials and their implications for WPCS harvest management will be discussed in this paper.

In Bal et al. (2000b), a conventional corn hybrid was harvested as WPCS at one-half milkline stage of maturity (35% DM) and at 0.95-cm theoretical length of cut (**TLC**) without processing (control) or at 0.95-, 1.45-, or 1.90-cm TLC with processing at a 1-mm roll clearance. Corn silage treatments were fed in total mixed rations (**TMR**) containing 50% forage (67% WPCS and 33% alfalfa silage) and 50% corn and soybean meal based concentrate (DM basis). Dry matter intake (**DMI**; 25.9 vs. 25.3 kg/d) and milk (46.0 vs. 44.8 kg/d) and fat (1.42 vs. 1.35 kg/d) yields were higher for processed WPCS treatments compared with the control WPCS. Within the processed WPCS treatments, there were no chop length effects on intake, milk production, or milk composition. Chewing activity was not different among the four WPCS treatments averaging 12 h/d. Total tract digestion of dietary starch was lower for control WPCS (95.1%) compared with fine-, medium-, and coarse-processed WPCS treatments, which averaged 99.3%. Total tract digestion of dietary NDF was reduced for fine-processed WPCS compared with control WPCS and coarse-processed WPCS (28.4% vs. 33.9 to 33.7%, respectively). Processing WPCS improved DMI, starch digestion, and lactation performance. Under the conditions of this study and with TLC ranging from 0.95 to 1.90 cm (three-eights to three-fourths inch), length of chop effects were minimal in processed WPCS. But, ruminal mat consistency was improved for coarse-processed vs. fine- and medium-processed WPCS. Improved ruminal mat consistency elicited no cow health benefits, but may have in a longer-term study or in early lactation cows. Machine throughput is lower and the power requirement is higher for fine-processed compared with coarse-processed WPCS. Coarse chopping of processed WPCS prevented the depression of NDF digestibility observed with fine-processed WPCS while still achieving improved starch digestibility with processing. These observations support a 1.90 cm (three-fourths inch) TLC recommendation for processed WPCS produced from conventional hybrids. Results also suggest less sorting and cob refusal in the feed manger for TMR containing processed WPCS.

In Schwab et al. (2002) with a *bm3* hybrid, WPCS treatments were harvested at three-quarter milk line stage of maturity at 1.3 and 1.9-cm (one-half and three-fourths inch) TLC without processing, or at 1.9- and 3.2-cm (three-fourths and one and a quarter inch) TLC with processing at a 2-mm roll clearance. Treatments were fed in TMR containing 60% forage (67% WPCS and 33% alfalfa silage) and 40% shelled corn and soybean meal based concentrate (DM basis). Milk yield was unaffected by treatment. Dry matter intake was unaffected by corn silage processing, but increasing WPCS chop length reduced dry matter intake in unprocessed (26.6 vs. 25.5 kg/d) and processed (25.9 vs. 25.1 kg/d) chop length contrasts. Processing reduced milk fat content (3.36% vs. 3.11%) and yield (1.43 vs. 1.35 kg/d), increased total-tract starch digestion (92.9 vs. 97.4%), and decreased total-tract NDF digestion (51.0 vs. 41.8%). Reductions in milk fat test and total-tract fiber digestibility associated with the higher starch digestibility due to kernel processing may have been avoided if the *bm3* WPCS had been fed in higher NDF, lower starch diets. Total chewing time (min/d) was unaffected by treatment. Masticate mean particle length was unaffected by chop length in unprocessed and processed WPCS treatments. In this study with *bm3* WPCS, there were no benefits from crop processing or increasing chop length on lactation performance. As concluded from Bal et al. (2000) for processed WPCS produced from a conventional corn hybrid, a 1.9 cm (three-fourths inch) TLC seems to be adequate for processed *bm3* WPCS.

The recommended roll clearance ranges from 1 mm to 3 mm. Roll clearance is determined using feeler gauges. If you do not have feeler gauges, lay the blade of your pocketknife flat between the rolls and adjust the clearance until the rolls tighten against the blade. Harvest some whole plants, shake out the chopped material, and visually inspect each screen for the degree of kernel and cob processing. We would like to see all of the kernels broken. Pieces of cob, if discernible, should be no larger than the end of your little finger. If kernel and cob breakage is not complete, then tighten the rolls until kernel damage is complete or consider reducing your TLC. This may be necessary for processed WPCS that is harvested at 40% DM or more. With processed WPCS harvested at an immature or wet stage that tends to mush, you can set roll clearance to 3 mm. Make sure that you follow all recommended safety practices whenever making any machine adjustments.

Based on our research with conventional and *bm3* corn hybrids, the recommended chop length for WPCS harvested with a harvester fitted with a crop processor is 1.9 cm (three-quarters inch) TLC. This normally means that about 20% of the processed WPCS will be in the coarse particle fraction or retained on the top screen of the Penn State-Nasco shaker box. Processed WPCS that is harvested at black-layer stage of maturity with 40% or more DM or from a high vitreousness hybrid may need to be chopped finer (1.27 cm or one-half inch TLC). Our data shows no benefit to chopping conventional or *bm3* processed WPCS at lengths greater than 1.9 cm (three-quarter inch) TLC, and there have been field reports of excessive equipment wear at TLC of one inch or more and achieving the proper silo packing density may be an issue.

Based on Schwab-Shaver summative energy equations for WPCS (Shaver, 2002), ½ and ¾ of the energy value of WPCS and corn grain, respectively, come from starch. Understanding better the inter-relationships between kernel vitreousness, maturity, kernel processing, fineness of chop, and starch digestibility may allow for further improvements in the utilization of corn silage-based diets by dairy cattle. More research evaluating these inter-relationships and the starch properties of corn is needed.

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Figure 1. Relationship between corn kernel vitreousness and days from planting to harvest of fourteen USA dent hybrids at three maturity stages (? Half milk line, ¦ Black layer, ? Mature).

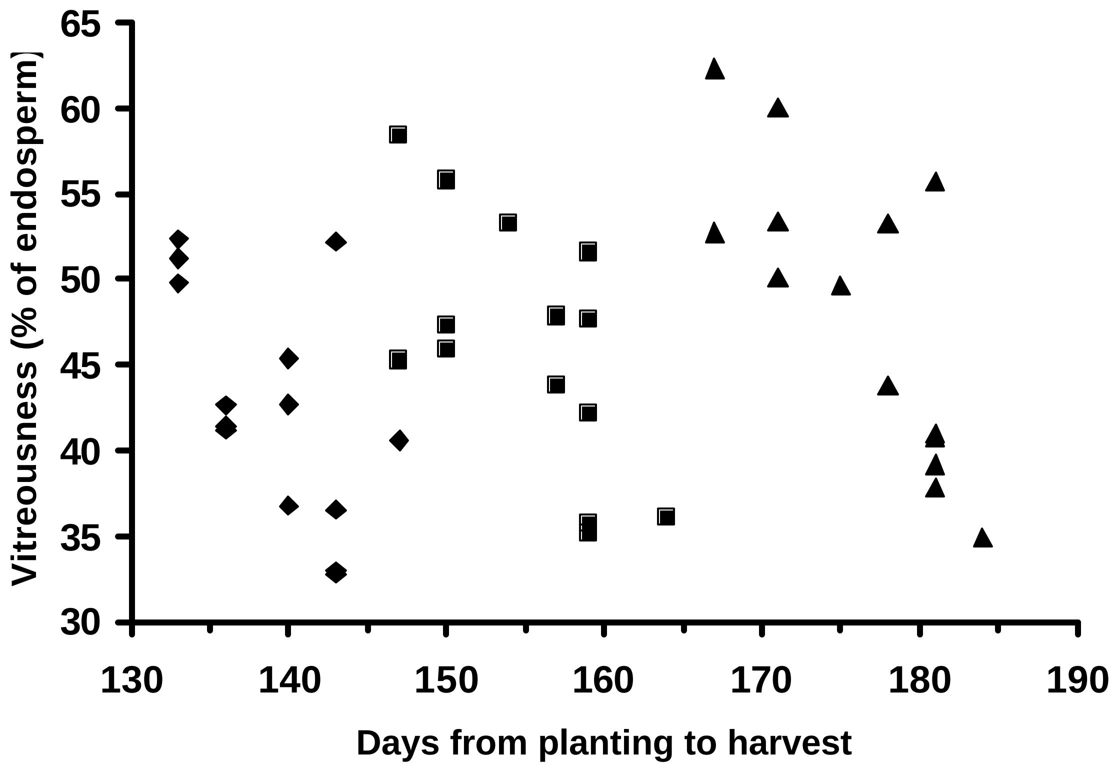

Table 1. Kernel dry matter, vitreousness, density, and starch content of kernels from fourteen USA dent corn hybrids harvested at one-half milk line (HM), black layer (BL), and mature (MT) stages of maturity**.**

	HM	BL	MT	SEM	*P* <
DM (%)	62.0	74.3	87.1	0.6	0.001
Vitreousness (%)	42.8	46.1	48.2	1.0	0.001
Density (g/cm^3)	1.173	1.176	1.201	0.003	0.001
Starch (% of DM)	79.3	80.1	79.9	0.6	0.70

Figure 2. Relationship between corn kernel vitreousness and ruminal in situ starch availability measured in three USA dent (¦) and three Brazilian flint (?) hybrids harvested at the mature stage of maturity and two USA dent (¦) hybrids harvested at half milk line, black layer, and mature stages of maturity. Availability = A + B [$k_d/(k_d+k_p)$] with K_p at 0.08/h. Availability = 108.2 – 0.7605*Vitreousness. $r^2 = 0.87$. $P < 0.001$.

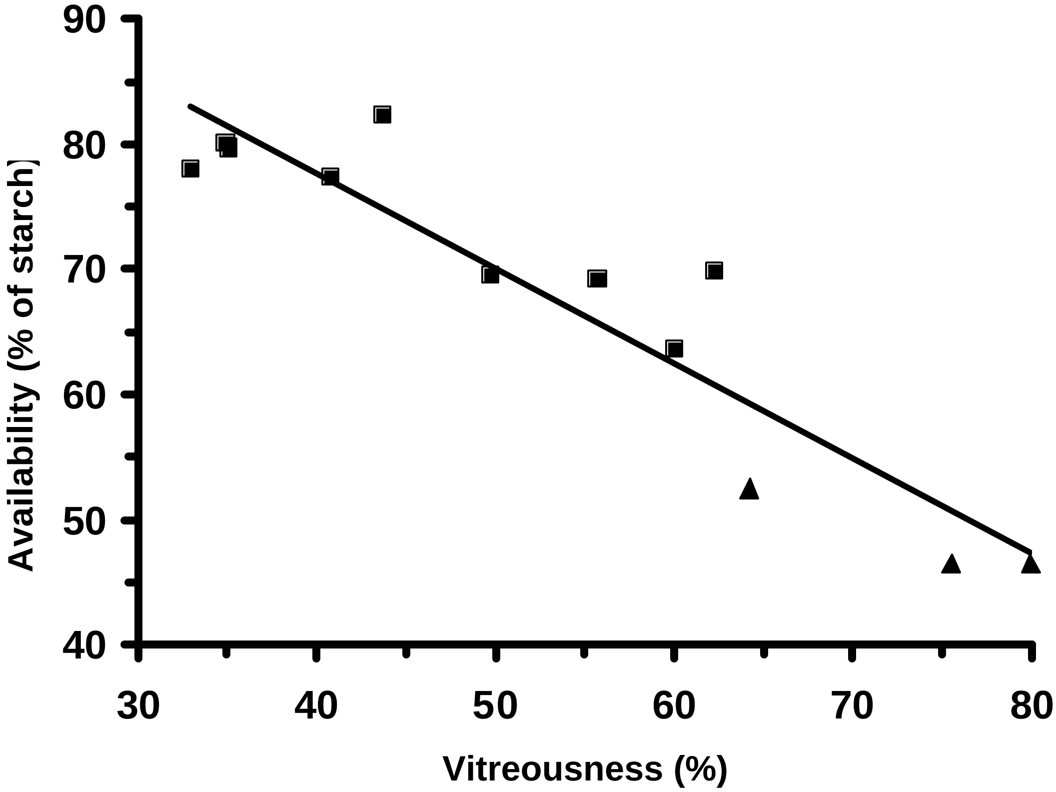

Figure 3. Relationship between ruminal starch availability and days from planting to harvest (X) of low (LVH; ?) and high (HVH; ?) vitreousness USA dent hybrids. Availability = A + B [$k_d/(k_d+k_p)$] with K_p at 0.08/h. Availability = -44.639 + 1.6511 X – 0.0055 X^2, r^2 = 0.15 (P < 0.001) for LVH and Availability = -55.086 + 1.7886 – 0.0064 X^2, r^2= 0.69 (P < 0.001) for HVH.