Effects of Genetics and Management on the Yield and Nutritional Variability of Corn Silage

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Introduction

Corn silage is becoming increasingly popular due to the ability of the corn plant to provide high tonnages of digestible and palatable feed that requires harvesting only once a year. The 2002 USDA crop production report indicates that corn silage represents about 9% of the corn acres (7.5M acres out of 79M total corn acres) with the top ten silage producing states being Wisconsin, California, Minnesota, New York, Pennsylvania, Iowa, South Dakota, Nebraska, Colorado, and Kansas. It is interesting that these same states also account for the vast majority of U.S. dairy cows.

Traditional and biotechnology-assisted corn breeding has resulted in tremendous productivity improvements since Henry Wallace sold the first 600 bushels of hybrid seed corn in 1926. Genetic and management improvements in the livestock industry have kept a similar pace. What has **not** been keeping pace with corn and animal productivity is access to routine laboratory analysis to help interface the two disciplines. This is a critical point as dairy producers in certain regions of the U.S. are trending towards increasing the inclusion rate of corn silage in dairy rations to levels exceeding 20 lbs. of corn silage dry matter per cow per day. It is important for nutritionists to understand and manage nutritional variability, particularly when a single feedstuff comprises more and more of the total ration dry matter. The recent availability and use of starch and neutral detergent fiber digestibility (**NDFD**) analysis among nutritionists demonstrates the importance of cutting-edge laboratory analyses in helping cattle feeders and dairy producers better characterize and manage corn silage variability.

This paper provides an overview of the yield and nutritional advances in corn production, discusses key management areas to help identify and reduce corn silage variability, and concludes with a composite, corn silage case study of several dairies in Texas and New Mexico.

Advances in Corn Genetics

Since the 1926 commercialization of hybrid corn (*Zea mays*), steady advances in grain yield per acre have occurred. Former Vice President of Research at Pioneer Hi-Bred, Dr. Don Duvik, has conducted *Pioneer decade (grain) studies* using saved seed representative of the corn genetics of every decade from the 1930's to today. Much of what has contributed to corn yield improvements has been improved stress tolerance, allowing plants to respond better to higher planting populations (Wikner, 1996; Paszkiewicz and Butzen, 2001). Hybrid corn in the 1930's was typically planted at densities of 4-5,000 plants per acre (**PPA**); whereas today, hybrids can routinely withstand the population stress of over 30,000 PPA. Under good growing conditions, staygreen (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 staygreen. This fact, along with depleting agricultural water supplies, is driving seed companies to actively research mechanisms and genes controlling drought tolerance.

Biotechnology has certainly been an important instrument in maintaining the historical legacy of continuous improvement in the agronomics and yield of corn. 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).

Commercialized biotechnology in corn, to date, includes genetically engineered resistance to certain herbicide families 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. The entire seed industry has partnered with university researchers to compile an impressive research dossier as to the safety and nutritional equivalency of genetically modified corn (see Appendix A and B for listing of published dairy references). Some of the advantages of ECB/SWCB-resistant corn include improved plant health resulting in improved yields and nutritional quality. A June, 2003 study of Bt corn by the National Center for Food and Agricultural Policy (NCFAP, 2002) showed that Bt corn generated an additional $125 million for U.S. farmers in 2001 by increasing yields and reducing pesticide use. Another advantage to livestock feeders is the potential for Bt corn to help reduce field mold growth and toxin production (Munkvold et al., 1999).

Corn Silage Genetics

The corn silage version of *Pioneer decade (grain) studies* has been conducted at the University of Wisconsin (Coors et al., 2001; Lauer et al., 2001). This UW *corn silage era* research 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 in *in vitro* digestibility.

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). Undersander et al. (1977) and Twumasi-Afriyre and Hunter (1982) reported that improvements in stalk lodging were associated with relatively small changes in lignin concentrations. Marten and Geadelmann (Albrecht et al., 1986) from 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 (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 industry 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 US 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).

Selecting a Silage Hybrid

Differences do exist among commercial corn hybrids for digestibility, NDF digestibility, and protein. Many seed companies are developing forage quality profiles of their corn hybrids. Silage hybrids should have high forage yields, high digestibility, low fiber levels, and highly digestible stover. The best silage hybrids have high grain yields, because grain is so highly digestible and accounts for upwards of 65% of the energy in corn silage. However, ranking for top yielding hybrids used for silage may vary based on differences in fiber digestibility and grain to stover ratio (Coors, 1996).

Findings of the UW Corn Silage Consortium have led Dr. Joe Lauer, Wisconsin state extension corn agronomist, to suggest to dairy producers

(Lauer, 1997) 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. This group of agronomically adapted hybrids should next be evaluated for silage yield performance. Many studies have shown that grain yield is a good general indicator of whole-plant yield; that is 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 data available on these hybrids. In simpler terms, a good silage hybrid has to first be a good grain hybrid, but not all grain hybrids make good silage hybrids. According to Lauer, the final consideration for hybrid evaluation should be quality.

Silage Data Needs

It is not valid to primarily attribute hybrid genetics to the cause of nutritional differences when comparing hybrids grown on different farms. This is why seed companies and university plots only compare hybrids grown in the same location (side-by-side). One can draw an analogy to proving bulls. The AI industry uses statistical procedures to factor out genetics (of the dam) and environment (housing, hygiene, 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 daughters 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 of growing environment suitability limitations. Therefore, seed companies have to compare hybrids grown next to each other, across multiple plots (so they all receive the same environment). 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 NDF digestibility). Significant genetic-by-environment (**GxE**) interactions can occur if a silage trial contains hybrids spanning a large range of maturity and 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.

Grain (Starch) Content of Corn Silage

As corn genetics improve, and considering that 91% of corn is grown for grain yield, it is not surprising that silages may be increasing in quantity of starch. 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. 18 inches vs. traditional 6-8 inches), it is not uncommon to find starch in the low-to-mid 40% range.

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. This is a more analytical approach to quantifying nutritional components in ration balancing rather than relying on measuring fiber content that is simply diluted as grain (starch) content of silage increases. Nutritionist can then use tools such as the University of Wisconsin MILK2000 spreadsheet 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 1-5 mm depending upon kernel maturity) and objective quantification of the extent of subsequent kernel damage. Mertens and Ferreira (2001) conducted research into a laboratory method to quantify the degree of kernel damage and suggested equations to predict starch digestibility (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. (Taysom, 2003).

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 (Correa et al., 2002) and supports that silage, harvested wetter than about 35% DM, exhibits very little differences in starch digestibility attributable to kernel texture or vitreousness. Specifically, that ruminal starch availability showed a decline only **after** the blacklayer stage of maturity.

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). Coors (1996) concluded from the four-year UW corn silage consortium that while evaluating forage potential of hybrids might require separate testing programs, grain yield need **not** be sacrificed when developing hybrids with high dry matter yields and improved nutritive value.

Reviewing nutritional data from hybrids entered in university silage evaluation programs reinforces 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 (Lauer et al., 2003) containing a spectrum of conventional, leafy, Bt, herbicide-resistant, and brown midrib (**bmr**) hybrids. 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 (72% NDFD, %NDF, 48 hr).

This notion that corn silage can have **too** much grain seems to also conflict with commonly held guidelines for the amount of starch dairy cows can safely handle in the ration. To put this in perspective, one can consider an **extreme** example of 70 lbs. of 30% DM corn silage containing 50% starch (highly unlikely, even with high-chop corn) consumed per cow per day. This would only contribute 10.5 lbs. of daily starch intake. If cows are consuming only 50 lbs of dry matter intake, the total ration starch level from the corn silage in this extreme 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 without having to sacrifice reduced fiber digestibility.

Corn Silage Fiber Digestibility

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 NDFD was associated with .37 lb increase in dry matter intake. However, the digestibility of the corn silage fiber provided in the ration is a function of not only genetics but also planting population, growing environment, harvest maturity, and fermentation quality. This causes a tremendous amount of variation in silage and has to be dealt with by the grower and nutritionist as best they can.

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 midrib 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). However, because of inherent problems handling agronomic stress, yield is generally compromised (10-30% or more) when compared, not to their base genetics, but against other elite silage hybrids. These 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. Increased agronomic risk and yield drag has typically relegated these products to limited acres for dedicated use in rations desiring high intakes such as transition cow or fresh-pen rations. Some producers have opted to high-chop (e.g. 18 inches vs. traditional 6-8 inches) to achieve NDF digestibility values approximating bmr genetics (Lauer, 1998). Unpublished research by Pioneer indicates about a 1-1.5 ton (30% DM) yield drag for every six-inch increase in plant height.

Lundvall et al.'s (1994) evaluation of 45 elite inbred lines (including three bmr mutants) found normal 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. There is also debate over the role of lignin in stover digestibility. Research from Michigan shows lignification of NDF highly related to IVNDFD across corn plant parts and researchers suggested 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, Buxton (1996) reports that the relationship between fiber digestibility and lignin concentration is often low when genetic materials of a common maturity are compared. They also reported that lignin as a percentage of NDF in multiple regression equations with NDF, only explained an additional 13-17% of the variation in stem digestibility. The availability of routine NDF digestibility testing at many reputable commercial laboratories may make the question of lignin moot to nutritionists when their real interest is determining 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 are also 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. Lundvall et al.'s (1994) inbred research found relatively large variation (8.3 percentage units) in digestibility of the stover and suggested that due to this range and the high heritability of forage quality traits, that silage breeders should evaluate inbreds for quality characteristics and emphasize grain yield, maturity, and lodging resistance in **hybrid** testing. This was suggested because their study showed only a 4.5 percentage unit range in stover digestibility in the **hybrids** they tested. More recent research (Coors, 1996) 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.

A narrow range in stover digestibility is typically observed among (non-bmr) commercial hybrids (when comparisons are among hybrids grown in the same plot; Lauer et al., 2003) and not the huge range suggested by some seed company advertising. The narrow range in NDFD further supports the hybrid selection priority recommendations that came out of the UW Corn Silage Consortium (Lauer, 1997). 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.

Genetics and Environment

Corn breeders are very interested in the interaction between 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 similarly 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 either grain or whole plant yield (Coors, 1996).

The influence of growing conditions (especially moisture) seems a major source of the nutritional variability seen within hybrids across years and locations. Van Soest (1996) and Van Soest and Hall (1998) suggest that cool, dry years are best for corn silage quality and that slight moisture stress might stimulate seed (grain) production. 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 appears important. Research by Mertens (2002) indicates the weather before and after silking may interact to affect final corn silage nutritive value. 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).

Agronomic Considerations

It is dangerous to offer generic agronomic recommendations at national conferences because of the tremendous influence of local growing conditions. For the sake of brevity, nutritionists should be aware that fertility primarily impacts yield and crude protein of the plant. Variation in planting row spacing and populations can alter yield, starch content, and NDF digestibility. 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 (Lauer and Cusicangui, 1997; Roth, 2003; Shaver, 2003; Allen et al., 2003).

Corn Silage Composite Case Study

Several dairies in West Texas and Eastern New Mexico experienced challenges feeding the 2002 corn silage crop. Several nutritionists, veterinarians, and company representatives worked together to identify the problems and work towards a solution. As background, renewed agronomic attention was focused on the 2002 corn crop by many of these growers resulting in excellent quality silage containing starch in the mid-30% range along with 48 hour NDFD in the high-60% to low-70% range. The crop was also harvested 4-5 percentage points wetter than normal. The dairies had also intended on increasing corn silage inclusion rates to the 40-45 lbs. as fed level, up from the more traditional level of 20-30 lbs. as fed, to offset the higher price of alfalfa hay and in response to lower milk prices.

Herds that had difficulties typically observed loose manure, **elevated** fat test, and **very high** dry matter intakes whenever corn silage inclusion rates exceeded about 30 lbs. as fed per cow per day in the ration. Subclinical ruminal acidosis (**SARA**) was suspected, but high intakes and elevated fat test seemed to run counter to how many nutritionists viewed symptoms associated with classical SARA (thinking both intakes and fat test would be depressed with rumen acidosis).

Several other herds, feeding similar testing corn silage, were **not** experiencing the same difficulties. Upon analyzing their rations, two key differences emerged. These herds were feeding much lower RFV, flatter-stemmed alfalfa and/or coarser-cut wheat silage **or** were feeding more mature corn silage with a lower NDF digestibility. Both of these differences likely contributed to more physically effective NDF (**peNDF**) in their rations, helping form a better rumen mat for improved cud chewing and buffering of the rumen environment.

After consulting with several SARA specialists, notably Dr. Gary Oetzel, from the University of Wisconsin College of Veterinary Medicine, it became apparent that current SARA research findings did indeed align with the symptoms of these herds experiencing problems. Current thinking is that high intakes are **normal** for acidosis herds and that low peNDF rations allow cows to eat more because of poor rumen mat development and increased rates of fiber passage. Intake depression, following acidosis, is very real for **individual** cows; but is difficult to pick up within **pens** because it is a sporadic, individual cow response and not all cows go up (or down) in intake on the same day. Current thinking is also that milk fat depression is an inconsistent symptom of SARA. Butterfat depression is probably more related to unsaturated fatty acids being converted to trans fatty acids which depress milk fat production rather than any reduction in acetate production from a rumen experiencing low pH.

Some of the herds experiencing problems tried topdressing coarser hay but cows tended to sort out this fibrous feed preferring the 190-220 RFV alfalfa and high-energy corn silage. There were also feed delivery issues on some dairies where the coarser, 120 RFV hay was over-mixed in the TMR so by the time it arrived in the feed bunk, it had lost much of it peNDF effectiveness.

The final diagnosis was SARA, likely a direct result of unusually high quality corn silage, compounded by the ration inclusion of 190-220 RFV alfalfa, which produced a rumen mat that digested/degraded much more quickly than desirable. The highly digestible forages caused elevated intakes and caused less than ideal rumen mat formation reducing cud-chewing stimulation. Rapid rumen feed turnover resulted in more *undigested* feed escaping to the hind gut (hence fiber and bubbles often found in the loose manure).

Here are the steps we have been suggesting to dairy producers to monitor the nutritional variation in their forages:

1) Start testing corn silage for starch & NDFD and alfalfa for NDFD;
2) Consider using NE-L estimates from MILK2000 which incorporates starch, NDFD and accounts for corn silage kernel processing;
3) Adjust supplemental concentrate levels and degree of ruminal availability based on forage NE-L's; and
4) Pay attention to ration peNDF by monitoring both delivered TMR and ration refusals with the Penn State Separator.

Solutions these Texas and New Mexico herds have used include:

1) Complimenting higher corn silage feeding rates with the inclusion of hay with no greater than160-180 RFV (although relative feed quality (**RFQ**) would be a better benchmark);
2) Limiting highly digestible corn silage to less than 30 lbs. as fed, in the ration if it is being coupled with very high RFQ alfalfa;
3) Including sorghum silage and/or wheat silage as other forage sources to maintain a proper rumen mat;
4) Using *slow release* grain (e.g. ground corn or steam flaked milo, no steam flaked corn), or replacing grain with byproducts (such as beet or citrus pulp); and
5) Increasing levels of soluble protein to compliment increased rumen energy availability.

Conclusions

Here is a concluding management checklist to help growers and nutritionists manage and reduce corn silage variability:

1) Foster communications between dairy producer, nutritionist, growers, and custom choppers 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;
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 livestock group);
6) Inoculate silage with a research-proven product to improve both feed value and consistency (VFA profile, smell, taste);
7) Analyze silage for starch and NDFD, and use the Schwab-Shaver NE-L estimate from MILK2000;
8) Monitor kernel processing on the way into the pit and quantify with lab test during feed-out; and
9) Frequently monitor feed delivery and check TMR for sorting and effective fiber levels.

Note: The Microsoft ® PowerPoint ® presentation of this paper may be requested by contacting authors at bill.mahanna@pioneer.com or david.a.peterson@pioneer.com.

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