Managing Corn Silage From Seed to Feed

Bill Mahanna, Ph.D., Dipl. ACAN
Global Nutritional Sciences Manager
Pioneer, A DuPont Company
7100 NW 62nd Avenue, Johnston, Iowa 50131
Tel 800-247-6803
bill.mahanna@pioneer.com

Introduction

Corn silage is a popular feed with dairies because the corn plant can provide large volumes of digestible, palatable feed and requires harvesting only once-a-year while possessing the ability to utilize large quantities of manure. Corn silage can be thought of as "grass with high-moisture corn attached". Having that perspective helps dairies focus on the key traits that need analyzing when feeding new-crop silage or selecting next years' silage hybrids.

Research at the U.S. Dairy Forage Research Center suggests that cows and environmentally-friendly rations should have a forage base consisting of at least 1/3 alfalfa, 1/3 corn silage and the remaining 1/3 as any combination of alfalfa or corn silage depending on local agronomic conditions, labor supply and feed economics. However, the relative ease of obtaining this energy-rich forage has dairy producers trending towards increasing the inclusion rate of corn silage in dairy rations to levels as high as 50-70 lbs of wet corn silage per cow per day. It is important for dairies to understand and manage corn silage nutritional variability, particularly when this forage is comprising more and more of the total ration dry matter.

This paper provides a dairy-producer (as opposed to corn-grower) an overview of the yield and nutritional advances in corn genetics and discusses key management areas to help identify and reduce corn silage harvest and feeding variability.

Corn Market

Corn is the primary cultivated crop in North America, varying from about 77-84 million acres and adding over $16 billion to the value of the U.S. economy. About 20% of U.S. corn is exported, another 23% used for food, seed and industrial uses (with ethanol being the fastest growing segment at 13% of all corn acres and currently growing at 20%/year), with the remaining 57% used as livestock feed (dairy about 15% of this segment).

Corn silage for both beef and dairy fluctuates between 8-10% of the total corn acres. According to the 2003 USDA Crop Production Report, the top ten corn silage producing states are: WI, NY, CA, PA, MN, IA, SD, NE and ID. A generalized segmentation of this market is that a third of all silage growers are interested in tonnage only, a third interested in both tonnage and quality and a third primarily focused on quality, and willing to sacrifice some yield to obtain increased quality. The beef industry accounts for 30-40% of corn silage utilization and drives a considerable amount of the "tonnage" segment because they tend to use silage at low inclusion rates as a source of rumen "scratch". The increased reliance on contractual silage production in the dairy business makes for interesting and confusing market dynamics in that dairies want quality but tend to pay growers for yield. This sends the message to growers (who typically purchase the seed) that silage tonnage should be the focus because that is what influences their profitability.

Take Home: Corn Market

The corn silage market comprises 8-10% of the total U.S. corn production. Silage yield is the biggest overall driver of value and is influenced to a great degree by the agronomic strengths of a particular hybrid. Sectors interested in both tonnage and quality, like the dairy market, need to send the appropriate pricing signals such that growers who deliver higher quality silage are incented with a higher price. (Note: Contact the author to obtain several spreadsheets developed at Pioneer to help price corn silage on tonnage and quality).

Advances in Corn Genetics

North American corn genetics consists primarily of dent rather than flint background. Dent corn contains more soft, floury endosperm (hence the "dent" at the top of the kernel when it dries), which is more "open" in structure and opaque in appearance. Dent corn has about equal proportions of soft, floury starch to hard, vitreous endosperm. Flint corn is similar to popcorn with much more vitreous starch. European, shorter-season (<90 day) corn still contains considerable flint influence because of the agronomic advantages, such as early growth vigor, provided in flint lines. Recent Wisconsin work showed vitreousness of flinty hybrids averaging 73%, while mature dent hybrids averaged 48% hard starch (Correa, 2002).

Since the 1926 commercialization of hybrid seed corn, steady advances in grain yield per acre have occurred. Much of what has contributed to corn yield increases has been improved stress tolerance, allowing plants to respond better to higher planting populations (Paszkiewicz and Butzen, 2001). Hybrid corn in the 1930's was typically planted at densities of 4,000-5,000 plants per acre (PPA); whereas today, hybrids can routinely withstand the population stress of over 30,000 PPA. Under good growing conditions, late-season plant health and kernel weight (grams per kernel) have also increased steadily since the 1950's. When these same genetics are exposed to moisture-stress, there is less observed improvement in yield, kernel weight, and plant health. This fact, along with depleting agricultural water supplies, is driving seed companies to actively research mechanisms and genes controlling drought tolerance.

Technology that reduces stress on corn (e.g. moisture, insects, disease) tends to benefit forage producers even more than grain producers. This is because when under stress, corn tends to direct energy into seed production at the expense of forage yield. Cornell has shown that controlling corn rootworm had more effect on increasing forage yield than grain yield (Thomas, 1997). Biotechnology has been important to maintaining the continuous improvement in corn agronomics and yield. Commercialized biotechnology in corn, to date, includes genetically engineered resistance to certain herbicides (e.g. Roundup®) and expression of various Bacillus thuringiensis (Bt) toxin events for the control of Lepidopteran insects such as European corn borer (ECB), Southwestern corn borer (SWCB) and corn rootworm (CRW).

United States corn and soybean growers lead in global seed biotechnology adoption. In 2003, the U.S. planted 105.7 million acres (out of a total 77M acres of corn and 73.5M acres of soybeans) of biotechnology-enhanced crops, up 10% from the 2002 planting season and accounting for 63% of the global total of biotechnology crops (ISAAA, 2004). The National Center for Food and Agricultural Policy (NCFAP, 2004) released an October, 2004 study on the impact of 2003 biotech crops on U.S. agriculture. Among the positive benefits of biotechnology cited in the report are that biotech corn (especially ECB resistant corn) produced the greatest yield increase at 4.9 billion pounds, which helped put an additional $258 million in farmers' pockets. These crops represented a 41 percent increase in yield gain and a 27 percent higher economic return for farmers from the additional 26 million more acres planted to biotech crops. Biotech crops also reduced the total use of pesticides on 2003 crops by 46.4 million pounds.

The seed industry has partnered with university researchers to compile an impressive research dossier as to the safety and nutritional equivalency of genetically-modified corn (Available: http://www.dupont.com/biotech/science_knowledge/feed_livestock/scientific_narrative.htm#References).
Despite all this research, it is not uncommon to have dairy producers still question the nutritional equivalency, (especially the fiber digestibility) of biotech corn. However, when genetically modified hybrids are tested, side-by-side, against their isogenic controls, it becomes more apparent to the dairy that there are not differences in digestibility and that poor nutritional value can usually be explained by base genetics or environmental factors such as plant population or moisture stress. From a livestock-feeder perspective, the nutritional advantage to ECB/SWCB-resistant corn includes improved, late-season plant health resulting in the ability of the plant to actively photosynthesize later into the growing season thus improving yields and nutritional-quality (especially starch content) and also the potential to help reduce field mold growth and toxin production (Munkvold et.al., 1999).

Take Home: Advances in Corn Genetics

Modern dent corn hybrids are bred to withstand increased stress from high populations, pests/diseases and environmental factors such as moisture-stress. Biotechnology traits that reduce stress likely have more potential yield benefits for silage growers than even grain farmers. Biotech corn undergoes a comprehensive and rigorous assessment process to validate safety by the USDA (environmental safety), EPA (environmental, food and feed safety for pest-protected product registration) and FDA (feed and food safety). With nearly 50% of the corn grown in the U.S. containing a biotech-enhanced trait, it is unlikely that agronomic or nutritional problems can be ascribed to specific biotech traits, but rather, is typically associated with the base-genetic issues or local growing conditions.

Corn-For-Silage Genetics

The University of Wisconsin has conducted corn silage “era” studies using saved seed representative of the typical corn genetics of every decade from the 1930’s to today (Coors et al., 2001; Lauer et al., 2001). This study shows that as corn genetics have advanced, dry matter yield of both stover and whole plant have increased. Grain production has been the greatest driver of yields; so whole plant yields have increased faster than yields of stover. Over time, cell walls (neutral detergent fiber, NDF) have comprised less and less of the whole plant, because of the dilution effect of higher grain yields. Stover, per se, has not changed significantly in percentage of NDF or NDF digestibility (NDFD).

Some nutritionists question if breeding for improved agronomic traits, such as standability, has negatively impacted corn stover (cell wall) nutritional composition and digestibility. In normal corn hybrids, there is no obvious association between either fiber or lignin concentration and stalk lodging. Distribution of structural material may be as important, or more important, than concentration of structural components, per se (Allen et al., 2003). Others have reported that improvements in stalk lodging were associated with relatively small changes in lignin concentrations (Undersander et.al., 1977, Twumasi-Afriyre and Hunter, 1982). Research at the University of Minnesota evaluated representative hybrids used from 1930 to 1980 and found only a slight decrease or no change in stalk fiber and lignin concentration as lodging resistance and stalk strength were improved with new hybrids (Albrecht et.al., 1986, Carter et.al., 1991).
The University of Wisconsin Departments of Agronomy and Dairy Science led a 1991-95 UW Corn Silage Consortium that was jointly funded by all the major seed companies. Dr. Jim Coors offered a review of their findings at the 1996 Cornell Nutrition Conference, indicating there was genetic variation

for nutritive value among adapted U.S. corn hybrids with both silage yield and grain yield potential. However, forage quality and agronomic traits were not highly correlated; and it should be possible, through routine screening, to identify productive hybrids with improved intake potential (low NDF) with higher protein and digestibility (high NDFD). They also detected few significant correlations among yield and whole-plant quality characteristics in either the early or late hybrid trials (Coors, 1996).

Seed companies provide a laundry list of agronomic and nutritional ratings on their genetics. Two oft-misunderstood agronomic traits are staygreen and dry down. Both of these traits are determined on the corn plant after it reaches kernel physiological maturity (black layer) and should not be used in reference to silage or silage maturities. Neither of these traits are single gene traits; that is, there is no staygreen gene. Staygreen scores are based on the percentage of leaves that are green (does not include stalk observations) and describe plant health and ability to photosynthesize late into the fall. Biotechnology traits like ECB-resistance often result in a healthier plant under heavy corn borer pressure, hence typically higher staygreen scores. Staygreen scores are pooled averages from many environments and are not very predictive in any individual environment. Only limited research has been conducted into the relationship of staygreen and silage harvest moistures. Kernel dry down scores only reflect moisture decline from black layer to marketable dry grain standards (e.g. 15% moisture). Current grain dry down scores do not address the silage concerns about the time it takes a kernel to mature from 1/3 milk line to blacklayer.

Take Home: Corn-For-Silage Genetics

Modern corn breeding has increased grain (starch) content of the corn plant to a greater extent than stover yield. Breeding for improved standability has not increased stover lignin content nor negatively impacted stover digestibility. Neither agronomic traits nor silage yield are highly correlated with corn silage quality making it possible to find agronomically-sound hybrids containing high (forage) yield along with desirable starch and fiber digestibility content.

Selecting a Silage Hybrid

Differences do exist among commercial corn hybrids for digestibility, NDF digestibility, and crude protein. Many seed companies are developing silage profiles of their corn hybrid lineup to help growers select hybrids most suitable for silage production. One seed company has commercialized brown midrib (BMR) genetics specifically for the silage market.

The ultimate goal of corn breeders is to provide silage hybrids that combine high forage yields, with both high starch and highly digestible stover. The best silage hybrids also have high grain yields, because: 1) starch is so highly digestible and 2) starch and the kernel accounts for 55% and 75% of the energy of corn silage respectively (Shaver, 2001). However, ranking for top-yielding grain hybrids used for silage may vary based on differences in fiber digestibility and grain-to-stover ratios (Coors, 1996).

Findings of the UW Corn Silage Consortium referenced previously, has led Dr. Joe Lauer, Wisconsin state extension corn agronomist, to suggest to Wisconsin dairy producers that hybrid selection for corn silage should begin by identifying a group of hybrids adapted to the growing environment/maturity, along with standability, disease resistance, and drought tolerance needs unique to the grower's conditions (Lauer, 1997). This group of agronomically adapted hybrids should next be evaluated for silage yield performance. Many studies have shown that grain yield is a positive indicator of corn silage yields; meaning that high grain yielding hybrids tend to have high silage yield. However, within the high grain-yielding group there can be differences in whole plant yield and fiber digestibility, reinforcing the need to have silage yield and nutritional data available on these hybrids. Stated simply, a good silage hybrid has to first be a good grain hybrid, but not all grain hybrids make good silage hybrids. According to Wisconsin recommendations, the final consideration for hybrid evaluation should be quality. This makes sense because the genetic variation (in non-BMR genetics) for fiber digestibility is relatively small for fiber digestibility compared to the genetic variation in silage yield or starch content.

Hybrids are no different than bulls. Their genetic transmitting ability must be evaluated independent of environmental influences. It is not valid to assume hybrid genetics as the primary cause of nutritional differences when comparing different hybrids grown on different farms. This is why seed companies and universities only compare hybrids grown in the same location, planted reasonably close to each other (e.g.10-12 rows apart, especially where soils are highly variable) for what agronomists called side-by-side, paired comparisons. The AI industry uses statistical procedures to factor out genetics (of the dam) and environment (housing, health, nutrition, etc.) to sort out production differences among bull daughters born into herds across the country. This is possible because there is no growing environment limitation to where a bull's daughter can be born. We can also have enough daughters, born into enough herds that we can, in effect, zero-out the non-genetic effects of production to arrive at the genetic transmitting ability of the bull. This is not possible with corn genetics because hybrids have regional and maturity limitations as to where they can be grown. It is also important to compare hybrids within the same maturity, seed treatments, technology segment, and planting populations (e.g. low populations will result in higher NDFD). Significant genetic-by-environment (GxE) interactions can still occur if a silage trial contains hybrids spanning too large a range of maturities or when a killing frost prevents normal hybrid development (Carter et.al., 1991; Allen et.al., 2003).

Research by Pioneer statisticians suggest that to be 95% confident you are selecting the best hybrid for silage yield or nutritional traits, you need approximately 20 direct, side-by-side comparisons (in the same plots), preferably grown across multiple years to account for unique yearly environmental effects. Data from a single plot is almost meaningless due to causes of one location variability, which include: soil compaction, previous crop history, fertility history, dead furrows, uneven plant height causing shading, soil type, water availability, uneven fertilizer application, manure history, tillage, and insect damage. Consider this fact relating to grain yield, on soil with 150 bushel/acre yield potential, a hybrid would have to be 34 bushels/acre better in order for you to be confident of predicting future performance with only one location of data.

Take Home: **Selecting a Silage Hybrid**
Don't get hung-up on marketing labels like dual-purpose, silage-specific or grain hybrids. Let actual data (e.g. agronomic profile, maturity, silage yield, starch content and fiber digestibility) from valid silage plots help you decide which hybrids meet the specific agronomic and nutritional needs of your dairy. Do not settle for only a couple of comparisons because they can be deceiving as to the true genetic differences between hybrids. Having 15-20 direct, side-by-side comparisons, over at least three growing seasons is ideal. Demand high repeatability in your "silage proofs", just like you do from sire proofs.

Grain (Starch) Content of Corn Silage
As corn genetics improve, and considering that over 90% of all corn is grown for grain yield, it is not surprising that silages are increasing in quantity of starch. Several studies have documented that starch content increases with increasing maturity of the corn plant (Bal, et.al., 1997 and Johnson, et.al., 2002). It is not unusual for starch content to increase 30% or more from ¼ milk line to ¾ milk line showing the geometric deposition in starch during the last few weeks of plant development. This is why kernel processing first became popular in the West. It allowed Western starch deficit dairy sheds the ability to

delaying harvest to capture this starch, while processing allowed access to the starch by rumen bacteria. The Pioneer Livestock Nutrition Center analyzed corn forage (not yet fermented) samples from 3414 customer plots in 1993, with the average starch content of 22.7%. In 2002, 3614 customer plot samples were analyzed containing an average of 27.8% starch. It is not uncommon to find upwards of 35% starch in midwestern corn silage samples. If the crop is high-cut (e.g. 20 inches vs. traditional 6-8 inches), it is not uncommon to find starch in the low-to-mid 40% range.

Beginning at the R5 (dent) stage of kernel development (about 35-42 days after silking), the starch/milk line advances towards base of kernel (toward cob). At the beginning of R5, kernels are about 55% moisture and the whole plant starch content will typically be in the high-teens. It takes about 3 weeks to progress to the R6 stage (kernel physiological maturity or blacklayer) when the kernels are typically 30-35% moisture (past ideal silage maturity, but ready for combining for high moisture corn). Determining harvest timing using kernel milk line is less reliable as one moves East of the Missouri River. It may be necessary to test for desirable whole plant moistures by chopping individual plants, shredding in a chipper-shredder and analyzing with a Koster ™ or a microwave oven.

Given the variability in grain yield from both genetics and subsequent growing conditions and management, it is critical corn silage be analyzed for starch content. Starch analysis is the preferred analytical approach rather than relying on the dilution in fiber content as the starch content of silage increases. Nutritionists can then use tools such as the University of Wisconsin MILK2000 spreadsheet (http://www.uwex.edu/ces/crops/uwforage/dec_soft.htm) that incorporates starch content along with NDF digestibility (%NDF, 48 hr) and other nutrients to estimate net energy of lactation (NE-L), milk per ton, and milk per acre (Shaver, 2002).

The use of on-chopper roller mills to process corn silage can also have an effect on the variation in the rate and extent of corn silage starch digestion. To simply say silage was processed is not enough. What is needed is information on the roller mill setting (e.g. typically 1-5mm depending upon kernel maturity) and objective quantification of the extent of subsequent kernel damage. The U.S. Dairy Forage Research Center conducted research into a standardized laboratory method to quantify the degree of kernel damage and suggested equations to predict starch digestibility (Mertens and Ferreira, 2001, Mertens, 2002). This laboratory procedure is currently being used at Pioneer and is also commercially available as a "corn silage processing score" at Dairyland Laboratories, Inc., in Arcadia, Wisconsin for $16/sample (Taysom, 2003). Our recommendation is that >70% of the total starch in processed corn silage should be in damaged kernels. Damaged kernels are defined as starch from kernel pieces that are small enough to fall through a 4.75mm screen when dry sieved on a Ro-Tap unit. However, because this analysis is not a field test, producers still need to discuss processing goals with their nutritionist and custom cutter (if outsourcing chopping) and develop their own (bunker-side) system for monitoring the number of undamaged kernels in a given volume of silage. It is important to monitor each chopper several times per day to ensure processing consistency across fields and hybrids

Some growers have expressed concern about the texture or vitreousness of corn kernels in silage. The most recent work on vitreousness, per se, comes out of Wisconsin and supports that silage, harvested wetter than about 35% DM, exhibits very little differences in starch digestibility attributable to kernel texture or vitreousness (Correa et al., 2002). Specifically, that ruminal starch availability showed a decline only after the blacklayer stage of maturity; which is past the ideal kernel maturity for harvesting corn silage. This agrees with published (Andrighetto, 1998) and unpublished work at Pioneer (Owens, 2004) that shows high test-weight, high-vitreous grain (versus low test weigh, softer-texture grain) does not have a negative effect on ruminal starch disappearance when fed as corn silage or even high moisture corn (>24% kernel moisture). The published negative effect on feed efficiency and decline in ruminal starch digestion of high, test weight grain appears to only occur when this grain is fed as dry (14-18% moisture), rolled corn (Jaeger, et. al., 2004).

There are some that suggest corn silage can have too much grain (starch). Their logic is that grain can always be added to corn silage and one should not sacrifice fiber digestibility to obtain high grain yields. This assumes that high grain yield and high fiber digestibility are mutually exclusive traits. This assumption conflicts with university research showing no relationship between grain content and stover digestibility (Vattikonda and Hunter, 1983) and other research reporting no correlation between ear content and stover digestibility (Deinum and Baker, 1981). Brown mid rib silage is a perfect example. It is very high in fiber digestibility yet fairly competitive with traditional hybrids for starch content primarily because it is a short-stature plant, so on a percentage basis, the starch content is relatively high. UW corn breeders concluded from the four-year UW corn silage consortium that while evaluating forage potential of hybrids might require separate testing programs, grain (starch) yield need not be sacrificed when developing hybrids with high dry matter yields and improved nutritive value (Coors, 1996).

Reviewing nutritional data from hybrids entered in university silage evaluation programs reinforces that fact that grain yield need not be sacrificed to obtain high fiber digestibility. A typical example is the late-maturity, southern zone hybrid set in the 2003 University of Wisconsin silage plots containing a spectrum of conventional, leafy, Bt, herbicide-resistant, and BMR hybrids (Lauer et al., 2003). The plot average for NDFD (%NDF, 48 hr) was 63% (LSD @.10 = 2) and starch content averaged 30% (LSD @.10=5). While there were numerous examples of significant hybrid genetic differences for yield and starch content, very few hybrids differed significantly for NDFD except for the BMR entry which had 72% NDFD, (%NDF, 48 hr).

The notion that corn silage can have too much grain also conflicts with commonly held guidelines for the amount of starch dairy cows could safely handle in the ration. To put in perspective, consider an extreme example of a cow fed 70 lbs of 30% DM corn silage containing 50% starch (highly unlikely, even with high-chop corn). The silage would contribute 10.5 lbs of daily starch intake. If the cow was consuming 50 lbs of dry matter intake, the total ration starch level from the corn silage in this example would only be 21% starch. This is well within the acceptable guidelines of most nutritionists. By maximizing starch from corn silage, one can significantly reduce ration costs from supplemental starch sources without having to sacrifice reduced fiber digestibility.

Take Home: Grain (Starch) Content of Corn Silage

The kernel accounts for 75% of the energy in corn silage so grain yield is important to both silage tonnage and energy density. Fiber digestibility does not have to be sacrificed to obtain silage with high grain (starch) content. Striving for maximum starch content through hybrid selection or management practices (e.g. high-cutting) will not adversely affect cow performance if the concentrate level is reduced accordingly. This strategy can actually improve income over feed cost by reducing need for supplemental starch sources. Kernel texture or test weight of the hybrid is not a significant nutritional issue if silage is harvested before the kernel blacklayer stage of maturity. Determining proper harvest timing by monitoring kernel milk line is increasingly less reliable as one moves East of the Missouri River. All parties involved, including the nutritionist, the feeding manager and the chopper-operator, should agree upon the acceptable degree of kernel damage. Kernel damage should be closely monitored as the silage is coming to the bunker and post-harvest analysis using standardized laboratory methods.

Corn Silage Fiber Digestibility: Moving on the "grass" portion of the corn plant

It is clear that reduced stover (cell wall) digestibility can "handcuff" a nutritionist. Variability in corn digestibility impacts both the energy value and intake potential of the silage. Oba and Allen (1999a, b) reported that enhanced forage NDF digestibility significantly increased dry matter intake and milk production of dairy cows. They concluded that a one-percentage unit increase in ration NDF digestibility was associated with 0.37 lb increase in dry matter intake. The digestibility of the corn silage fiber provided in the ration is a function of genetics along with planting population, growing environment, harvest maturity, and fermentation quality. This causes a tremendous amount of variation in corn silage NDFD that has to be dealt with by dairy.

The desire to drive intakes and improve digestibility has generated renewed interest in low lignin, BMR corn silage hybrids. Most single-gene mutants exhibiting radically altered morphology have not had much use as forage types due to their inherently poor productivity compared to adapted hybrids selected for grain production (Coors et al., 1994). Practical limits may also exist concerning how much lignin and other cell-wall constituents can be reduced in corn through breeding without adversely affecting the ability of corn to grow and survive in field environments (Buxton et al., 1996). Brown mid rib mutants typically show 8-10 percentage units higher fiber digestibility in university plots (Lauer et al., 2003) and have also demonstrated ability to increase milk production (Oba and Allen, 1999a). A recent review of the Michigan State BMR trials shows that most, if not all, of the milk production effect of BMR can be explained by increases in total TMR intake by the BMR-fed cows (Mertens, 2004). It also appears that increase in total DM intake more than offset the increased in fiber digestibility in BMR corn resulting in increased, not reduced, fecal excretion in BMR rations. The relationship between improved corn silage fiber digestibility and increased total ration intake needs to be studied further in regards to overall feed efficiency and the environmental impact of potentially increased fecal N-excretion.

University evaluation of 45 elite inbred lines (including three BMR mutants) found normal corn inbreds that equaled or exceeded the BMR lines for both extent and rate of fiber digestion. These results suggest that improving digestibility of corn stalks by selecting within agronomically superior inbreds, without incorporation of undesirable agronomic characteristics associated with the BMR trait, should be possible (Lundvall et.al., 1994). There is also debate over the role of lignin in stover digestibility. Research from Michigan shows lignification of NDF highly related to in vitro fiber digestibility across corn plant parts and suggests that lignin might be a preferred test to index NDF digestibility versus directly measuring NDF digestibility with *in vitro* methods (Allen et al. 2003). In contrast, Iowa researchers report that the relationship between fiber digestibility and lignin concentration is often low when genetic materials of a common maturity are compared (Buxton, 1996). They also reported that lignin as a percentage of NDF in multiple regression equations with NDF, explained only an additional 13-17% of the variation in stem digestibility.

One seed company has also commercialized leafy hybrids for the silage market. They are tall plants that produce 6-8 extra leaves above the ear. Total leaf content is higher but each leaf tends to be smaller. Unpublished research at Pioneer showed no significant increase in total leaf area in leafy genetics over traditional hybrids. Leafy genetics typically do not handle population stress as effectively and are planted at 3-5,000 PPA lower populations than comparable hybrids. The lower plant populations can account for a slight increase in their NDF digestibility observed in some trials. However, the notion that leafy genetics have significantly higher fiber digestibility than traditional hybrids has not been proven in university silage plots or well-designed lactation trials comparing them against traditional hybrids of similar relative maturities (Kuehn, 1999, Bal, 2000).

The availability of routine NDF digestibility testing (either NIR and actual rumen fluid incubations) by many reputable commercial laboratories may make the question of plant type or lignin moot to nutritionists when their real interest is in determining the extent and rate of NDF digestibility, not the underlying physiological reasons causing the differences. Organizations like the NIRS Forage and Feed Testing Consortium (http://www.uwex.edu/ces/forage/NIRS/home-page.htm) and the University of New Hampshire-led Ruminant Feed Analysis Consortium (http://rfac.sr.unh.edu/) are helping by providing recommended laboratory methods and standards against which to benchmark forages.

When it comes to selecting corn silage genetics to plant, the fact is that there are minimal genetic differences between (non-BMR) hybrids for NDF digestibility. The huge variation in NDFD observed by nutritionists is more of a result of environmental factors such as growing conditions and harvest timing. One study showed only a 4.5 percentage unit range in stover digestibility in the hybrids they tested. Inbreds used to develop these hybrids showed relatively large variation (8.3 percentage units) in NDFD, suggesting that silage breeders should evaluate inbreds for quality characteristics and emphasize grain yield, maturity, and lodging resistance in hybrid testing (Lundvall et.al., 1994). More recent research also showed that on a whole plant basis, ranges in quality traits were statistically significant, but quite small in magnitude, relative to what was observed for inbreds (Coors, 1996).

A narrow range in stover digestibility is typically observed among (non-BMR) commercial hybrids (when comparisons are among hybrids grown in the same plot and not the huge range suggested by some seed company advertising (Lauer et al., 2003). The narrow range in NDFD further supports the hybrid selection priority recommendations that came out of the UW Corn Silage Consortium. Growers should certainly consider fiber digestibility when selecting hybrids to grow, but its selection pressure should be below that applied to agronomic traits, grain yield (starch content), and silage tonnage (Lauer, 1997).

The primary reason only one seed company has decided to commercialize BMR corn is because of agronomic and yield instability. Yield of BMR silage is generally compromised (10-30% or more) when compared, not against their base genetics, but against other elite silage hybrids. This is due to inherent problems BMR genetics have had, to date, in handling agronomic stress. These BMR silage products are also priced considerably higher than conventional silage hybrids and, to date, do not contain other agronomic traits such as herbicide tolerance or ECB protection desired by many growers, especially those that contract raise corn silage and are paid solely on the basis of DM yield. Increased agronomic risk and yield drag has typically relegated these products to limited acres for dedicated use in transition cow or fresh-pen rations where high dry matter intakes are desired.

Some producers have opted to high-chop traditional hybrids to achieve NDF digestibility values that approximate that of BMR genetics (Lauer, 1998). A recent Penn State summary of corn silage cutting height trials indicates high-cut silage starch content was increased by 6%, NDF content reduced by 7.4%, NDFD improved by 4.7% while reducing DM silage yield an average of 7.3% (Wu and Roth, 2004). Research by Pioneer indicates about a 1-1.5 ton (30% DM) yield drag for every six-inch increase in plant cutting height.

Caution should be exercised when interpreting published data from high-cut or processed corn silage research. This is because these treatments typically increase the starch content or, in the case of processing, increase the rate of ruminal starch digestibility (Andrae et. al., 2001; Johnson, et.al., 2002). The difficulty in evaluating published research is that peer-reviewed journals require that researchers feed the cows the same amount of concentrate, even if one of the treatments alters starch content or availability. This means that the processed silage-fed cows (with the increased rate of starch availability) could be receiving excess ruminal available starch, causing acidosis, likely reducing intake and/or milk production. This leads the researcher to interpret processing or high-chopping as not beneficial (example: Quellet et.al., 2003). This research design is contrary to how field-nutritionists would balance rations. If silage analysis showed increase starch or a processing method increased the anticipated rate of ruminal starch digestion, field nutritionists would simply reduce the level of concentrate feeding accordingly.

Harvest maturity impacts not only starch content, but also fiber digestibility. Stover digestibility declines with maturity just as would be expected from a grass plant. However, some hybrids tend to decline in fiber digestibility at a faster rate than others (Andrae et. al., 1999). What makes corn silage compositionally confusing is that starch content is increasing at the same time stover digestibility is declining. What this provides is a relatively wide window in which energy content of the entire silage mass is relatively stable. However, what is dramatically changing is the source of the energy content. At early stages (¼ milk line) considerable energy is coming from immature, highly digestible stover. At later stages of maturity (¾ milk line) more of the energy is coming from the starch pool. This is why a composite net energy estimate on corn silage is difficult to use when formulating or troubleshooting corn silage-based rations.

What is more meaningful is quantifying the amount and digestion rate of the fiber and starch pools that together comprise the energy in corn silage. The recent availability of routine NDF digestibility analysis among nutritionists demonstrates the importance of cutting-edge laboratory analyses in helping dairy producers better characterize and manage corn silage variability (Hoffman, 2004). While this is certainly a positive step forward, nutritionists still lack needed information on digestion lag, starch digestibility and the fate of corn silage starch that may flow to the intestines. To help meet some of these analytical needs, Pioneer developed the Tripartite Method of forage analysis (patent applied for) to quantify the site, rate and extent of fiber and starch digestion for both hybrid advancement and to help dairy nutritionists capture maximum nutritional value from corn silage (Sapienza, 2002).

Take Home: Corn Silage Fiber Digestibility

Despite all the media and marketing hype, there are minimal "genetic" differences (2-3 percentage points) between commercial (non-BMR) hybrids for fiber digestibility. The large variation in fiber digestibility observed by nutritionists is more a function of planting population, growing environment, harvest maturity, and fermentation efficiency. Growers should consider fiber digestibility when selecting hybrids to grow, but its selection pressure should be below that applied to defensive agronomic traits (e.g. corn borer or root worm protection), silage tonnage and starch content, which possess much larger genetic variation.

Growing environment and harvest timing is the biggest influencer of fiber digestibility in corn silage. Stover digestibility declines with advancing maturity. At early corn silage harvest maturities (¼ milk line) considerable energy is coming from immature, highly digestible stover. At later stages, (¾ milk line) more of the total plant energy is coming from the starch pool. Benchmark samples of old-crop against new-crop corn silage. Freeze samples and send both at the same time to a reputable lab with whom you or your nutritionist have had communication about their methods (e.g. incubation times, actual incubations or NIR, the confidence they have in their NIR calibration, do they have a fresh-plant calibration) and equations they use (e.g. NE-L equation like Schwab-Shaver or do they use the 2001 NRC formulas). Not all labs are equally qualified and your ration content and cost is influenced greatly by the numbers they generate.

Genetics and Environment

Corn breeders are keenly interested in the interaction between genetics and environment (GxE). If GxE (in a statistical sense) is significant, then it means hybrids grown in different environments could rank differently for any particular trait. Contrast this to environmental influence on genetics meaning they will rank similar across environments, but the relative magnitude of difference will be smaller or bigger depending upon the particular environment. It could also mean the absolute values will change with no change in the hybrid differences between environments. There is no indication that nutritional characteristics were more susceptible to environmental interactions than grain or whole plant yield (Coors, 1996).

The influence of growing conditions (especially moisture) appears to be a major source of the nutritional variability seen within hybrids across years and locations. Cornell research suggests that cool, dry years are best for corn silage quality and that slight moisture stress might stimulate seed (grain) production (Van Soest, 1996, Van Soest and Hall, 1998). Cool temperature (especially at night) may inhibit secondary cell wall development These studies suggest that accumulated growing degree days after silking may be most important in affecting corn silage nutritive value because of the impact on grain yield.

The specific timing of environmental stress during the development of the corn plant also appears important. Research at the U.S. Dairy Forage Research Center indicates the weather before and after silking may interact to affect final corn silage nutritive value (Mertens, 2002). In a cooperative research study with Pioneer, Mertens analyzed unfermented whole plant corn samples from various genetics grown in multiple locations, with each location geo-referenced to allow for weather station data to be included in the analysis. Early indications are that weather prior to silking, affects corn plant height (and yield) and fiber quality. Weather after silking appears to exert more effect on corn grain yield, neutral detergent solubles:NDF ratio, and total dry matter digestibility (Mertens, 2002). The 2003-growing season in the upper Midwest proved a good example. Adequate moisture through silking resulted in average-to-below-average fiber digestibility and the dry weather from silking to harvest caused reduced kernel starch-fill. The environmental conditions conspired to produce a fair-to-average corn silage crop. High- chopping the 2003 crop might have been a good idea because it would have concentrated the grain and increased fiber digestibility.

Take Home: Genetics and Environment

There is no such thing as an "average growing season"…particularly in the Midwest and East. Plants need to be monitored by a qualified crop consultant during the growing season. At harvest, dairies should delegate someone to be responsible for determining proper harvest timing for each field, monitoring the degree of kernel processing, and observe bunker/pile compaction ability and methods. The quality of the corn silage your cows will rely on all winter, depend on the decisions made during fall harvest. Determining harvest timing using kernel milk line is less reliable as one moves East of the Missouri River. It may be necessary to test for whole plant moistures by chopping plants, shredding in a chipper-shredder and analyzing with a Koster ™ or microwave. Consider rapid nutritional analysis of these fresh-cut plants to determine which fields to chop or chop height.

Agronomic Considerations

As mentioned in the introduction, this paper is orientated to dairy producers rather than corn growers. This is because it is dangerous to offer generic agronomic recommendations at a national conference because of the tremendous influence of local growing conditions. Farming corn silage in Tulare County, California is much different than in Marathon County, Wisconsin. The resultant crop will also be considerably different in terms of grain:forage ratio and exposure to environmental stress. For the sake of brevity, nutritionists should be aware that fertility primarily impacts yield and crude protein of the plant. Variation in planting date, row spacing and plant population can alter yield, starch content, and NDF digestibility (especially in growing zones north of I-80). These agronomic issues should be discussed with university/consulting crop advisors or your seed company agronomist. There are also several excellent reviews that address the agronomics of producing high-quality corn silage (Cox et. al., 2004, Lauer and Cusicangui, 1997; Roth, 2003; Shaver, 2003; Allen et al., 2003).

Take Home: Agronomic Considerations

The best thing a large commercial dairy producer can do is find a good farmer (or relative) and work to develop a strong working relationship with clearly understood goals. Every dairyman serious about growing and feeding corn silage should consider having these texts on the shelf and websites bookmarked on their computer:

- UW Extension Forage Resources: http://www.uwex.edu/ces/crops/uwforage/uwforage.htm
- Purdue KingCorn.org: http://www.agry.purdue.edu/ext/corn/
- UW Corn Agronomy: http://corn.agronomy.wisc.edu/
- ISU Corn Page: http://maize.agron.iastate.edu/corngrows.html.
- Purdue Corn Growth CD set. Available: http://crop.agriculture.purdue.edu/
- A text for the highly analytical, Silage Science and Technology ($180.00) at: http://www.asa-cssa-sssa.org/cgi-bin/Web_store/web_store.cgi?page=monographs.html&cart_id=7589845_24053

Conclusion

Here is a concluding management checklist to help growers and nutritionists manage and reduce corn silage variability:
1. Foster communications between dairy feeding manager, nutritionist, growers, seed rep and chopper operator because the dairy has to live with these decisions for an entire feeding year,
2. Select hybrids with proven (and similar) nutrient profiles backed by adequate yield and nutritional data (e.g. starch content and fiber digestibility),
3. Minimize number of hybrids to improve consistency (without compromising agronomic risk),
4. At harvest, focus on harvest timing, degree of kernel processing, and bunker/pile compaction (especially the tails of piles),
5. Consider segregating silage (by quality and/or milking string), just as you do with lots of hay,
6. Inoculate silage with a research-proven product to improve both feed value and feeding consistency (VFA profile, smell, taste),
7. Consider using UW MILK2000 to rank hybrids and estimate silage NE-L for ration balancing,
8. Monitor kernel processing on the way into storage and quantify with lab test at feed-out; frequently check feed delivery and check TMR for sorting and effective fiber levels.

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