Corn Silage, Managing the Manageable

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Abstract

The intent of this paper is to leverage over 60 years of combined corn silage experience by the two authors to review corn silage production factors which are under the control of the silage producer impacting yield, starch content, starch digestibility and fiber digestibility. Production practices where the producer has control include hybrid selection, agronomic practices (e.g. planting date, population, fertility, irrigation, fungicide use), harvest timing, chop height, degree of kernel processing, storage/feed-out management and nutritional analysis. Factors where the silage producer lack control will also be discussed and include growing environment (e.g. rainfall, heat units), disease/pest pressure and within field variability.

Introduction

Why should we carefully review management tools when producing corn silage? The management considerations discussed in this paper have significant impact on feed costs and animal performance. In a paper presented at this conference, Kezar (2013) referenced that improvements in silage management could improve profits by as much as $30.00 per ton. While many silage producers have improved management practices, most silage growers could likely implement additional management protocols to further increase profits.

Over six million acres of corn silage are grown in the United States each year. Corn silage has been called the “king of forages” even though there are more than 16 million acres of the alfalfa (queen of forages) produced annually in the United States. The acres of alfalfa harvested as green chop or fermented haylage are about 4.5 million acres. This makes corn silage the forage with the most acres and tons harvested and stored as a fermented livestock feed.

The average yield for corn silage in the United States is about 20 tons per acre at 30 percent dry matter. The northwest states of Washington, Idaho and Oregon are all in the top five states for corn silage yield producing closer to 30 tons per acre state wide. There are areas in the three northwest states consistency produce 35-45 tons of corn silage per acre. Two factors allowing these higher yields are: 1) irrigated acres, usually center pivot which allow precise feeding of nutrients to the crop during the growing season and 2) high intensity sunlight with few cloudy days during the growing season. These two factors allow higher plant density to be utilized

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allowing silage hybrids to grow taller and produce more grain and stover yields compared to growing the same hybrids in other areas of the country.

There are several reasons why corn silage is the preferred fermented forage for many producers including: 1) high yields compared to other forage options, 2) palatability, 3) starch content driving high energy, 4) adequate sugar content to ensure good fermentation, 5) consistent fiber digestibility, 6) harvested once without requiring wilting and 7) allows for high manure applications. A recent article in the Journal of Dairy Science (Martin et. al., 2017) reported between the years 1982-2017 alfalfa hay, hay crop silage and green chop decreased by 32% while corn silage acres remained unchanged yet production increased by 33%.

There has been a trend in recent years for dairy producers under certain cropping programs, to feed higher amounts of corn silage in their diets. In most cases, this is done to lower feed costs and is made possible because silage breeders have improved both yield and energy density.

Silage Hybrid Selection

At the time the two authors of this paper began their careers, little research had been conducted to explore the question if all hybrids were equal in terms of nutrient quality or "bite for bite value. Early work by Pioneer, in conjunction with the University of Idaho, published research (Hunt et al., 1992) showing significant differences did exist between six hybrids grown in Idaho and California and harvested at three maturity stages. Further work at the University of Idaho (Hunt et al., 1993) showing significant differences in animal growth performance between two commercially available hybrids commonly used in the Northwest at that time.

Important genetic traits, which deserve selection consideration, include agronomic traits, which confer stability of dry matter and energy yield. The primary agronomic traits would be heat units to silking and maturity, stress emergence, drought tolerance and disease/pest resistance. Some of these traits are delivered by genetic modifications and some by natural genetic adaptability/resistance.

Once proper maturity and agronomic traits are decided, the next trait which should be considered, is dry matter (DM) yield. In silage, this is primarily determined by the amount of starch and height of the plant (biomass). Starch content is highly correlated with DM yield typically contributing 45-50% of silage dry matter yield. The kernels in corn silage, because of starch and oil content, are responsible for 60-70% of the plants energy contribution followed by 25% from cell walls (NDF) and 10% from cell contents.

A trait of minimal importance during hybrid selection is fiber digestibility. This is because the growing environment (e.g. amount of moisture the plant receives during vegetative growth stages) is the primary driver of fiber digestibility. Meta-studies have shown that growing environment is three-times more influential on fiber digestibility than hybrid genetics (Owens, 2015). While fiber digestibility is highly heritable, variation among high yielding silage genetics is minimal. Despite years of industry and academic attempts to improve fiber digestibility, limited success has been achieved. The more recent exception to this has been the commercialization of hybrids containing the brown midrib (BMR) mutant (non-GMO) gene which produces higher fiber digestibility corn plants due to reduced lignin content in the stalk and leaves.

Silage Yield

Concurrent with continuous 1-2 bushel/acre/year yield increase in North American corn yield is the parallel tonnage increases in silage yield. This is not surprising given the relationship between starch content and silage yield. Much of the increase in grain and silage yield in the last 15 years can be attributed to plant breeding efforts producing hybrids which tolerate the stress of high plant populations. In the Northwest, plant populations in the early 1980s were about 24,000 plants per acre. Today, most silage growers are successfully planting and harvesting high quality corn silage at plant populations of greater than 40,000 plants per acre.

A summary of University of Wisconsin silage hybrid plot results from 1995-2007 showed that the top three drivers of silage DM yield were: 1) kernel maturity at harvest, 2) hybrid genetics and 3) planting date (Lauer, 2014).

Starch Content

If you ask animal nutritionists the amount of starch they prefer in corn silage, they almost always say, "as much as I can get". If pressed for a more precise answer, it usually falls closer to 30% or higher on a dry matter basis. Corn kernels are about 70% starch so grain content in silage producing 30% starch would be 42% on a dry matter basis (30 divided by 0.70). Corn plants producing 35% starch would contain 50% grain on a dry basis (50 X 0.70).

Kernel maturity at the time corn silage is harvested is a significant driver of silage DM yields. Harvesting when kernels are immature (e.g. 1/3rd milk/starch line) will result in lower DM yield compared to harvesting at later kernel maturities (e.g. ¾ milk/starch line). Research conducted by DuPont Pioneer in conjunction with the University of Illinois reported kernels could increase in starch content by over 25% from ½ milk line to black layer maturity in the kernels (Walker et al., 2010). Kezar (1989) reported starch increase of 22% between 1/3 and 2/3 milk line. Delaying harvest to allow kernels to more fully mature demands a plant, which maintains good late-season plant health. This is a constant goal of all corn breeders and is aided by fungicide use in those geographies prone to foliar diseases, (Mahanna and Thomas, 2012).

Corn silage DM content of 30-32% is often referenced as being the goal for silage stored in bunkers or drive-over piles. This traditional DM recommendation comes from two perspectives: 1) ensuring enough moisture for adequate silage compaction and 2) concerns that delaying harvest will result in significant reductions in plant fiber digestibility. However, technologies have advanced in both silage-making and plant genetics allowing for targeting ¾ milk line (approximately 36-38% whole plant DM) to capture more starch. A DuPont Pioneer meta-analysis of all published corn silage literature in the Journal of Animal Science and the Journal of Dairy Science (Owens, 2015) found that in healthy plants, fiber digestibility declined only minimally (2-

3% points) from 1/3 milk line (~30-32% DM) to ¾ milk line (36-38% DM). Corn is a "modified grass", but generations of corn breeding efforts for improved late-season plant health has allowed corn plants to retain high fiber digestibility, even in later maturities, while the kernel is still depositing valuable starch.

Fiber Digestibility

Fiber digestibility is not recommended as an important silage hybrid selection trait. Recent research suggests that growing environment the plant endures during the vegetative growth period is the primary determinant of fiber digestibility given that by tassel stage, plant stover growth has terminated. Silage plots by the University of Michigan containing the same hybrids grown in a normal precipitation year (2007) and subsequently in a drought year (2006) showed expected lower starch levels in the drought year but an average 6.5 percentage point increase in 48-hour neutral detergent fiber digestibility (NDFD).

Under wetter than normal growing conditions during vegetative growth stages, plants have longer internodes and grow taller. Differences in lignin content are difficult to document but fiber digestibility as influenced by lignin cross-linkages to hemicellulose, is typically reduced in these plants. This may be why corn silage grown under irrigation is typically lower in fiber digestibility than the same hybrids grown in dry-land conditions.

In drier than normal vegetative growth environments, internode length is shorter, reducing yields, yet plants tend to have higher fiber digestibility (Van Soest, 1996). While total DM yield may be lower in these condition, being a shorter plant, starch is further concentrated. Research at Cornell University suggests the moisture the plant receives is seven-time more influential on fiber digestibility than the heat units the plant receives (VanAmburgh, 2015). The growing environment post-tassel appears to have minimal effect of fiber digestibility, but does exert a significant influence on ear development and silage starch content. It should be noted that unlike starch digestibility, fiber digestibility does not change during fermented storage so the fiber digestibility at harvest will be the fiber digestibility for the entire feed-out period.

While there is an abundance of knowledge about how to irrigate corn for grain yield, there is a dearth of information about how to irrigate the corn plant for silage production. Granted, starch will drive yield and overall energy density, but what are of interest are vegetative stage irrigation regimes that might manipulate fiber digestibility. Agronomists are wary of reducing irrigation schedules with pivot irrigation given concerns about not being able to keep up with plant evapotranspiration needs. Producers using flood irrigation may be in a better situation to experiment with reducing irrigation during vegetative stages to increase fiber digestibility without reducing plant growth. These growers should then fully irrigate as the plant enters the reproductive stage to ensure high starch content. This is an area in need of further research.

Another issue related to growing environment is within field variability. Corn silage fields do not possess the same soil profile, water-holding capacity or fertility. There is unpublished data by DuPont Pioneer to suggest within field variability in fiber digestibility and starch content may be greater than the differences between hybrids. One of the ways for silage feeders to manage this variability is to "face" the entire bunker or pile and in this way, average out the variation that might exist in any one area of the bunker/pile.

While growers have limited control over growing environment, they do have control over chop height as a method to manipulate fiber digestibility. A review of eleven published studies on high-chopping corn silage by researchers at Pennsylvania State University (Wu, 2005) report increasing chop height from 7 inches to 20 inches increased fiber digestibility by 6.7% and concentrated starch by 6%. Research by Pioneer and the University of Idaho demonstrated all hybrids do not respond to high chopping in the same manner. There appears to be a strong genetic by environment (G x E) interaction with high chopping. To predict what effect high-chopping might have on increasing fiber digestibility, it is necessary to chop plants at different heights and analyze to see if increasing chop height is worth the loss in stover and effective fiber. Unpublished research by Pioneer indicates for every 4-6 inches of increased chop height, the average hybrid will be reduced in yield about 1 ton (30% DM) per acre.

One of the newest laboratory analytical measurements relating to forage fiber is undigested NDF (uNDF). The research is clear that NDF does not degrade in the rumen at a constant rate, but rather as three pools: fast, slow, and undigested NDF. Large slow and uNDF pools in the forage and diet cause greater rumination, slower eating speeds but problematically, lower intake potential due to increased rumen fill. One of the advantages of corn silage as the primary forage ingredient is that it typically has the lowest uNDF of all forages and it is further diluted in the diet in corn silages possessing high starch content. Consulting nutritionists are starting to observe depressed DM intake and lower milk production when total $uNDF_{240}$ intake/cow/day for forages (over 4mm in length) in the entire diet exceeds about 5.0-5.5 lbs (or about 0.35-0.40% of body weight). uNDF is only appropriate for cows where DM intake is limited by rumen fill, which is typical of intakes during peak milk production. Exceeding these amounts may lower peak production, especially if cow persistency is high.

A discussion about fiber digestibility would be remiss without delving into the role of BMR hybrids. The main nutritional advantage of BMR silage is higher fiber digestibility due to less lignin, which interferes with rumen bacteria degradation of cell walls. Higher fiber digestibility impacts: 1) the amount of forage in the diet (typically more forage equates to a cheaper ration), 2) energy obtained from the corn silage and 3) amount of forage cows can consume per day. BMR fiber appears to be more fragile and exits the rumen faster than fiber from non-BMR hybrids. While DM yields of BMR hybrids are behind non-BMR silage hybrids by 5-10%, many silage growers and their nutritionists are adopting agronomically improved BMR hybrids. They seem willing to sacrifice yield to obtain higher fiber digestibility and drive higher dry matter intake among transition and high production cows. This is not that different from alfalfa growers harvesting at late-bud stage rather than full-flower and sacrificing alfalfa yield to obtain forage with higher fiber digestibility and intake potential.

Silage producers who are considering BMR hybrids need to have realistic expectations including: 1) potential for more agronomic risk, standability, 2) reduced yields of 5-10% depending upon growing conditions, 3) extra inventory needed due to reduced yields and higher feed intake of BMR silage, and 4) possible need to segregate this silage given the biggest benefit will be in diets fed to transition and early-lactation cows. It should also be noted that high-chopping, while increasing fiber digestibility on lab reports, will not drive DM intakes as much as the fragile fiber found in BMR hybrids.

Starch Digestibility

It is commonly understood today that starch digestibility in corn silage with relatively immature kernels (pre-black layer) is a moving target. Corn silage ruminal starch digestibility of new-crop silage is about 70% and drifts upwards (about 2% units/month) for about 6 months before plateauing (Mahanna, 2011). Florida and Brazilian researchers (Junges, et al., 2017) recently reported that silage bacterial activity, not acid load, appears to be cause of solubilizing of the proteinaceous (zein) matrix surrounding corn starch granules resulting in increased ruminal starch digestion over time in fermented storage.

The greatest silage improvement tool to evolve during in the careers of the two authors of this paper was the development and adaption of on-chopper kernel processors, which proved to be a significant tool to improve starch digestibility. One early study comparing two different hybrids, (Andrae, et al., 2001) showed kernel processing increased in situ 24-hour starch digestion from 73.4 % to 85.8 %. Today, very little corn silage is harvested in the United States which has not been kernel processed at the time of harvest. The main factors influencing kernel damage at the chopper are: 1) chop length (shorter chop length typically results in better kernel processing if effective fiber from corn silage is not an issue), 2) synchronized timing between header and feed rolls, 3) roller mill wear, 4) roller mill gap setting (typically 1-3mm), and 4) roller mill differential speed (many at 50% or greater).

Many laboratories offer kernel-processing scores, which are helpful to nutritionists balancing diets. There is, however, a need for protocols to assure corn silage is being evaluated for processing at the time it is being harvested. Pioneer developed a field test employing a 32-oz (1 liter) cup where the goal is to have less than two, whole or half, kernels in that volume of silage. Fecal starch analysis can be a good post-harvest indicator of degree of kernel damage. In a 2015 Pioneer field study of the high-production strings in 32 Wisconsin dairies (Powel-Smith et al., 2015), only two of the dairies showed more than the goal of <3% fecal starch and those two dairies had poor corn silage processing scores.

There have been discussions about the value of soft-floury (low vitreous, low prolamin) endosperm in corn silage kernels. There does not seem to be significant variation in amount of hard, vitreous starch or starch digestibility at the immature kernel maturity (pre-black layer) at normal corn silage harvest. DuPont Pioneer field studies from side x side trials (in the same field receiving the same environment) show no significant difference in 7-hour ruminal starch digestibility between advertised “floury-kernel” and normal hybrids at silage (or high-moisture corn) kernel maturities. Ohio State University researchers concluded vitreousness (hard starch) of corn grain in corn silage is more digestible in contrast to vitreousness of dry corn grain where it should be ground more finely, (Firkins, 2006). This is consistent with research from France showing the negative effects of flint corn (very high vitreousness) on total tract starch digestion could be eliminated by grinding dry corn to 550 microns (Ramos et al., 2009).

Harvest and Storage

We cannot have any discussion about corn silage quality and potential profits, without covering management objectives once the corn plant is ready to be harvested and ensiled. In the paper presented at this conference five years ago, Kezar (2013), discussed the economic significance of reducing silage losses. It must be understood that the losses in silage dry matter during fermentation, storage and re-exposure to oxygen at feed-out are not a straight percentage of the total biomass. Aerobic losses associated with initial respiration and again when silage is exposed to oxygen at feed-out, are from oxidation of highly digestible soluble carbohydrates, primarily sugars, yielding carbon dioxide, heat and water. The result is the loss of highly digestible nutrients without gaining anything of value in return. A one-percentage fermentation loss (ex: 18% to 17%) is as valuable as increasing corn silage starch by one percentage (ex: 31% to 32%) (Kezar, 2013). This paper will not discuss specific ensiling management, (as the Kezar, 2013 paper did so) but silage growers should not discount the importance of reducing dry matter loss by focusing on: 1) correct moisture content of the corn silage at harvest (63-68%), 2) adequate compaction density (>16 lbs/ft^3) to reduce porosity, 3) proper covering, including use of oxygen-barrier film), 4) proper face management of silage as it is being removed from the storage unit. 5) use of an effective combination inoculant, containing *Lactobacillus buchneri* strains, to inhibit yeast growth which initiates the heating process in silage during re-exposure to oxygen.

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