SILAGE FOR BEEF CATTLE
2018 CONFERENCE

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SILAGE FOR BEEF CATTLE
2018 CONFERENCE AGENDA

8:30 A.M. — **WELCOME**

8:45 – 9:15 A.M. — **KEY STEPS TO IMPROVE NUTRITIVE VALUE OF CORN SILAGE**
Dr. Luiz Ferraretto,
Assistant Professor,
University of Florida

9:15 – 9:45 A.M. — **BEEF UP YOUR SILAGE MANAGEMENT FOR MINIMAL SHRINK**
Dr. Renato Schmidt,
Technical Services – Forage,
Lallemand Animal Nutrition

9:45 – 10:15 A.M. — **GARBAGE IN, GARBAGE OUT: IMPACTS OF SILAGE MISMANAGEMENT**
Dr. Andy Skidmore,
Technical Services – Ruminant,
Lallemand Animal Nutrition

10:15 – 10:30 A.M. — **BREAK**

10:30 – 11 A.M. — **THE VALUE OF SILAGE IN BACKGROUNDING RATIONS**
Dr. Jason Warner, Nutritionist,
Great Plains Livestock Consulting, Inc.

11 – 11:30 A.M. — **CONSIDERATIONS FOR USING SILAGE, EARLAGE, & HMC IN FINISHING CATTLE**
Dr. Allen Stateler , Nutritionist,
Nutrition Services Associates

11:30– 12:15 P.M. — **PANEL DISCUSSION ON SILAGE EXPERIENCES:**
Dr. Jason Warner, **Dr. Allen Stateler**,
Mark Blackford (Craig Cattle Co.)
and **John Schroeder** (Darr Feedyard)

12:15 – 1:15 P.M. — **LUNCH**

1:15 – 1:45 P.M. — **SILAGE GROWING PROGRAMS AND IMPORTANCE OF PROTEIN (RUP)**
Dr. Andrea Watson,
Research Assisant Professor,
University of Nebraska – Lincoln

1:45 – 2:15 P.M. — **CHARACTERISTICS OF SILAGE USE IN IOWA FEEDLOTS**
Russ Euken, Beef Specialist
and **Dr. Dan Loy**, Professor,
Iowa State University

2:15 – 3 P.M. — **FEEDING SYSTEMS FOR FINISHING CATTLE EVALUATING INCLUSION, HYBRID AND KERNEL PROCESSING**
Dr. Galen Erickson, Professor,
University of Nebraska – Lincoln

3 – 3:30 P.M. — **ACCURATELY PRICING CORN SILAGE**
Dr. Terry Klopfenstein,
Professor Emeritus and
Henry Hilscher, Graduate Student,
University of Nebraska – Lincoln

4 P.M. — **ADJOURN**

SILAGE FOR BEEF CATTLE
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KEY STEPS TO IMPROVE NUTRITIVE VALUE OF CORN SILAGE

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Dr. Luiz Ferraretto is originally from Brazil where he earned his B.S. in Animal Science from São Paulo State University in 2008. Immediately after the completion of his B.S. Degree, Luiz joined the University of Wisconsin-Madison for an internship (2009) followed by a M.S. (2011) and Ph.D. (2015) in dairy science with focus on applied dairy nutrition and forage quality. After the completion of his Ph.D., Luiz joined The William H. Miner Agricultural Research Institute as a Post-doctoral Research Associate. Currently, Luiz is an Assistant Professor of Livestock Nutrition in the Department of Animal Sciences at University of Florida and his research interests are applied dairy cattle nutrition and management with emphasis on starch and fiber utilization by dairy cows, corn silage and high-moisture corn quality and digestibility, the use of alternative by-products as feed ingredients, and supplementation of amino acids and feed additives to lactating cows.

INTRODUCTION

Whole-plant corn silage (**WPCS**) is the predominant forage used in dairy cattle diets worldwide. Furthermore, there is a continuous increase in the interest to include WPCS to beef cattle diets. On average, 116 million tons of fresh corn forage was harvested per year in the United States over the last decade. High quality WPCS contributes greatly to supplying the energy, starch and forage NDF needs of high-producing animals, reducing purchased feed costs from expensive grain and byproduct supplements, and generating revenues for producers throughout the world. The purpose of this paper is to review selected strategies that may enhance the nutritive value of WPCS.

KERNEL PROCESSING AND THEORETICAL LENGTH OF CUT

The energy value of WPCS contributed by starch is approximately 50% (calculated from NRC Dairy, 2001). An increase in starch digestion may lead to better nutrient utilization and decreased feed costs. However, starch digestibility of WPCS may be affected by several factors. First, corn is a seed and has a hard coat, the pericarp, which surrounds and protects the embryo and the starch endosperm from external threats. If intact, the pericarp is highly resistant to microbial attachment (McAllister et al., 1994); therefore, the breakdown of the pericarp and correspondent exposure of the starch endosperm must be the primary objective at harvest to maximize energy availability.

It is well established that the use of kernel processors enhance kernel breakdown at harvest. Ferraretto and Shaver (2012), from a meta-analysis of WPCS trials with lactating dairy cows, reported greater total tract starch digestibility (**TTSD**) when WPCS was processed using 1 to 3 mm (0.04 to 0.12 inches) roll gap settings compared with 4 to 8 mm (0.16 to 0.31 inches) processed and unprocessed WPCS. This is related to increased surface area for bacterial and enzymatic digestion of finer particles (Huntington, 1997).

Degree of kernel processing in WPCS, however, may be inhibited by other factors. Length of cut settings is one of these factors. Processing increased the diet TTSD when theoretical length of cut (**TLOC**) was set at 0.93 - 2.86 cm (0.37 to 1.13 inches) but not when length of cut was shorter or longer (Ferraretto and Shaver, 2012). This is likely related to greater kernel breakage by cutting knives when using short TLOC settings (Johnson et al., 1999) or inhibition of kernel breakage during passage through the rollers by the stover portion at the longer TLOC. No overall effect of TLOC on TTSD was observed. (Ferraretto and Shaver, 2012) suggesting that the combined effects of TLOC and kernel processing is more important than TLOC alone with regard to TTSD.

Delayed WPCS harvest may increase concentration of starch while reducing concentrations of CP, NDF and ash. Thus, it was suggested as tool to enhance starch and DM yield per acre. However, maturity at harvest may also influence the breakdown of kernels. Kernel vitreous endosperm proportion increases with increased DM content of WPCS (Phillipeau and Michalet-Doureau, 1997) and thereby kernel hardness which in turn causes kernels in very dry WPCS to be less susceptible to breakage during kernel processing at harvest. This explains why processing increased TTSD for diets containing WPCS with 32% to 40% DM at feed-out, but not when WPCS was above 40% DM in the review by Ferraretto and Shaver (2012).

Other factors, such as proper processor maintenance from wear, frequent quality-control monitoring of kernel breakage during harvest and adequate TLOC and roll-gap settings for the chopper and processor used are also crucial for obtaining optimal kernel processing. It is always important to remember that optimal kernel processing requires constant monitoring of silage physical characteristics throughout harvesting.

MATURITY AT HARVEST

Although the breakdown of kernels with a corresponding exposure of starch endosperm for digestion is the primary limiting factor on starch digestibility in WPCS, even the exposed endosperm is not fully digested due to existence of a starch-protein matrix formed by the chemical bonds of zein proteins with starch granules (Kotarski et al., 1992). Reduced TTSD observed in diets containing WPCS above 40% DM in the meta-analysis review by Ferraretto and Shaver (2012) may be related to an increase in the proportion of vitreous endosperm in the kernel associated with greater maturity (Ngonyamo-Majee et al., 2009). Alternatively, a reduction in the extent of fermentation for drier WPCS (Der Bedrosian et al., 2012) may attenuate proteolysis of zein proteins during fermentation (Hoffman et al., 2011).

Likewise, digestibility of NDF in WPCS is limited primarily by the cross-linking of lignin to other fibrous components (Jung et al., 2012). As maturity progresses, lignin content in WPCS increases (Cone and Engels, 1993). Therefore, increased maturity at harvest may limit not only starch, but also NDF digestibility of WPCS. Interestingly, however, Ferraretto and Shaver (2012) reported greater NDF digestibility when WPCS was harvested above 40% DM in a meta- analysis. This was thought to be related to negative effects of greater starch digestibility in the rumen on NDF digestibility (Russell and Wilson, 1996). However, this is in contrast to the commonly reported ruminal in situ NDF digestibility reduction with very dry corn silage (Bal et al., 2000).

CHOP HEIGHT

Another harvesting management option to reduce lignin concentration is chop height. Lignin is an important structure component concentrated in the bottom part of corn plants. With enhanced chop height more lignin is left with the portion that remains in the field, and thus, digestibility of the harvested material is greater. Results from a recent industry-university collaborative study from our group is in Table 1 (Ferraretto et al., 2017). Although our study compared 6 vs. 24 inches, these results are similar to other trials comparing 6 vs. 18 inches of chop height. Briefly, DM yield is reduced as the row-crop head is raised. This is consistent across several studies conducted across the United States. However, decreased DM yields are offset by an increase in the milk per ton estimates at the higher chop height. Greater milk estimate is a response to the greater fiber digestibility and starch concentration of the harvested material. In addition, most studies reported that estimated milk per acre is reduced by only 1 to 3% with high-chop. Also, increased quantities of high-chop silage could be included in the diet, rather than corn grain being added to the diet, providing an economic benefit to implementing increased chop heights. Team discussions among farmers, nutritionists and crop consultants is advised to determine individual farm priorities for maximum yield versus higher quality, prior to the establishment of new chop height guidelines. Those needs may vary in different years depending upon the yield and quality of the crop and existing on farm inventories.

SILAGE FERMENTATION

Experiments evaluating extended WPCS storage length consistently reported a gradual increase in starch digestibility as fermentation progressed. Across these studies, at 30 or 45 days of ensiling, ruminal in vitro starch digestibility (**ivSD**) was increased by 7 percentage units. Interestingly, these studies also showed a gradual increase in ivSD after 30 or 45 days of additional storage (approximately 60 to 90 days of fermentation). Proteolysis, the main mechanism responsible for the disruption of the zein-proteins cross-linked to starch granules, occurs under acidic conditions suggesting that continuous alterations in fermentation profile as storage progressed may directly affect starch digestibility.

Ferraretto et al. (2015) evaluated the interaction between hybrid type and ensiling time on a study where 8 WPCS hybrids (4 BMR and 4 leafy) were ensiled for 0, 30, 120 and 240 d. Fermentation profile, ammonia-N and soluble-CP contents, and ivSD were similar for the 2 hybrid types and there was no hybrid type × time of ensiling interaction detected. Increases in WPCS ammonia-N and soluble-CP contents were accompanied by increases in ivSD in response to increased time of ensiling. The effects of ensiling time and exogenous protease addition on fermentation profile, N fractions and ivSD in WPCS of various hybrids, maturities and chop lengths were evaluated by Ferraretto et al. (2015a). Extended time in storage increased ammonia-N, soluble CP and ivSD in WPCS of various hybrids, maturities and chop lengths. However, contrary to our hypothesis, extended ensiling time did not attenuate the negative effects of kernel vitreousness and maturity at harvest on ivSD. Exogenous protease attenuated but did not overcome negative effects of maturity on WPCS ivSD.

Although allowing an extended ensiling period may be beneficial for increasing starch digestibility, research does not support the same fate for neutral detergent fiber (NDF) digestibility. Overall, data from several sites across the U.S. demonstrate that extended storage does not change or slightly reduces NDF digestibility in corn silage.

In summary, research supports the use of inventory planning so a newly harvested crop would be fed only after four months in storage. Although prolonged storage of corn silage would be a valid management practice, it requires proper silo management during filling, packing and covering to ensure beneficial fermentation patterns.

TABLE 1.

Effect of cutting height on whole-plant corn silage nutrient composition, digestibility and yield[1]

Item	Low	High
Cutting height, inches	6	24
NDF, % of DM	37.7	33.8
Starch, % of DM	37.5	41.7
ivNDFD[2], % of NDF	49.6	52.7
Yield, ton/acre	8.9	8.1
Milk, lb/ton	2224	2378
Milk, lb/acre	24009	23498

[1] Adapted from Ferraretto et al. (2017).
[2] Ruminal in vitro NDF digestibility at 30 h.

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BEEF UP YOUR SILAGE MANAGEMENT FOR MINIMAL SHRINK

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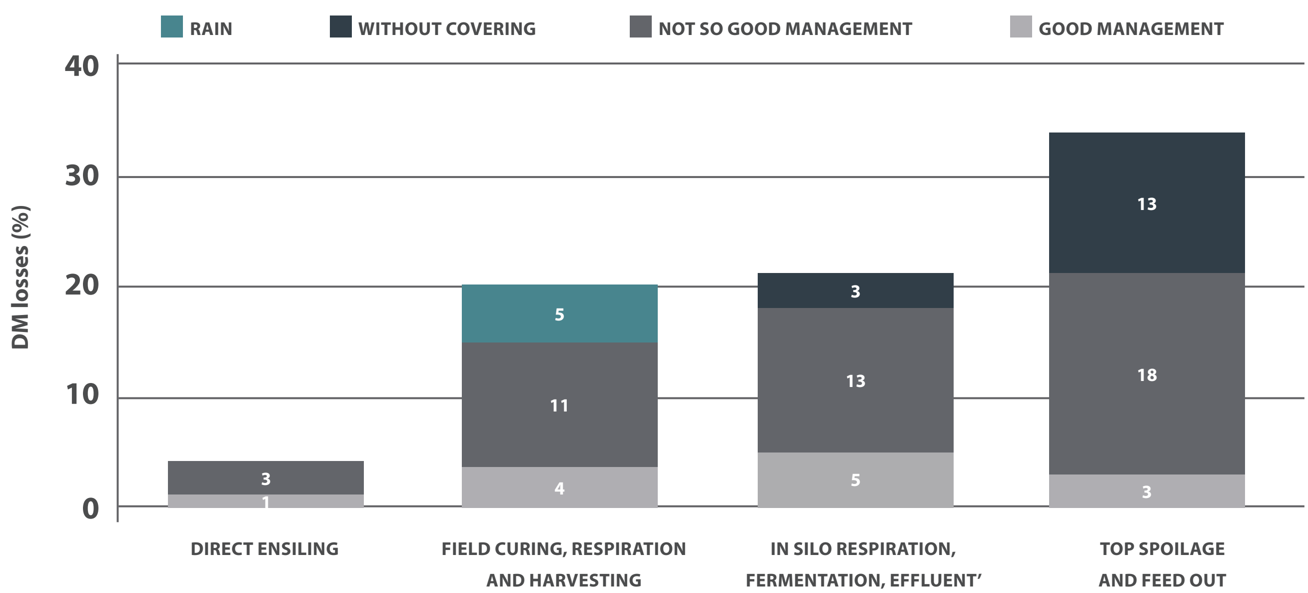
Dr. Renato Schmidt has a dairy/beef cattle farm background and is originally from Brazil, where he obtained a B.Sc. degree in Agronomy and a M.Sc. degree in Animal Sciences. He moved to the US to earn his Ph.D. in Animal Sciences from the University of Delaware with Dr. Limin Kung Jr. He worked on numerous experiments evaluating the effects of different additives on the fermentation of forage crops, and specifically developed molecular techniques to study microorganisms during ensiling. He's authored and co-authored 14 peer-review journal publications and 27 scientific abstracts. He joined Lallemand Animal Nutrition, North America as Forage Products Specialist in February 2008 and has presented technical/ scientific talks in Brazil, Canada, Mexico, Costa Rica, Nicaragua, Czech Republic, England, Scotland and throughout the USA.

INTRODUCTION

Silage can be defined as a product formed when forage with adequate moisture content is stored anaerobically, being at the risk of spoilage by aerobic microorganisms (Woolford, 1984). The inclusion of higher amounts of ensiled feeds (high-moisture corn, corn silage, haylages) in feedlot rations has recently been gaining popularity in the U.S.

There are two ultimate goals of the ensiling process - (1) to retain as much as possible of the original nutrients and dry-matter (DM) through an efficient lactic acid fermentation; and (2) to have a stable product throughout the phases of storage and feed-out. Unfortunately, losses inevitably occur during the ensiling process, field harvest, through plant respiration and microbial fermentation, effluent production and exposure to air during storage and feed-out. Furthermore, the level of management has a major impact on the magnitude of these potential losses, since some are avoidable (Figure 1).

FIGURE 1. Potential losses during the phases of ensiling (Borreani et al., 2018)



LOSSES OCCURRING BEFORE ENSILING

Some forage crops require a period of wilting in order to be ensiled at the correct moisture content. Ensiling wet forages results in seepage losses and the fermentation is more extensive; i.e. the extra moisture allows the microorganisms to remain active for a longer period of time during ensiling which uses nutrients, therefore, the lactic acid bacteria needs to produce more acid to stabilize the forage mass, as it is more "diluted".

A fast wilting in the field is vital for minimizing nutrients and DM losses. Conditioning the forage and spreading the crop are important management tools. Depending on the weather, wide swathing can reduce the field drying time and result in a more homogeneous moisture content of the forage; however, there is a good chance of driving over the swath, leading to leaf losses, reduced regrowth and lowered yield. The length of wilting impacts the final contents of soluble sugars, which will be the substrate for an effective fermentation, with minimal losses. This point is of particular concern when ensiling legumes that normally have high buffering capacity. Recent research showed that mowing in the morning can maximize dry down and avoid sudden weather changes. In contrast, when cutting in the afternoon, the sugar content of the plant is increased due to photosynthetic activity.

OXYGEN – THE WORST ENEMY OF ENSILING

Before the active fermentative phase takes place, oxygen must be excluded from the forage mass. Packing the forage tight is one of the most important (and most overlooked) factors when making good silage.

General guidelines for silages packing densities are at least 15 lb DM/ ft3 or 44 lb fresh matter (FM)/ft3. Silage porosity, which is defined as the volume of gas-filled voids as a fraction of total silage volume, should be less than 0.4 (Holmes and Bolsen, 2009). There are spreadsheets available from the University of Wisconsin Extension website to help calculate the packing weight needed for specific situations (http://www.uwex.edu/ces/crops/uwforage/storage.htm).

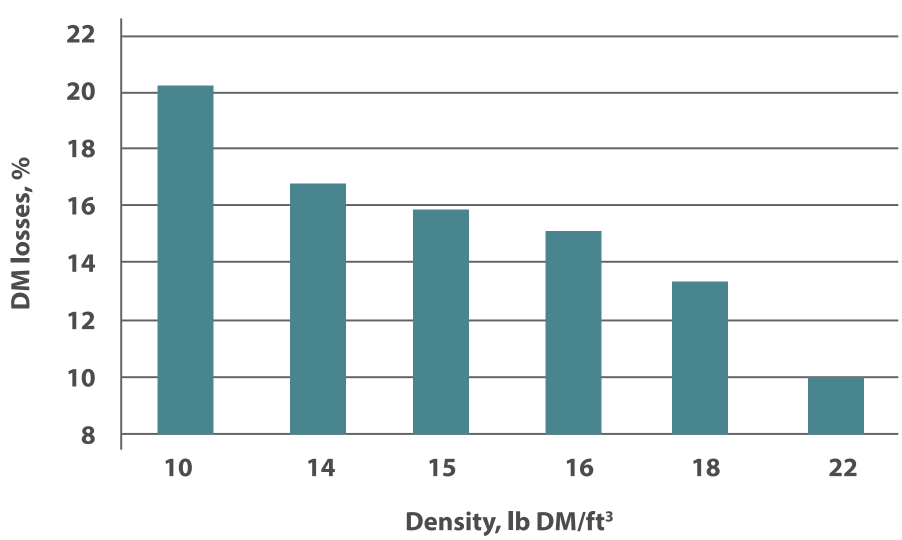
Packing density is affected by DM content, particle size and degree of packing. The degree of packing in turn is affected by the weight of the packing tractor(s), silage height, layer thickness of the forage spread and the packing time.

Ruppel (1992) showed that DM loss is directly related to the DM density of the silage. As we increase DM density of silage, we decrease DM loss in that silage (Figure 2). Noteworthy, densely packed silage also requires less storage space. Going from 13 to 15 lb DM/ft3 in a silo allows to ensile about 15% more forage in the same space.

Forages with high moisture content pack well but, as previously discussed, there is a chance of high losses due to seepage, in addition to an inefficient and/or undesirable fermentation.

FIGURE 2.

The effects of packing density on the DM losses in 25 bunker silos (Ruppel, 1992).



In contrast, dry forages will contain more air trapped and thus will need to be chopped more finely in order to facilitate a more dense packing and improve this situation. However, the short particle size may have negative effects on rumination time and rumen health because of decrease effective fiber in the feed.

To maximize the packing density, it is recommended to spread thin layers (6 inches thick) of fresh forage from each truck load. Slow delivery rate of forage to the silo normally results in thinner layers across the top of the silo, allowing more packing weight per amount of forage.

In field conditions, the "800" rule is a practical and easy tool on the basis that 800 lbs of packing weight is needed for every ton of crop delivered per hour (Ruppel, 1997); for example, for a delivery rate of 150 tons/h, 120,000 lbs of packing weight (tractors) would be required for the packing job.

FERMENTATION PATTERNS

Excess oxygen in the forage mass delays the fermentation. Trapped air allows plant respiration and microbial activity, which results in nutrient and DM losses, and heat production. Specifically, simple sugars are utilized in this process and converted to water and carbon dioxide; this lost carbon, which represents 2 to 4% of DM losses, is one of the main causes of shrink.

When anaerobic conditions are achieved, the actual fermentation starts and the dominant microbial population will dictate the fermentative pathway and subsequently the magnitude of the potential DM losses. In theory, homolactic bacteria produce only lactic acid from glucose and fructose, so no DM losses occur, while heterolactic bacteria produce 1 mol of $CO2$ per mol of glucose, resulting in 24% DM loss (McDonald et al., 1991). However, if microorganisms other than lactic acid bacteria dominate the ensiling process, such as yeasts or clostridia, the DM losses increase to approximately 50%.

Relying solely on the natural population of microorganisms for the fermentation process is a dicey decision. At the very best, the result is normally an inefficient fermentation with a slow rate of pH drop. Therefore, adding an efficient strain of homolactic bacterium (or more than one) is advisable to guarantee an efficient fermentation and save most of DM and nutrients.

STORAGE PHASE

After long hours, often days of packing the forage in the silo, it is imperative to properly cover and seal as soon as possible. If not properly covered, storage losses can be extensive due to air exposure and the effects of the elements. Bolsen et al. (1993) reported extensive DM losses when comparing the effects of covering bunker silos with a polyethylene film to uncovered silos. At the top 10-inch layer, corn silage that was covered only had 22.5% of DM losses whereas the uncovered silage had 80.4% of DM losses.

Horizontal silos have been usually covered with a polyethylene sheeting and weighted down with tires – ideally split tires or tires cut in half, to reduce the weight, the number of tires needed and to limit breeding grounds for mosquitos. A more recent technology is to cover the silo using "oxygen barrier" films, composed of two layers of polyethylene, and a middle layer of polyamide, totaling 0.45 μm in thickness. These type of films are less permeable to oxygen transfusion but require an additional sheet of regular polyethylene film or a tarpaulin to protect against mechanical damage. Another benefit is that oxygen barrier films clings to the surface of the forage, filling in the gaps and reduce the presence of air pockets.

FEED-OUT RATES FROM THE SILO

The feed-out removal rate of silage from the silo is comparable to a race against time, so air cannot penetrate as quick into the silage mass. Fast removal rates lead to reduced aerobic spoilage and low losses. It is recommended to remove 4-6 inches per day of silage from the entire silo face, however, this rate could be lower for stable silages during the winter (Borreani et al., 2018). In contrast, the removal rate should be faster when feeding out dry, unstable silages or that are fed during the hot summer months. As previously discussed, the degree of porosity or density plays a significant role in the rate and extent of air infiltrating the silage mass.

The recent emphasis on using mechanical defacers or rakes has helped to reduce aerobic face losses. Using a bucket to knock down the silage create fractures in the silo face, which allows for a deeper penetration of oxygen, leading to increased yeast activity, heating and greater DM and feed value losses. A defacer or rake minimizes the air penetration, and the face is straight to reduce the chance of creating overhangs that can fall and cause accidents.

The main cause of aerobic deterioration and losses during feed-out are the lactate utilizing yeasts. In the presence of air, they can grow at low pH using lactic acid and the remaining sugars. Once the pH increases due to decreasing content of lactic acid, other opportunistic microbes also become active. Shot-chain acids like propionic, sorbic and acetic have strong anti-fungal properties and have been used to inhibit yeast activity.

Chemical additives based on buffered propionic acids have been utilized although they should be applied at 0.2-0.3% FM for consistent improvements in aerobic stability of corn silage (Kung et al., 2003). A biological alternative is to use a Lactobacillus buchneri based inoculant; this bacterium produces moderate amounts of acetic acid during the storage phase. Applying the recommended dose of 400,000 colony-forming units per gram of forage instead of the standard 100,000 CFU/g for homolactic products results in consistent improvements in aerobic stability. Under farm-scale conditions, Queiroz et al. (2012) reported that the spoilage losses of bagged corn silage during feed-out that were inoculated with L. buchneri 40788 were 43% less than non-inoculated corn silage.

FINAL COMMENTS

Silage losses can easily happen between 15-20% in field conditions. If shrink can be reduce by a 5-point percentile, there would be savings of $2,000.00 USD per 1,000 tons of silage, assuming that the silage is valued at $40.00 USD per ton FM. Replacing 5% DM loss in 1,000 tons of corn silage (DM basis) would require 39.77 tons or 1,657 bu of 86% DM shelled corn, based on the assumed TDN (total digestible nutrient) values of 70 and 88%, respectively. Moreover, silage with high shrink or degree of deterioration not only has less overall tonnage to be fed, but the feed is also of lower nutritional quality.

With the time and money invested in seed genetics, growing and harvesting the plants also need to be considered before ensiling the crop; thus, it is unacceptable if the ensilage is done improperly. Paying attention to details and following the recommended management practices for all four phases of ensiling – aerobic, fermentation, storage and feed-out – are vital to retain most of the nutrients and DM, resulting in minimal shrink.

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Figure 1. Potential losses during the phases of ensiling (Borreani et al., 2018)

Figure 2. The effects of packing density on the DM losses in 25 bunker silos (Ruppel, 1992).

GARBAGE IN, GARBAGE OUT: THE IMPACTS OF SILAGE MANAGEMENT

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Dr. Skidmore received his DVM from Kansas State University. Following graduation, he joined a mixed animal practice in Wisconsin then attended Cornell University for his PhD in dairy cattle management. Following his PhD, he went on to be the dairy management specialist at Michigan State University. Departing Michigan State University lead Dr. Skidmore to a career path that includes diverse roles such as agricultural business consultant, turnaround dairy manager for a veterinary practice, technical advisor for a feed company and Merck Animal Health's Global Ruminant Technical Director for Reproduction and Parasite Control.

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Forage quality is the Achilles heel for any ruminant nutritionist. The better the forage is coming out of storage the better the nutritionist. Silage management is not easy and involves many complex interactions to get the greatest return for the significant investment made to grow, harvest, store and feed quality forages. When it is done right, life is on easy street. More times than not there are significant challenges to getting everything to line up and come out how it should. Something always happens and many times is out of our control. That is why we make plans A, B and C so that we have a contingency not "if" but "when" something happens.

One of the biggest issues we face around silage storage facilities is safety. It does not matter the type or size of storage. There are many safety hazards when working around silage storage facilities. The major hazards would include falling from a height, being run over by machinery, tractor roll overs, getting entangled in machinery, and being crushed by a silage avalanche. Always think safety first. A few recommendations to keep in mind would be:

1. Keep a safe distance from the face of a bunker or pile of silage
2. Always bring a buddy. Never work alone near a silage storage facility
3. Always be careful when filling a silo, be alert and work safely
4. Maintain the feed out surface carefully
5. Inspect or sample very cautiously
6. Feed out correctly

We want every person to go home to their family at the end of every day.

To store any kind of feed, either air or water must be removed to preserve nutrients. In the case of water removal, the feed is dried to a point that it stops microbial activity and the feed can be stored. Dry forages are stored as hay and dry grains are stored in a bin or other non-oxygen limiting storage unit. In the case of air removal, nutrient preservation is dependent on anaerobic fermentation creating an environment where microbial activity is almost eliminated or at least made dormant. When exposed to air again the microbes will reactivate consuming valuable nutrients and decreasing storage life. This process and management of this process has been described in previous papers. The purpose of this paper is to describe what can happen when it doesn't go right.

Silage contaminants can be put into 3 categories: Undesirable micro-organisms, undesirable chemicals and fermentation by products. Common sources of contaminants include soil, plant damage, manure, decaying carcasses, mold, wild yeast, wildlife, rodents and birds.

Undesirable micro-organisms would include organisms such as *Salmonella, E coli* O157:H7, other coliforms, *Listeria, Clostridials, Cryptospordia*, yeast and molds. Many of these organisms are normally found in the environment or may be transferred to crops when manure is applied before harvest. The key to minimizing their impact is managing the ensiling process such that they do not have the opportunity to proliferate or survive during fermentation or feedout.

A very good review was recently published in the May issue of the Journal of Dairy Science. One review was on contaminants found in silage and another was on foodborne pathogens and how they are affected by the ensiling process. A few highlights.

Salmonella contamination of silage is not that frequent and not a common source of contamination. It is usually associated with inadequate silage fermentation and application of animal waste on the forage crop before harvest. If the fermentation is well established early and pH drops below 4.0, *Salmonella* is not likely to survive. The duration of ensiling and rates of pH decline are important risk factors.

E. coli O157:H7 has often been found to be part of the microbial flora on forages. It can be eliminated from silage when the pH drops below 4.0 very rapidly. If the acidification rate is slow then *E. coli* may persist in the silage. It can also be found in aerobically challenged areas of a silo.

Coliforms can predominate the microflora in a fresh crop and compete with lactic acid producing bacteria for precious nutrients during fermentation. Their growth and viability reduces quickly as pH drops. A key factor in determining if coliforms are likely to develop in silage is the rate of lactic acid production. Anything that might impair a rapid fermentation and drop in pH can provide environments that are conducive to coliform growth.

Listeria monocytogenes is a common organism found in the soil and hence on forages. Undissociated lactic acid is particularly good at inhibiting growth. Growth of *Listeria* is inhibited when pH is below 5.0 but it can survive low pH when trace levels of oxygen are present. This can provide a point of growth should it become exposed to oxygen when a silo is opened or a seal is broken.

Cryptosporidium parvum has been shown to survive fairly adverse conditions in the silo. It forms a very resistant oocyst that can survive for considerable time. *Cryptosporidia* are not likely to be severe pathogens in adult cattle but certainly create major issues in newborn calves. Silage could be a vehicle by which it persist on an operation. It is also a human pathogen and concern.

Clostridial organisms are normally found in large numbers in the environment and are responsible for secondary fermentation of glucose and lactic acid to butyric acid and for proteolysis. Proteolytic activity can result in the extensive degradation of plant proteins to ammonia which can have a negative influence on health and productivity. It is most likely to be a problem is silages that are very wet and pH never gets below 4.6. *Clostridium botulinum* is of greatest concern as it is pathogenic to animals and man. Its risk is considerable higher if the silage is contaminated with dead animal remains.

A practice often overlooked is discarding spoiled silage from feed. Dilution is not the solution to pollution. A study to determine the effect of level of surface spoilage included in corn silage based diets was reported in 2000 (Whitlock et al.). I like this study because it actually measures the impact in live animals. Most studies have evaluated the chemical composition changes from spoiled silage and then extrapolate to the impact on animal performance.

Alternating loads of corn silage were either put into a 9 foot Ag bag and classified as "normal" corn silage or put into one of three experimental bunker silos and classified as "spoiled." The corn silage in the bunker silos was packed to a final depth of 3 feet. It was left uncovered for 90 days.

Twelve rumen cannulated steers when fed varying proportions of spoiled and normal corn silage. The four experimental rations contained 90% silage and 10% supplement (dry basis). The silages in the rations were: A) 100% normal, B) 75% normal: 25% spoiled; C) 50% normal: 50% spoiled, and D) 25%normal:75% spoiled. The slimy layer comprised 5.4, 10.7, and 16.0 % of the DM in rations B, C, and D, respectively. The rations were fed once daily at 7:00 a.m., and the amount fed was adjusted so that 5 to 10% of the as-fed ration was in the feed bunk at the end of each 24-h period.

At 90 days the bunker silage had reduced to a depth of 22 inches. A loss of 14 inches that vaporized and left behind 7 inches of slim and about 15 inches of wet, high-acid, corn silage with a bright yellow to orange color, a low pH, and a very strong acetic acid smell. The pHs and chemical compositions of the whole-plant corn silages fed are shown in Table 1. The composition of the spoiled silage is reported for each of the two distinct visual layers and for a composite of the two layers after they were mixed. The mixture represents the spoiled silage as it was actually fed in rations B, C, and D.

TABLE 1.

pH and chemical composition of trial whole plant corn silage.

Silage	pH	DM	OM	Starch	CP	NDF
	% of DM					
Normal	3.9	38.0	94.7	22.3	6.9	42.6
Spoiled composite	4.79	26.4	90.9	24.3	9.9	48.9
Spoiled Layers						
Slim layer	8.22	19.1	80.0	2.7	17.7	57.6
Acidic Layer	3.67	27.6	94.3	26.1	6.7	48.5

The high ash and fiber contents of the spoiled composite silage are associated with poor preservation efficiency and very high OM losses during the aerobic, fermentation, and storage phases.

The addition of spoiled silage decreased CP digestibility in a linear manner, and surface spoilage had large negative effects on DM intake and DM, OM, and NDF digestibilities (Table 2). When the ruminal contents were evacuated, the spoiled silage had partially or totally destroyed the integrity of the forage mat in the rumen.

TABLE 2.

Effect of the level of spoiled silage on nutrient digestibilities for steers fed four whole-plant corn rations.

	Ration			
% Spoiled Silage Item (% Slimy layer)	0 (0)	25 (5.4)	50 (10.7)	75 (16.0)
DM Intake (lb/day)	17.5[a]	16.2[b]	15.3[b,c]	14.7[c]
DM Intake (% BW)	2.36[a]	2.22[a,b]	2.10[b,c]	2.04[c]
	Digestibility (%)			
DM	74.4[a]	68.9[b]	67.2[b]	66.0[b]
OM	75.6[a]	70.6[b]	69.0[b]	67.8[b]
Starch	94.6	95.0	93.3	95.3
CP	74.6[a]	70.5[b]	68.0[b]	62.8[c]
NDF	63.2[x]	56.0[x,y]	52.5[y]	52.8[y]

[a,b,c] Means within a row with no common superscript differ (P<.05)
[x,y] Means within a row with no common superscript differ (P<.10)

Even though silage fermentation is a simple process it needs to be controlled to provide consistent high quality feed. There are 4 phases of silage preservation. **Phase 1 is the Aerobic Phase.** It is very short and should last less than 2 days. When the plant is harvested it does not die right away. It continues to respirate and metabolize nutrients in spite of being chopped into small pieces. As long as there is air and fuel (water soluble carbohydrates) it will continue to use those nutrients to produce CO2 and water. Microbial action will add heat to the mixture. There is some protein degradation as the plant continues to try and live. If the duration of phase 1 is extended then more water soluble carbohydrates are consumed, more heat is generated and pH is slow to decrease.

Phase 2 of silage preservation is the Anaerobic Phase. The duration of this phase should be less than 28 days. Oxygen has been eliminated and ideally homolactic bacteria have taken over fermentation producing lactic acid to preserve the silage. If heterolactic bacteria dominate the fermentation undesirable byproducts other than lactic acid are produced at the expense of water soluble carbohydrates and protein. There is one exception and that is the production of acetic acid by L. buchneri. L. buchneri is very efficient at producing acetic acid which is necessary for aerobic stability at feed out. The temperature of the silage during phase 2 will peak at about 20^0 F above ambient temperature. If it increases more than this then the fermentation is not anaerobic and excessive damage to the silage will result. The temperature will then gradually decrease over time to approach ambient temperatures. It is at the beginning of this phase that pH should drop really fast to preserve as many nutrients as possible.

Dry matter content of a silage has a large impact on Phase 2. If the feed is too dry then it is nearly impossible to get all the air out and make it anaerobic. If it is too wet it takes a very long time for the pH to decrease to desirable levels because of the large water load. It may even go beyond what is needed to preserve the forage creating a high acid load for the cattle. The challenge is to balance the needs of both. The ideal DM for each crop is different and needs to be evaluated under local conditions.

Phase 3 is the Stable Phase. There should not be anything happening during this phase if everything in previous phases went well. Silage can be preserved for years in this phase as long as it remains undisturbed and anaerobic.

Phase 4 is the Feedout Phase. It is during this phase that the silage is disturbed and oxygen is reintroduced to the silage.

Aerobic stability of silage is defined as the length of time it takes for disturbed silage (exposed to air) to heat 2^0C. Aerobic stability is very important in maintaining nutrients and quality of silage during feedout. It is as important at the silo as it is in the feed bunk. Many make the mistake of thinking that feed is only in front of the cows for less than 24 hours it should not make a big difference. Aerobic stability is the cumulative time from first exposure to air until consumed by the cow. If the face of a silo is not well managed exposure to air and aerobic deterioration could begin days before the feed reaches the feed bunk.

Aerobic deterioration begins when silage is exposed to air and the temperature gets above 50^0F (10^0C). At this point the wild yeast the silage wake up. They are ravenous for something to eat and start consuming sugars and lactic acid. They increase in numbers as well. The result is more heat and higher pH. None of these changes are visible. A thermometer could detect the increase in heat. Following the yeast the conditions are now just right for mold and bacteria to wake up and further deteriorate the silage. At this point changes start to become visible but by this time most of the damage has already been done.

The high lactic acid and low pH produced in the fermentation phase do not protect silage against wild yeasts. Yeast can use lactic acid as a food source. Acetic acid, butyric acid and propionic acid are good yeast inhibitors. Butyric acid in silage does not play well with cows and should be avoided at all costs.

To give you something you can take home and use to evaluate your own silage harvest is the results of a very good paper published in the Journal of Dairy Science (Borreani and Tabacco, 2010). Fifty-four bunker silos were evaluated in detail with temperature thermometers across the face. A sample was taken from 11 different locations and 7 heights at a depth of 200mm (7.9 in). A reference point for each silo was its center. This reference point was then used to compare other parts of the silo such that each silo served as its own control. Any moldy areas were sampled in addition.

A temperature differential from the center core of greater than 5^0 C (9^0 F) corresponded to an increased yeast count of greater than 5 log cfu/g. Greater than 90% of the time this was observed on the peripheral edges of the silo and in almost every moldy spot. Samples from the peripheral edges of a silo with no visible mold present resulted in values very similar to core samples to values that are characterized by deeply altered silage. Looks can be very deceiving. See table 3.

The core samples did not vary with ambient temperature. They remained about 68^0 F (20^0 C) throughout winter and summer at a depth of 15.75 inches (400 mm). This makes a great reference point to compare harvest management within a silo. It also means there is some retained heat in the silage mass. When steam rises the silage during feedout in the winter it could be just retained heat being released and not due to deteriorated silage.

TABLE 3.

Mean values of chemical and microbial characteristics from core, peripheral and moldy areas of corn silage.

	Silage Core	Peripheral area	Moldy Spots
DM content (%)	34.3	34.1	33.4
pH	3.64c	4.97b	6.84a
Yeast (log cfu/g)	2.93c	5.48b	6.33a
Mold (log cfu/g)	1.76c	3.71b	8.00a
Clostridial spores (log MPN/g)	1.36c	2.75b	5.08a
Sample Temperature (^{0} F)	65.5c	87.1b	95.7a

[a, b, c] means within a row with different superscript differ ($P < 0.05$)
MPN = most probable number

From a practical standpoint, diluting contaminated silage with mold free silage is not a healthy solution in highly productive cattle.

Management through all 4 phases of silage fermentation can significantly reduce the impact of silage contamination but the fermentation process must be controlled and not left to Mother Nature or chance. Rapid reduction in pH and aerobic stability at feed out are the hallmarks of well controlled silage fermentation and quality feed for the cows. Forage quality cannot be improved through the silage process it can only be preserved or destroyed – Garbage In = Garbage Out.

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THE VALUE OF SILAGE IN BACKGROUNDING RATIONS

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INTRODUCTION

Beef cattle production systems both domestically and globally are dependent on forages which are often of low-quality, and the impact of forage quality on cattle performance becomes greater as the percentage of forages in the ration increases. Therefore, forage quality is most critical for those production phases that occur before finishing. The harvesting and storing of forage crops as silage has been an important component of cattle feeding programs for many years, and some early instances of producers ensiling crops for subsequent feeding date back to the late 1800's. While silages have always been a centrally used feed for cattle, the production of traditional alfalfa and native grass hay has decreased in many regions over the last 10 to 15 years partly due to the increase in corn and soybean production. Crop residues represent a forage that has increased due to more grain production, but many have re-evaluated the use and value of silage in backgrounding and cow-calf rations which is the focus of this discussion.

SILAGE STATISTICS

The forages used in our industry have changed in recent years and are continuing to evolve with the ever-moving dynamics of beef and crop production. Our first-hand experience with producers and research data have proven that to be true. In the U.S., total acres harvested for all hay production in 2017 were 12% lower than in 1990, with production down approximately 10% (USDA). During that same time, both acres harvested and tonnage of alfalfa hay produced declined by approximately 35% nationwide. However, during the same 27-year time span, all acres harvested for corn in the U.S. increased by 22% with total grain production increasing by 84% (USDA). It appears that the feeding industry has responded to these changes in forage availability by altering the type of forages used in rations. Vasconcelos and Galyean (2007) reported in their initial survey of consulting feedlot nutritionists that 31% of respondents used alfalfa hay as either the primary or secondary source of forage in finishing rations. The same survey was conducted again recently (Samuelson et al., 2016) and showed that while alfalfa hay was used as the primary forage source by only 20.8% of nutritionists, more respondents surveyed used other forages such as crop residues than in the prior survey. In general, we have also observed much less availability of traditional forages like alfalfa and grass hay, and more use of low-quality crop residues such as corn stalks or wheat straw. The land-use shift from hay and pasture towards crops is very real and is contributing to the increased use of crop residues in growing and finishing rations. Interestingly, these survey data suggest that silage use in feedlots has stayed relatively constant. In the initial survey (Vasconcelos and Galyean, 2007), 41 and 34% of respondents used corn silage as the primary and secondary forage source, respectively. In the follow up survey (Samuelson et al., 2016) the percentage of nutritionists using corn silage as either the primary or secondary forage source was equal at 37.5%, with a noticeable increase (13.9%) from the prior survey in the use of sorghum silage as a secondary forage source. In recent years, we have seen a general trend of more interest in silage production, particularly from producers that have not harvested silage as of late.

On a broader scale, USDA data can be helpful in identifying trends in silage production overtime. During the 1970s, corn harvested for silage in the U.S. averaged over 9.2 million acres per year yielding approximately 12.4 ton per acre. Acres harvested for silage in the U.S. in the 1990s averaged 5.9 million per year at 14.7 ton per acre. Over the past 8 years, U.S. acres harvested for silage have average 6.3 million per year at 19.1 ton per acre. These data suggest that while silage acres have declined from 40 years ago, production has not dropped due to improvements in corn hybrid technology (i.e. use of silage varieties, drought and disease resistant genetics) and growing conditions (i.e. increased use of irrigation, fertilization, and pest and weed control). Again, this supports the nutritionists' survey data that silage use in the beef cattle feeding industry appears to have either remained steady or increased in recent years.

Corn and sorghum silage production data for 2017 for selected states are presented in Tables 1 and 2, respectively. As a percentage of total corn acres planted, producers harvested 2.19 to 6.12% of acres as silage averaging 21 ton per acre. The exception was drought-affected South Dakota, where 9.12% of total corn acres planted were harvested for silage yielding only 12.5 ton per acre. Producers in NE, KS, SD, and TX harvested sorghum silage at an average yield of 12.3 ton per acre with most of the production located in KS and TX.

BACKGROUNDING

The use of silages lends many benefits to backgrounding operations, particularly for those producers that own or rent crop ground. For backgrounding yards that strictly purchase their feed, using silage is typically not as feasible unless they can buy it from another operation and haul it a reasonable distance. Although harvesting silage represents a significant time and monetary investment for the producer, one of the biggest advantages is simply having a high-quality feed stored in inventory. This gives operations with silage more flexibility with rations and at times they may be less affected by hay and forage shortages due to drought or other causes. A disadvantage to silage is that once the crop is chopped and packed, it must be fed for it to be marketed, unlike hay which can be sold more easily due to its ability to be transported with less cost per ton of DM. A recent report (Asem-Hiablie et al., 2016) indicated that feedlots in the Northern Plains and Midwest fed silage in backgrounding rations at average dry matter inclusions of 17.1% (range 0-78%) and 22.2% (range 0-67%), respectively. Feeding silage at 20 to 50% (dry matter basis) would be very common in many backgrounding rations, but cattle do well at levels above 50% which are fed in some instances. Often, our inclusion levels in rations are set by the tonnage harvested and cattle inventory throughout the year, with the goal to avoid running out early or carrying over large amounts of silage into the next year. We recommend keeping silage limited to ≤ 15% of the ration on a dry matter basis in starting/receiving rations for most cattle coming directly off pasture, but cattle can be adapted to higher levels once started and eating well.

As with any feeds, managing silage to minimize shrink is very important. For a custom backgrounding operation that is marking up their feed to sell, minimizing shrink represents a way to capture revenue.

Poorly managed silage that spoils and loses dry matter represents a cost and requires additional mark up to account for the lost feed. Every step in the process of making silage affects shrink: dry matter at harvest, chop length, bunker or pile filling and packing, inoculation, covering, and feedout. At current feed prices, silage appears to be economical in growing rations. Silage priced in the ration at $35 per ton can lower ration costs by as much as $16 per ton as-is or $7 per ton of dry matter depending on the inclusion and moisture level of the ration. If gain is constant, cost of gain could be lowered $0.02-$0.04/lb, with further reductions as the level of silage in the ration increases. With hay prices near $70+ per ton, silage becomes an attractive feed because it is a less expensive, higher quality forage source with additional energy from the grain component.

COW-CALF OPERATIONS

There is significant value of silages to beef cow-calf operations in today's production environment. In past years, it may have been considered uncommon to feed silages to beef cows but we have observed that it is recently becoming more typical. One reason may be that cow-calf operations are generally becoming larger, and consequently most producers can afford to own a mixer wagon or truck by spreading out the cost of machinery over more animals. Also, when the ethanol industry experienced significant growth 10 to 15 years ago, wet by-products were relatively inexpensive so many producers capitalized on it by purchasing feed mixing and delivery equipment if they didn't have it already. With the price of pasture near $2.00 per cow per day or greater (depending on region and stocking rate), a TMR using silage can be often fed to cows at a price less than grass or other supplementation methods with those savings put back towards paying machinery costs and depreciation. It is also common for many cow-calf producers to retain their calves for backgrounding after weaning allowing them to use the equipment throughout the year for more than one purpose. Likewise, those same producers likely find more justification for harvesting silage as they can feed it to both cows and calves.

Nutritionally, silages represent an excellent energy source in cow-calf rations by providing digestible fiber. They can be used to meet the energy requirements of cows to maintain BCS and weight and fit particularly well in rations fed post-calving with other forages. A big advantage to using silages in cow rations is the improvement in palatability and conditioning observed by adding a wet feed. This can be very important in situations where wet by-products are limited or unavailable, and the remaining feeds in the ration are dry. Cows can easily utilize 10 to 40 lb per cow per day of silage as-fed depending on the composition of the other ingredients.

Another important reason for the increased use of silage in cow-calf operations is that many producers are diversified with both crop and cattle enterprises. This obviously gives producers significant flexibility in being able to devote acres to silage as needed in conjunction with their existing plans for crop production. The increased conversion of traditional forage and pasture acres to crop production in recent years has been well documented (Wright and Wimberly, 2013) and more cow-calf operators are seeing the benefits of utilizing forages in tillable acres as cover crops and silage crops. One common challenge with silage for many cow-calf producers lies in harvesting and storing the crop itself. Unlike dairies or large feedlots that routinely harvest silage, cow-calf producers may not necessarily harvest silage annually and may lack experience with putting up quality silage. As is often the case in drought years, they may plant acres with the intention of harvesting the crop as grain and don't consider it for silage until the crop has failed. This clearly presents a challenge because by the time the decision is made to harvest it for silage, the dry matter is often too high for adequate packing and fermentation to occur. Adequate labor to accomplish all the tasks necessary for harvesting silage can be an issue for many operations. Most silage piles are made as drive-over piles or in an earthen bunker or trench, and many piles are not adequately packed or tarped. When a silage is not packed well due to moisture content, packing pressure or time, or chop length, oxygen is not completely packed out of the silage, allowing mold growth to occur. The end result is often a silage with higher dry matter and pH, shorter bunk life, more spoilage and shrink, and less digestible fiber. This demonstrates the importance of forethought and planning on the part of the producer, and likewise working with their nutritionist to ensure all steps are taken to maximize the quality of the feed.

FORAGE SORGHUMS AND SMALL GRAIN SILAGE CROPS

Sorghums can be an excellent silage crop for use in high forage rations for backgrounding cattle or cows. There are many different varieties of sorghums and Sudan grasses, some of which are high yielding for silage production and others which are better suited for grazing. Therefore, it is important for producers to understand their intended use when selecting a type of sorghum to use. In general, the silage hybrids identified by seed companies produce more tonnage and are later maturing (Bean and Marsalis, 2012). Forage sorghums for silage differ from corn silage in that the ratio of forage to grain is much higher as these crops generally are taller and have more leaf area than grain. Consequently, starch levels are typically lower for forage sorghum silage (≤ 25%) than corn silage (32-33%) resulting in a feedstuff that is lower in energy. However, if harvested at the correct DM (30-35%) and stored properly, these silages can be a very good source of digestible fiber. Most forage sorghum hybrids are either brown midrib (BMR) or non-BMR, with BMR hybrids containing less lignin than non-BMR sorghums. The main advantage with BMR hybrids is improved fiber digestibility. Relative to corn, forage sorghums are more resilient under high heat and drought conditions and accordingly are common in the Southern Plains. Production costs are also much lower for sorghum compared to corn. Under most growing conditions, forage sorghums produce 10 to 15 ton as-is per acre but yields in excess of 20 ton per acre can be achieved with adequate moisture. Since forage sorghums are harvested later in the fall, the timespan in which the crop can be harvested at 30 to 35% DM may at times be longer than with corn silage, giving it more flexibility on harvest timing. However, two common issues with sorghum silage include getting it to dry down adequately for proper harvesting and lodging (Bean and Marsalis, 2012).

Silage crops from small cereal grains have become very common in recent years again due to the increased use of alternative cover crops in existing corn and soybean production. These silage crops can include oats, wheat, triticale, barley and rye. One of the biggest advantages for these cool-season crops is that they are a cost-effective way to produce forage for either silage harvest or grazing and fit well when planted after harvesting wheat, hybrid seed corn, high-moisture corn, or corn silage. Aside from moisture being a major factor limiting production, success with these fall-planted crops is largely dependent on planting date, so the earlier they are planted the more growing-degree days are available for forage production (Drewnoski and Redfearn, 2015).

Small grain silages usually yield in a range of 5 to 10 ton as-is per acre, depending on maturity at harvest. Although the forage is highly digestible, overall energy content typically is less for small grain silages than corn silage, but protein levels are often higher (Table 3). As with any silage crop, dry matter at harvest, cut length, and adequate packing is key in determining how well the forage ensiles and stores. When harvesting small grain silages, packing to an adequate density can be a challenge. The physical nature of the forage and the hollow stems can allow oxygen to easily remain in the silage pile, so we will often see more spoilage and DM loss as a result if packing is not adequate. Recommended packing densities for corn silage or earlage are 45 lb per ft^3 of as-is silage, while densities for small grain silages should be closer to 30 lb per ft^3. Targeting a particle chop length of 3/8 to 1/2 inch will provide for a better pack because it enables the oxygen to escape more easily. Since small grain silages contain less starch than corn, less substrate is available for microbial fermentation and pH does not drop as rapidly at the onset of the ensiling process. Therefore, applying an inoculant to increase both the rate and extent of the fermentation process is highly recommended for small grain silages.

Accumulation of nitrates can also be an issue for corn, forage sorghums, and small grain crops, particularly when plants are stressed due to drought, hail, or frost. High levels of nitrogen fertilization can also contribute to nitrate accumulation. A benefit of harvesting these crops as silage is that fermentation will reduce nitrates by 40 to 50%, but other cautionary steps (diluting high nitrate forages with other feeds, adaptation of cattle to increasing nitrate levels, supplementation) may need to be taken depending on the level of nitrates present (Bolsen and Kuhl).

TABLE 1.

Corn acreage planted and corn silage production data by state, 2017.

State	Total corn planted, acres	Silage harvested, acres	Silage acres, % of total	Silage yield, tons/acre	Total silage production, tons
Nebraska	9,550,000	210,000	2.19	19.5	4,095,000
Kansas	5,500,000	250,000	4.54	21.5	5,375,000
Iowa	13,300,000	330,000	2.48	21.0	6,930,000
South Dakota[1]	5,700,000	520,000	9.12	12.5	6,500,000
Texas	2,450,000	150,000	6.12	22.0	3,300,000

[1]Drought year in 2017.

TABLE 2.

Sorghum silage production data by state, 2017.

State	Silage harvested, acres	Silage yield, tons/acre	Total silage production, tons
Nebraska	22,000	10.0	220,000
Kansas	85,000	13.0	1,105,000
South Dakota[1]	37,000	11.0	407,000
Texas	65,000	15.0	975,000

[1]Drought year in 2017.

TABLE 3.

Silage nutrient composition of small grain cereal crops and corn, %DM[1].

Crop	%TDN	%CP
Barley	64-68	9-11
Wheat	58-64	9-11
Oats	56-62	8-10
Triticale	54-58	8-10
Rye	52-56	7-9
Corn	70-72	7-8

[1]Adapted from Watson et al., 1993.

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CONSIDERATIONS FOR USING SILAGE, EARLAGE, AND HMC IN FINISHING CATTLE

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INTRODUCTION

In feedlot diets corn is king. Yes, we periodically feed some small grains such as wheat, barley, oats, etc. but for the most part corn makes up the majority of finishing diets. In many feedyards, the corn plant actually represents 90+% of the finishing diet either from corn grain, corn silage, earlage, snaplage, stover, and(or) corn coproducts such as distillers grains and corn gluten feed. Often, the only dietary components not derived from corn are the supplemental vitamins and minerals and maybe their carrier and any roughage not coming from the corn plant. So it is clear that corn is an important crop to finishing cattle. Given that fact, it's no surprise that there is much thought and debate around the best ways to economically capture and preserve the energy (starch) and fibrous (stover) fractions of the corn plant. This paper will discuss various ideas and concerns about the use of the corn plant in finishing diets with emphasis put on crops that capture both fiber and energy (silage and snaplage). This will, by no means, be a comprehensive review as much more informed scientists have devoted their lives to the study of this topic and have written volumes of information on the topic. For an in depth review on the subject, I would point you to a publication recently presented by Fred Owens at the 2018 Plains Nutrition Council Spring Conference (Owens et al., 2018).

WHY IS CORN GROWN SO PREVALENTLY?

Church (1977) noted that Indian corn (Zea mays) can produce more digestible energy per unit of land than any other grain crop. Today this would be a gross understatement as the agronomic yield of corn can now produce around twice the ME/acre as small grains and three times ME/acre as vegetables while having similar protein yield/acre as alfalfa, and greater fiber (NDF) yield than most other roughages such as alfalfa, sorghum, and grass hays (Owens et al., 2018). So it's no wonder that corn finds itself easily atop the throne of plants grown for livestock food production and is the standard by which all other energy feedstuffs are measured.

WHAT FEEDSTUFFS CAN WE HARVEST FROM THE CORN PLANT?

There are several ways to slice up the proverbial pie that is the corn plant, being dependent on the maturity of the crop, portions of the crop parts wanted/needed, and the harvest method. The major variance in these different forms is the ratio of corn to stover captured. Stover is the non-grain (high NDF) portion of the corn plant and can include stalk, leaves, shank, husk, and cob. Different harvest methods capture varying proportions of grain and stover. Table 1 gives an overview of several products that can be harvested from the corn crop.

TABLE 1.

Characteristics of various products harvested from the corn crop.

Product	Equipment	Plant Parts Harvested	Typical DM, %
Silage	Chopper	Whole Plant	28-45
Earlage	Chopper w/ all crop head	Grain, Cob, Husk, Shank, Stalk	60-75
Snaplage	Chopper w/ snapper head	Grain, Cob, Husk, Shank	60-75
HM Corn	Combine	Grain	66-75
Ear Corn	Corn Picker	Grain, Cob	77-90
Dry Corn	Combine	Grain	84-90
Stover	Rake and Baler or other	Stalk, husk, shank, cob	70-90

When harvesting silage, earlage, snaplage, or HM corn, the product must be properly harvested, processed, delivered to storage (upright silo, bunker silo, pile, or bag), packed, and sealed for the ensiling process to proceed efficiently. Most of the management practices that apply to silage will also apply to the remainder of the ensiled feeds derived from the corn plant and will be covered by other speakers.

CORN SILAGE

Corn silage is obtained by harvesting and ensiling the whole corn plant with an all-crop head on a forage chopper. Harvest height is typically around 6 inches unless nitrates are a concern and chop height is raised to avoid the higher nitrate levels that accumulate in the lower stalk. Rough terrain may also necessitate raising the chop height.

There is a wealth of research and summary publications on the proper timing and methodology of corn silage chopping and preservation. Several university extension programs such as The University of Wisconsin (http://corn.agronomy.wisc.edy) and Penn State University (https://extension.psu.edu/corn-silage-production-and-management), have excellent websites to review the overall topic, in addition to information that will be presented at this symposium.

Snaplage is ensiled corn grain, cobs and husks plus a portion of the shank. Snaplage is typically harvested with a forage harvester equipped with a corn snapper head, chopped, and ensiled (Lardy & Anderson, 2016).

Earlage is harvested similarly but with an all-crop head on the forage chopper which yields corn grain, cobs, husks, shank, and a portion of the stalk above the ear. Earlage yields more tonnage but is lower in energy and protein content and is more difficult to pack and ensile than snaplage. The generic term earlage is commonly used to describe both earlage and snaplage (and sometimes HM ear corn). Twenty years ago I would see true earlage (containing part of the upper stalk) put up but I can't say I have seen much in the past 10 years or so. What we mostly put up is snaplage but we call it earlage. Consequently, the earlage of today versus 20 years ago tends to test higher in energy (starch) and lower in fiber (NDF).

High moisture ear corn (HMEC) is produced when a conventional combine or corn picker is used to harvest, grind, and ensile mainly corn with a portion of the cob. Some would also call this HM corn and cob meal. I don't run into this much so it will not be discussed here.

High moisture corn (HMC), in the broadest sense, is any corn harvested above 15.5% moisture (the standard for shell corn). However, if improving starch digestibility is on the list of goals for harvesting corn as high moisture, the moisture content should be in the 26-34% range. HMC is harvested by combine, usually processed through a roller mill, hammer mill, or tub grinder and packed in to an appropriate structure for anaerobic fermentation. HMC generally ferments slower and less complete than corn silage (Hoffman & Muck, 2011) with the extent of fermentation being directly proportional to the moisture.

NUTRIENT CONTENT.

The nutrient content of feedstuffs has long been tabulated by various university and industry groups from the available laboratory analyses and limited feeding trials. While nutrient content estimates abound for dry corn, HMC, and corn silage, the estimates for snaplage and earlage are more limited. Table 2 shows tabular values from the University of Nebraska (Stock et al. 1995), North Dakota State University (Lardy & Anderson, 2016) and Feedstuffs Magazine (Preston, 2016). Note that the

TABLE 2.

Nutrient content of various products harvest from the corn crop.

	DM	CP	DIP	TDN	NEm	NEg
PRODUCT	%	%	%	%	Mcal/lb	Mcal/lb
Dry Rolled Corn						
Stock[1]	86	10.0	40	90	102	70
Lardy & Anderson[2]	86	9.8	-	90	102	70
Preston[3]	88	9.0	46	88	98	65
High-Moisture Corn						
Stock[1]	75	10.0	60	90	102	70
Lardy & Anderson[2]	75	10.0	-	90	102	70
Preston[3]	74	10.0	58	93	104	71
Ear Corn						
Lardy & Anderson[2]	87	9.0	-	83	92	62
Preston[3] (corn & cob meal)	87	9.0	48	82	89	59
Earlage (all crop head)						
Lardy & Anderson[2] (well eared)	60-70	8.8	-	78	86	57
Lardy & Anderson[2] (less grain)	60-70	8.8	-	74	80	52
Snaplage						
Stock[1] (high moisture snapped)	74	8.8	60	81	90	59
Lardy & Anderson[2] (snapper head)	75	8.7	-	83	92	62
Corn Silage						
Stock[1]	35	8.0	75	72	74	47
Lardy & Anderson[2]	35	8.0	-	70	74	47
Preston[3]	34	8.0	72	72	75	47

[1]Stock et al. (1995) [2]Lardy and Anderson (2016) [3]Preston (2016)

"book values" are mostly in agreement but differ quite a bit from the Dairyland Laboratories one- year and five-year averages (Table 3). This underlines the necessity for nutrient analysis of the feedstuffs used on each feedyard rather than simply using book values.

TABLE 3.

Dairyland Laboratories Inc. dry corn, HMC, and earlage/snaplage analyes.[1]

	DM	CP	aNDF	Starch	OARDC NEg	
PRODUCT	**%**	**%**	**%**	**%**	**Mcal/cwt**	**n**
Dry Corn (<18% moisture)						
2017 Crop	86.1	8.41	7.28	71.2	66.8	1393
5 year average	85.6	8.25	8.21	69.5	66.3	9022
HMC (>22% moisture)						
2017 Crop	71.4	8.16	7.57	70.0	66.2	5169
5 Year Average	70.7	8.06	8.00	69.0	66.0	39544
Earlage/Snaplage (<30% moisture)						
2017 Crop	60.0	7.45	19.2	57.9	60.5	3038
5-Year Average	60.4	7.37	19.6	57.7	60.2	19806
Corn Silage						
2017 Crop	36.4	6.86	38.4	35.8	47.5	37517
5 Year Average	38	7.18	39.1	33.5	47.4	322311

[1]Compiled by Neal Wininger, Dairyland Laboratories Inc.

FINISHING DIET GOALS.

Finishing diets are generally formulated to provide rapid, efficient, cost-effective growth to achieve a desired end-weight and carcass composition. The prevailing paradigm for several decades has been to feed high energy diets that contain the minimal amount of roughage (scratch) to avoid metabolic disturbances while maximizing energy intake. Determining that minimal roughage level and the acceptable level of metabolic disturbances have been explored experimentally. However, on-yard adjustment of finishing diet roughage level relies more heavily on nutritionist and(or) feedyard experience as each feeding situation has its own set of unique facility x management x feedstuffs x goals interactions. As feed conversion is one of the major measurements by which commercial feedyards are currently evaluated, much attention is paid to minimizing the roughage level of finishing diets.

WHAT TO HARVEST?

Determining what product to make from the corn crop is not as simple as it may seem. Each product that can be produced has its own set of agronomic and nutritional strengths and weaknesses and those must all be weighed and balanced against the feedyard nutrient needs. For the most part, we can evaluate corn silage, snaplage, and earlage based on the fractions of corn (starch) and roughage (NDF) that will be harvested, although there are a few feeding interactions that must be considered. Since we know there is a need for some minimal level of roughage in finishing diets, if we are to get both our energy and roughage from the corn crop, then harvesting a crop that contains at least some level of built-in roughage seems prudent (rather than going back to get the stover later). However, proper harvesting, packing, and ensiling of corn silage and snaplage requires a large footprint, focused labor, and attention to detail. Absence of any of those will result in a less than favorable fermentation and excessive shrink and spoilage, potentially negating the positives.

HIGH-MOISTURE CORN IN FINISHING.

Advantages of harvesting HMC include the elimination of drying costs, potential increase in corn yield due to less ear drop, earlier harvest, potential to grow longer season, higher yielding varieties, and earlier availability of corn stalk grazing. Disadvantages include limited marketing flexibility (feeding to cattle is the only outlet), the need for storage facilities and equipment, potential spoilage and shrink during ensilation and feedout, and the need to account for the higher fermentation potential in diet formulation and bunk management. There is much debate about the actual feeding value of HMC as its feeding value has been shown to be affected by moisture level, feeding rate, degree of processing, roughage source (Mader et al., 1991) and level, corn coproduct and level, and blending with DRC.

Owens et al. (1997) summarized 164 grain processing studies from 1974 to the mid 1990's. In this summary, while the observed ME for HMC (grain alone) was greater ($P < 0.05$) than for DRC (1.55 vs 1.48 Mcal/lb), total ME intake (calculated by Buchanan-Smith, 1997) was lower ($P < 0.05$) for HMC diets (27.6 vs 28.2 Mcal/d) due to lower DMI ($P < 0.05$). This resulted in lower ($P < 0.05$) performance for HMC versus DRC (3.02 vs 3.20 lb/d) with similar ($P > 0.05$) feed:gain (F:G). It should be noted that the roughage (DM basis) levels in this summary were 7.0 for HMC and 7.9 for DRC. One potential reason for lower DMI associated with the feeding of HMC may be an increase in subacute ruminal acidosis resulting from increased ruminal starch digestion (Owens & Soderlund, 2006) causing lower ruminal pH for HMC-fed cattle as observed by Krause et al. (2002).

CORN SILAGE IN FINISHING.

It has been demonstrated that cattle can be finished (reach a desirable carcass endpoint) fed diets that vary in ingredient makeup and energy density and that cattle can sometimes maintain ADG by offsetting a lower energy concentration with increased DMI. DiCostanzo et al. (1997) demonstrated a linear increase ($P < 0.05$) in DMI with similar ($P > 0.05$) ADG and an increase in F:G in cattle fed corn silage up to 48% of diet DM. More recently, the University of Nebraska has shown renewed interest in using higher levels of corn silage to produce moderate-energy finishing diets. In a series of trials they consistently showed a reduction in gain and an increase in F:G with higher levels of corn silage inclusion (45% vs 15% of diet DM) with variable effects on DMI (Burken et al., 2013a, Burken et al., 2013b, Burken et al., 2014, Burken et al., 2015 and Hilscher, et al., 2018), however they have sparked some interesting conversations about cost of gain and feedstuff valuation, both of which will be covered by Galen Erickson at this symposium.

With the renewed interest in higher corn silage finishing diets, there has also been renewed interest in the brown midrib (bm3) mutation which yields silage with lower lignin content and higher NDF digestibility. In the past, the limitations to bm3 have been lower yield, susceptibility to weather damage due to lower lignin content, and the need to identify the crop to be put up as silage at planting time, however there are efforts to advance the breeding to bring bm3 more into the mainstream. Hilscher et al. (2018) looked at feeding a standard silage hybrid (CON), a bm3 hybrid (BM3), and an experimental softer endosperm bm3 hybrid (BM3-EXP) at 15 or 45% of diet DM to steers. The premise was that the improvement in NDF digestibility of the bm3 might offset the negative effects on gain and conversion previously seen with feeding the higher level of corn silage. At the 45% inclusion rate BM3 and BM3-EXP improved ($P < 0.05$) ADG over CON (3.67 and 3.68 vs 3.49 lb, respectively), with BM3 also improving ($P < 0.05$) F:G over CON (6.09 vs 6.38). At the 15% silage inclusion rate, BM3-EXP improved ($P < 0.05$) ADG (3.88 vs 3.73 and 3.73, respectively) and F:G (5.63 vs 5.77 and 5.92, respectively) over both CON and BM3. Since BM3 and BM3-EXP at 45% silage inclusion had similar ADG to CON at 15% silage inclusion, they concluded that the improvement in digestibility from the bm3 trait allowed more corn silage to be fed without compromising ADG. Feed conversion, however, was poorer in the comparison suggesting that, while not statistically significant, the trend is still that it takes additional DMI to hold ADG together when feeding elevated levels of corn silage. It is also of interest that even though the fixed effect of silage concentration showed a decrease ($P < 0.1$) in dressing percentage with the 45 versus 15% silage inclusion rate, the bm3 trait was able to alleviate that effect.

It will be interesting to see how the bm3 research progresses. As of now, the agronomic limitations of bm3 along with the feedyard industry's focus on feed efficiency will likely dictate that we continue to harvest conventional hybrids for corn silage production at least for the near future.

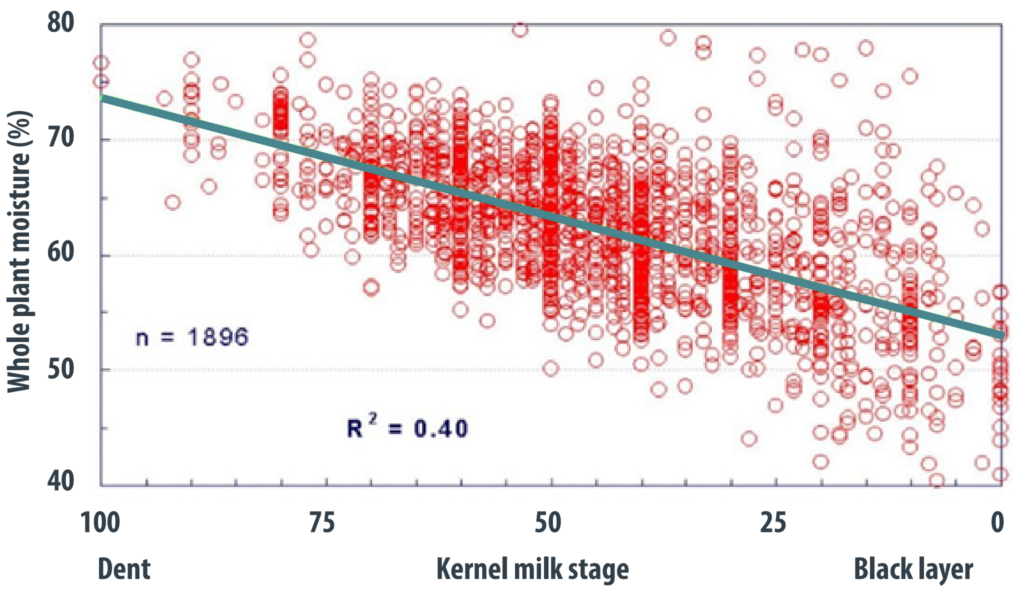
At minimum, corn silage can be used to provide all of the roughage needs in a finisher diet. With a roughage (non-grain) concentration in the 45-55% range (DM basis), corn silage is typically included at 15-20% of diet DM providing approximately 7.5% to 10% roughage, which generally provides adequate effective NDF (eNDF) as evaluated by the NRC model (NRC, 1986). In finishing diets formulated to maximize gain and feed conversion, we could speculate that the ideal corn silage would be high in starch content and low in NDF concentration and digestibility allowing us to meet the scratch requirement while having minimal effect on energy concentration.

WHEN TO CHOP CORN SILAGE?

The combination of moisture and maturity will define the best time for corn silage harvest. However, there is a paradox here; the more mature the corn plant is, the higher the starch content and energy yield/acre but the harder the crop is to properly pack and ensile due to lower moisture. Corn silage is easiest to pack and ensile when the DM of the whole plant is in the 32 to 38% range but the weight of grain, cob, and husk is not maximized until the whole plant reaches somewhere in the 45 to 55% DM range (Owens et al., 2018). While plant moisture and kernel maturity (as measured by milk line) are positively correlated, the variation is quite high (Figure 1). For these reasons, both kernel maturity (milk line) and whole plant moisture must be monitored to optimize nutrient yield and silage preservation. In a perfect world, we would have kernels that are mature (black layer) while the whole plant DM remains at or below 40%. Typically we end up harvesting corn silage at ¾ milk line to balance maturity and moisture. Hilscher et al. (2016) harvested corn silage at 37 and 43% DM and fed at either 15 or 45% of the diet to yearling steers. Later harvesting of silage improved total silage yield, raised the starch level of the silage from 35.4 to 40.8% and reduced the NDF from 31.55 to 28.88% while having no statistically detectable effect ($P > 0.05$) on performance. However, harvesting corn silage at 43% DM did numerically increase ADG from 3.89 to 4.05 lb at the 15% inclusion level due to a numerical increase in DM intake (DMI) from 27.8 to 29.0 lb/d. It is interesting to note that the 43% DM silage would have produced a diet higher in starch and lower in roughage than the 37% DM silage as both silages were fed at the same inclusion rates. Implications?

FIGURE 1.

Relationship between corn silage moisture and kernel maturity (1990-1999). (Lauren, 1999)



SNAPLAGE IN FINISHING.

Advantages of snaplage over high-moisture corn include ~15-20% more dry matter yield per acre (snaplage is typically 80-85% corn), built-in roughage that can either provide all of the needed roughage or at least reduce the need for additional roughage, simple, rapid, and economical harvest using a snapper head on a chopper, earlier harvest, and faster fermentation due to availability of sugars from the cob. Disadvantages include being more difficult to adequately pack which can lead to more shrink and spoilage, additional storage capacity, and potential mycotoxin in the cob fraction.

The timing of snaplage harvest is between corn silage and HMC with much overlap across fields so timeliness of harvest can be a concern, especially if you are relying on custom harvesting. Harvest moisture is critical for snaplage, probably more so than with corn silage or HMC. Harvest should begin when the kernels are black layered and the kernel moisture is at 35% with the goal of getting the pile put up with kernel moisture in the 30-35% range. This will typically result in snaplage with a moisture level of 35-40% due to the cob carrying more moisture than the grain. Snaplage that is harvested too dry can lead to poor packing and fermentation and lower NDF digestibility. Snaplage that is harvested too wet will produce lower DM yields and incur seepage loss at the pit, however it is more favorable to harvest snaplage too wet than too dry. Attention should also be paid to chopping and processing of snaplage with chop length being as small as you can get it (consider a recutter screen) and the kernel processor set between 1 and 2 mm with 40+% differential. Beyond that, good silage making practices should be followed.

Although earlage/snaplage has been a staple in the feeding industry for a long time, there really has been very little research on the feeding value. The simplest is to view it as HMC with added roughage. If we consider snaplage to be around 15 to 20% roughage then the practical feeding rate is up to about 70% of diet DM (depending on the earlage roughage level) when fed with a corn coproduct if we are trying to hold energy concentration up and meet the minimum scratch needs. However, in my experience, most feedyards don't typically put up enough earlage to maximize the inclusion rate and end up feeding some combination of earlage with corn silage or dry roughage to meet the scratch needs along with another energy source such as DRC for the balance of the energy. This can be a good strategy as the combination of snaplage and DRC is favorable from a ruminal fermentation standpoint. It is important to remember that the corn in snaplage should be treated with the same considerations as HMC with regards to diet balancing (roughage level, DIP needs, coproduct interactions, etc.).

ECONOMICS

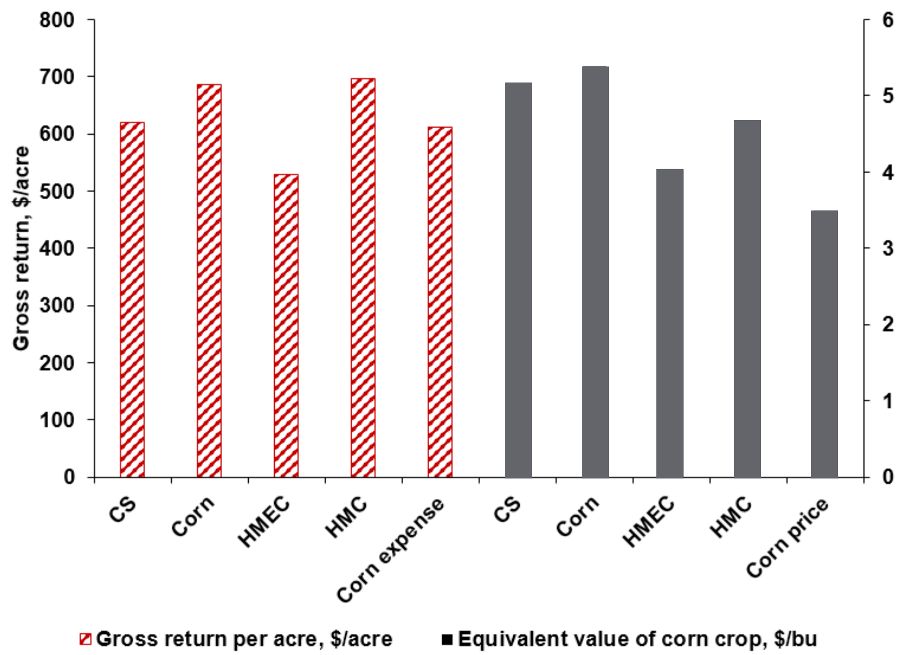
There has been little work done to determine which product is better to harvest from the corn crop. It is simply an arduous task to undertake and there are so many variables and interactions. Johnson et al. (2016) undertook such a study where they harvested and fed the corn plant to yearling steers as either DRC, HMC, HMEC, or silage at 75% of diet DM. Predictably, ADG was lowest for the higher NDF crops (silage and HMEC), with HMC being intermediate (and not different from HMEC) and highest for DRC ($P < 0.05$). Decreased DMI was seen feeding HMC vs DRC as previously discussed.

It should be noted that in this trial HMEC was harvested with a silage harvester head raised to just below the ear. Therefore, the HMEC included all of the upper portion of the plant and was only 53% corn, not much higher than the corn silage at 45% corn, and resulted in a diet that was approximately 33% roughage. I would consider this product a high-roughage earlage and not snaplage or HMEC as typical snaplage will contain 80 to 85% corn. This underlines the importance of properly defining the actual product produced from the corn crop when making crop endpoint decisions. Had the HMEC in this trial been harvested with a snapper head, results of the HMEC treatment might have been expected to rival the HMC treatment. Hill et al. (1995) compared HMEC with or without 8% added alfalfa hay to HMC with 8% added alfalfa hay fed to finishing steers. Similar ($P > 0.05$) ADG, F:G and calculated corn and dietary ME values were noted for all three treatments. Interestingly, the addition of 8% alfalfa to the HMEC diet did not reduce animal performance, suggesting that the dilution of energy by adding roughage to a diet comprised of a highly fermentable feedstuff may be offset by improved digestibility, presumably related to less propensity for subacute acidosis.

From the performance and yield data, Johnson et al. (2016) calculated gross return ($/acre) and equivalent value of the corn crop ($/bu). The authors concluded that despite the differences in agronomic yields and animal feed conversion, interactions between these parameters resulted in no differences in gross return per acre or value of the crops expressed as $/bu of corn harvested (Figure 2).

FIGURE 2.

Gross return per acre and realized grain value for corn silage (CS), corn (fed as DRC), high-moisture ear corn (HMEC) or HMC expressed as $/bu after feeding yearling steers. Corn expense and corn price refer to the total dollars spent to plant, grow and harvest corn and market price at the time of analysis, respectively (Johnson et al., 2016).



The levels of corn silage and HMEC fed in this trial are well above the levels that most nutritionists would practically feed in finishing diets, given the high roughage content of the HMEC, but the performance data may not be the primary point. The authors suggested that since no differences were seen in gross return per acre of equivalent value of the corn crop, the results suggest flexibility in choice of harvest endpoint, which would allow the growing, harvesting, and feeding of a combination of these crops to optimize ruminal starch fermentation while retaining gross returns per acre at least similar to harvesting shell corn.

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SILAGE GROWING PROGRAMS AND IMPORTANCE OF PROTEIN (RUP)

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A tremendous benefit of cattle is their ability to convert a wide range of feedstuffs into edible products for humans. This is very evident in the growing or backgrounding component of the industry where it seems variation and creativity are the norm. With this wide range in feedstuffs, formulating diets to meet nutrient requirements becomes very important, especially for young, growing cattle that have high protein requirements.

Most growing diets are forage based. While forages can have fairly high CP levels, the majority is rumen degradable protein (RDP). The RDP is fermented in the rumen and utilized by the microbes for growth. The growing calf also requires metabolizable protein (MP) which is composed of rumen undegradable protein (RUP; feed protein that escapes degradation in the rumen) and microbial crude protein (MCP; microbes that pass out of the rumen and are a fairly high quality protein source for the animal). Growing diets based on corn silage largely depend on MCP as the source of amino acids for the animal as the RUP content of corn silage is very low.

Accurately measuring the RUP content of corn silage has been challenging. Lab techniques designed to measure RUP values of feedstuffs are specific to either forages or concentrates, and corn silage is a blend of both. The DM content of the corn silage impacts the degradability of the protein (wetter corn silage has a lower RUP content) and the protein continually becomes more degradable with longer ensiling times. Thus, RUP content of corn silage is a moving target. Two experiments using duodenally fistulated steers and in situ bags measured the RUP content of corn silage by breaking the silage down into forage and grain. Results suggest the RUP content of corn silage is 10% of the CP, meaning that the CP within corn silage is 90% rumen degradable (Oney et al., 2018).

Corn silage growing diets are therefore deficient in MP for growing calves. This is clearly demonstrated by a series of trials (Table 1). Folmer et al. (2001) fed a 90% corn silage diet to 619 lb growing steers. The remaining 10% of the diet was composed of soybean meal (6.5%), urea (0.85%), dry-rolled sorghum (1.2%), vitamins and minerals. The soybean meal and urea are both excellent sources of protein, but soybean meal is approximately 70% RDP and urea is 100% RDP. The CP of the diet was 12.4% and cattle gained 2.95 lb/d with a F:G of 6.33. Weber et al. (2011) had a very similar trial with an 80% corn silage diet fed to 613 lb growing steers. Supplement in this trial was 15% distillers grains (DGS), fine ground sorghum (3%), vitamins and minerals. The DGS contain 30% CP and this CP is 63% RUP. The CP of the diet was 13.0% and cattle gained 3.61 lb/d with a F:G of 5.75. Felix et al. (2014) fed a 79% corn silage growing diet to 590 lb growing steers. Three treatments were evaluated, cattle supplemented 1.43% urea, 9.2% soybean meal with 9.6% ground corn, or 18% DGS. The CP of all diets was 10.7% and cattle gained 2.90, 3.39, and 3.45 lb/d day for the urea, soybean meal, and DGS diets, respectively. Within this trial, F:G improved from 5.29 for the urea treatment to 4.74 for the DGS treatment. In another trial by Felix et al. (2014) cattle were fed a 90% corn silage diet with 1.37, 1.74, or 2.11% urea. This increased CP of the diet from 12.9 to 15.4% and resulted in a linear increase in F:G

(5.80 to 6.15) as urea in the diet increased. Supplying equal or even greater amounts of CP does not result in equal performance and correctly formulating diets on an MP basis is critical.

The response to DGS in these trials is not solely due to its RUP content. Therefore, 2 trials were done with individually fed cattle to evaluate the response to increasing amounts of RUP supplement [Hilscher et al., 2016 (Table 2); Oney et al., 2017(Table 3)]. The supplement was a blend of SoyPass (50% CP, 75% of CP is RUP) and Empyreal (Cargill Corn Milling, Blair, NE; 75% CP, 65% of CP is RUP). Between the 2 trials, 9 levels of supplement were offered from 0 to 13% of diet DM. The highest level of supplement provided 5.5% of diet DM as RUP. With the combined data there was a quadratic increase in ADG as supplement increased, going from 2.50 lb/d to 3.05 lb/d with a peak at approximately 3.2% RUP. Supplementing the RUP improved both ADG and F:G by meeting MP requirements, interim BW measurements suggest this response was even more apparent early in the feeding period when MP requirements of growing calves are greatest. The first 30 days of a growing period are a critical time for RUP supplementation.

At this time the most economical source of RUP is DGS. Feeding corn silage with DGS will promote good growth (up to 4 lb ADG) fairly efficiently. Comparing 2 trials feeding 15 or 21% DGS in corn silage growing diets shows increased ADG (3.62 vs 4.17 lb/d) and increased efficiency (5.86 vs 4.98 F:G) for the 21% DGS (Hilscher et al., 2018; Ovinge et al., 2019). These treatments have not been evaluated within the same trial; however, it appears that blending corn silage and DGS gives great opportunity to program feed or target a desired level of gain. The economics of feeding these diets is constantly changing and will be addressed by others at this conference (Accurately Pricing Corn Silage; Terry Klopfenstein and Henry Hilscher).

With high quality corn silage and a little protein calves can grow at a rate approaching 3 lb/d. Utilizing DGS to provide some of the CP as RUP can increase gain beyond 3.5 lb/d. Formulating diets to meet the MP requirements of cattle is very important in order to be able to optimize the blend of corn silage and DGS and reach target body weight gains. This is especially true early in the growing period when MP requirements are greatest.

TABLE 1.

Summary of trials feeding corn silage diets to growing cattle

	% of diet DM					
REFERENCE	Silage	CP	RUP[1]	Initial BW, lb	ADG, lb	Feed:Gain
Folmer, 2002[2]	90	12.4	2.24	619	2.95	6.33
Weber, 2011[3]	80	13.0	3.69	613	3.61	5.75
Hilscher, 2018[4]	80	13.3	3.67	714	3.62	5.86
Ovinge, 2019[5]	75	15.1	4.76	699	4.17	4.98

[1] Assuming RUP content of corn silage is 10% of CP
[2] 101 d trial, 128 steers fed in 16 pens
[3] 86 d trial, 240 steers fed in 20 pens
[4] 76 d trial, 216 steers fed in 18 pens (data shown are from control treatment; 72 steers and 6 pens)
[5] 70 d trial, 288 steers fed in 36 pens (data shown are from control 75% silage treatment; 48 steers and 6 pens)

TABLE 2.

Effects of increasing RUP in silage based growing diets on steer performance

	Treatments[1]					P - value	
Variable	0.5%	1.4%	2.4%	3.3%	4.2%	Lin.	Quad.
Initial BW, lb	595	597	597	596	600	0.98	0.60
Ending BW, lb	791	824	855	842	868	< 0.01	0.88
ADG, lb	2.51	2.91	3.31	3.15	3.43	< 0.01	0.82
Feed:Gain	6.74	6.26	5.71	5.52	5.35	< 0.01	0.57

[1] Adapted from Hilscher et al. (2016). Treatments were based on amount of RUP provided by the supplement (% of diet DM). All cattle were fed 88% corn silage with 0, 2.5, 5.0, 7.5, or 10% SoyPass + Empyreal (% of diet DM).

TABLE 3.

Effects of increasing RUP in silage based growing diets on steer performance

	Treatments[1]					P - value	
Variable	0.4%	1.7%	3.0%	4.2%	5.5%	Lin.	Quad.
Initial BW, lb	605	606	604	608	604	0.99	0.86
d 1-37							
Interim BW, lb	692	707	713	730	729	0.03	0.26
ADG, lb	2.34	2.74	2.96	3.29	3.38	< 0.01	0.06
Feed:Gain	6.45	5.62	5.24	4.83	4.48	< 0.01	0.10
d 38-83							
Ending BW, lb	808	833	829	864	857	0.01	0.17
ADG, lb	2.52	2.74	2.51	2.92	2.78	0.10	0.28
Feed:Gain	6.58	6.76	7.30	6.33	6.54	0.64	0.86

[1] Adapted from Oney et al. (2017). Treatments were based on amount of RUP provided by the supplement (% of diet DM). All cattle were fed 85% corn silage with 0, 3.25, 6.5, 9.75, or 13% SoyPass + Empyreal (% of diet DM).

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CORN SILAGE AND EARLAGE
Characteristics and Use in Iowa (2017)

An Iowa Beef Center Project

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INTRODUCTION

Approximately 349,000 acres of corn are harvested as corn silage in Iowa. (USDA Census of Ag 2012-2016) No data is available on number of acres harvested as earlage. Both of these feeds can increase beef production per acre as compared to corn grain but require good management from production through feeding to optimize beef production. Little information has been collected about production practices that are being used in Iowa and if there is any correlation to the feeding value of the feeds.

A survey of production, harvesting, storage and feeding practices combined with sample analysis was completed to help characterize production and feeding practices and nutrient analysis.

SURVEY METHODS

A survey was developed to gather data from producers who utilized corn silage or earlage. The survey included questions on acres harvested, verities used, type of harvesting equipment, estimated yield, storage methods and feeding practices (Table 1). The survey was mailed to selected producers and also made available on line through the Iowa Beef Center website during the winter and spring of 2017. Ninety six completed surveys were returned. Forty six of the surveys were from producer using silage, 31 were from producers who utilized both corn silage and earlage, and 19 used earlage only.

TABLE 1.

Survey results

Survey information reported	Silage	Earlage
Number of surveys: 96 total	**77 (31 for both)**	**50 (31 for both)**
Hybrid for corn silage planted	32%	NA
Total acres of those completeing surveys	10000	18000
Average acres harvested per producer	129	427
Range in acres harvested per producer	8- 1000	7-2800
Reported yield range wet basis	20 to 31 ton/acre	9.3 to 15.8 ton/acre
Harvest time per acre average and range	1.44 hours/ acre avg 1 -6.7 hours/acre	.025 hours/acre avg .08-.34 hours/acre
Reported moisture target for harvest	63% avg 55-66% range	33.6% avg 30% - 40 % range
Estimated reported moisture at harvest		
Start and finish	64% start and 56% finish	36% start -31.5 % finish
Use Custom harvester	60%	80%
Kernel processing used	72%	NA
Inoculant used	58%	58%
Storage type	37% bunker, 32 % silage bag, 18% drive over pile, 13 % upright silo	52.5% bunker, 24.6 % silage bag, 13.1% drive over pile, 9.8 % upright silo
Testing	40% for moisture, 66% for nutrient	66% for both moisture and nutrient
Cut length	.625 in .25-1.25 in	NA

PRODUCER CHARACTERISTICS

80 % of surveys were from producers in northern Iowa but all of Iowa was represented.

Producers only harvesting silage

42 were cow calf producers with an average herd size of 162 head.

36 were feedlot operators with an average size of 666 head one time inventory.

Producers harvesting both corn silage and earlage

18 were cow calf with average herd size of 262 cows and

30 were feedlot with average inventory of 1297 head.

Producers harvesting earlage only

19 feedlot operators with an average inventory of 2544 head

For those using bunker or drive over pile storage for corn silage, reported packing time per load averaged 8.4 minutes per load with a range of 2 minutes to 15 minutes per load. Packing equipment most commonly used was a four wheel drive tractor with a blade. 78% of those using a bunker or drive over pile for storage used a cover.

For those using bunker or drive over pile storage for earlage, packing time per load averaged 10.7 minutes with a range of 3.5 minutes to 30 minutes per load. Packing equipment most commonly used was a four wheel drive tractor with a blade. 92% of those using a bunker or drive over pile covered the bunker or pile.

There was considerable variation in practices used in silage production, harvest and storage by producers represented in the surveys. The sample analysis data was sorted by several of the characteristics of production, harvest and storage in the survey responses. No major differences in averages of the nutrient analysis were observed.

USE OF SILAGE AND EARLAGE IN DIETS

The majority of those using corn silage or earlage fed them in a total mixed ration. The following tables show the average and range of percent corn silage or earlage being fed in diets on an as fed basis across all those who responded. 42% indicated they used corn silage as primary source of effective fiber in the diet.

On average the 42% of producers using corn silage as effective fiber had higher inclusion percent of corn silage in diets than the 58% that did not indicate that corn silage was the primary source of effective fiber. For 400-600 lb. cattle, corn silage was 20% points higher in the diet and 12-13% points higher on other weight ranges. For beef cows the inclusion percent 100-200 days pre calving was 19 % points higher, 16 % points higher immediately after calving and 5 to 7 % points higher in the other two defined periods. Average targeted cut length was .63 in for those using corn silage as effective fiber and 1 in for those indicating it was not the primary source of effective fiber.

TABLE 2.

Average and range of percent corn silage as fed included in diets for feedlot cattle and beef cows

	Feedlot cattle weight ranges in lbs.			
	400-600	**600-800**	**800-1000**	**>1000**
Avg	26.46	24.04	16.35	11.58
Min	5.00	5.00	5.00	4.00
Max	80.00	70.00	60.00	70.00
	Beef cow stage - days relative to calving			
	100-200 pre	**100 to calving**	**Calving to 50 post**	**50-100 post**
Avg	33.76	38.84	27.72	13.38
Min	10.00	10.00	10.00	20.00
Max	75.00	80.00	75.00	50.00

TABLE 3.

Average and range of percent earlage as fed included in diets for feedlot cattle

	Feedlot cattle weight ranges in lbs.			
	400-600	**600-800**	**800-1000**	**>1000**
Avg	30.0	36.0	38.2	35.0
Min	5	10	10	10
Max	95	75	75	80

SAMPLE ANALYSIS METHODS

Sample analysis of corn silage and earlage samples were available to producers participating in the survey. Sampling was completed by the producer or Extension Beef Field Specialist. Thirty five silage samples and 20 earlage samples were sent to Dairyland Labs for analysis. Corn silage samples were analyzed using the Near Infrared Complete Corn Silage analysis, which includes all nutrient analysis, digestibility analysis, and some fermentation analysis measures. Earlage samples were analyzed using the NIR UW Grain analysis which includes nutrient analysis, fermentation analysis and grain particle size analysis measures. Of those completing surveys, 27 submitted silage samples and 20 submitted earlage samples.

In addition to the laboratory analysis, the Penn State Particle Separator was used when possible to evaluate particle size, mainly on samples collected by field specialists. Ten silage samples and 17 earlage samples were evaluated using the particle separator

ANALYSIS RESULTS

Analysis of corn silage and earlage samples showed a large variation in most of the traits. Utilizing a book value for the individual samples in formulating a diet would result in an error in calculated feed and nutrient intake in most situations. Only 40% of survey respondents tested for moisture content routinely on silage and two-thirds analyzed silage for nutrients and moisture and nutrients for earlage. Analysis averages, minimums, maximums, and standard deviations for a few of the analyzed characteristics are shown in Table 4 and Table 5.

Samples were sorted by information provided on the associated survey. Averages by silage variety used or not, storage type or other characteristics did not vary greatly within this sample set. Sample moisture was compared to the target moisture indicated on the producer survey. Analyzed moisture of silage samples was on average 9.25% percent points and on earlage samples 6.25% percent points different than the targeted moisture indicated on the survey. As in any sampling of high moisture feed, sampling time and method could be a potential source of variation.

The Penn State Particle Separator results are shown in Table 6 for corn silage samples and Table 7 for earlage sample. Again, there was considerable variation among the samples. The targeted cut length stated on the survey was compared to the particle separator data where available. There was a clear trend that the smaller target cut size the particle size was smaller.

For the samples that had associated survey estimates on yield the corn silage to beef calculator excel spreadsheet was used to calculate beef per acre for corn silage and earlage. Those results ranked in order of beef per acre are in Tables 8 and 9.

TABLE 4.

Corn silage sample analysis 35 samples

	Average	Maximum	Minimum	Standard Deviation
Dry Matter	43.26%	58.85%	28.65%	8.12%
Crude Protein	6.84%	8.74%	5.47%	0.74%
Adj. Crude Protein	6.72%	8.74%	5.47%	0.73%
Calcium	0.21%	0.36%	0.16%	0.05%
Phosphorus	0.23%	0.27%	0.20%	0.01%
Magnesium	0.14%	0.23%	0.10%	0.03%
Potassium	0.92%	1.38%	0.10%	0.28%
Sulfur	0.13%	0.90%	0.09%	0.16%
Starch	40.50%	48.58%	21.78%	6.22%
Ash	5.19%	7.94%	3.58%	1.02%
Sugar (ESC)	1.17%	8.70%	0.25%	1.67%
NFC	51.75%	62.30%	36.80%	5.26%
Fat (EE)	3.36%	3.93%	2.80%	0.30%
ADF	23.27%	33.57%	19.36%	3.35%
aNDF	34.51%	46.84%	24.29%	4.53%
Lignin	9.61%	20.44%	7.55%	2.45%
NDFD 30	51.79%	60.64%	29.48%	5.58%
uNDFom30	16.19%	22.94%	11.63%	2.67%
pH	4.05	4.52	3.54	0.1988
Lactic Acid	2.74%	5.63%	0.60%	1.09%
Acetic Acid	1.83%	3.37%	0.57%	0.87%
Propionic Acid	0.39%	0.65%	0.21%	0.14%
Silage Acids	4.93%	8.29%	1.71%	1.51%
NEm OARDC, Mcal/cwt	72.55	79.27	0.77	15.32
NEg OARDC, Mcal/cwt	48.17	52.11	38.67	3.52
Nem ADF, Mcal/cwt	75.47	80.01	71.47	1.71
Neg ADF, Mcal/cwt	47.80	51.80	44.26	1.51

TABLE 5.
Earlage sample analysis 20 samples

	Average	Maximum	Minimum	Standard Deviation
Dry Matter	66.10%	76.84%	52.82%	6.13%
pH	4.17	4.77	3.44	0.35
Crude Protein	7.86%	8.62%	6.58%	0.60%
Adj. Crude Protein	7.77%	8.62%	6.58%	0.63%
Calcium	0.66%	6.00%	0.04%	1.77%
Phosphorus	0.26%	0.31%	0.23%	0.02%
Magnesium	0.11%	0.13%	0.10%	0.01%
Potassium	0.45%	0.51%	0.40%	0.03%
Starch	60.11%	65.99%	49.61%	3.94%
Ash	1.75%	2.24%	1.48%	0.19%
Sugar (ESC)	1.07%	2.33%	0.15%	0.55%
NFC	72.30%	78.77%	63.29%	4.05%
Fat (EE)	3.55%	4.01%	3.09%	0.25%
ADF	7.61%	12.03%	5.08%	1.83%
aNDF	15.65%	25.13%	9.43%	4.06%
Lactic Acid	1.12%	2.06%	0.41%	0.45%
Acetic Acid	0.50%	1.61%	0.12%	0.36%
NEM ORDAC Mcal/cwt	92.77	95.69	88.85	2.19
NEG ORDAC Mcal/cwt	62.82	65.31	59.47	1.87
Nem ADF Mcal/cwt	92.04	94.45	88.20	1.72
Neg ADF Mcal/cwt	62.20	64.26	58.91	1.47
Mean Particle Size MPS, microns	2101.00	2823.00	1630.00	368.37
Effective MPS, microns	711.54	1786.00	0.00	686.50

TABLE 6.
Penn State Particle Separator results for silage- 10 samples

	Average	Maximum	Minimum	Standard Deviation
Top tray	7.78%	15.40%	2.50%	5.21%
Middle tray	54.57%	61.90%	43.59%	6.48%
Bottom tray	37.65%	53.85%	26.50%	9.55%

TABLE 7.
Penn State Particle Separator results for earlage 17 samples

	Average	Maximum	Minimum	Standard Deviation
Top tray	4.55	10.00	1.34	2.94
Middle tray	23.78	44.16	12.50	10.31
Bottom tray	69.37	85.00	32.50	15.22

TABLE 8.
Pounds of beef per acre of corn silage

Bu yield	Silage yield ton	Dry matter	%NDF	% NDF digestibility	Beef per acre, lb.
247.5	28	58.85	32.51	54.9	3496.4
247.5	28	55.23	32.3	51.85	3208.0
220	21	51.01	30.98	54.44	2320.8
215	23.5	44.52	33.58	53.77	2151.0
228	26	38.99	31.77	56.88	2105.4
225	30	37.27	37.24	55.72	2077.9
225	24	44.30	37.4	54.65	1978.8
197.5	18.5	43.86	31.9	49.23	1876.6
190	18	39.89	31.64	53.8	1519.7
182.5	22	39.76	38.93	50.42	1479.2
197.5	18.5	37.92	36.19	49.97	1422.9

TABLE 9.
Pounds of beef per acre of earlage

Bu yield	Earlage yield ton	Dry matter	%NDF	% DM digestibility	Beef per acre, lb.
275	17.5	52.82	21.53%	82.67%	2961
225	12	76.84	18.55%	84.23%	2953
225	12	68.25	20.41%	82.70%	2623
210	11	66.39	9.43%	87.26%	2343
230	11	61.44	16.30%	84.47%	2166
248.5	8	67.92	12.36%	86.57%	1743

ACKNOWLEDGEMENTS

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FEEDING PROGRAMS FOR SILAGE IN FINISHING CATTLE

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INTRODUCTION

Feeding corn silage is not a new concept for finishing beef cattle. Most feedyards process corn silage to be fed as acroughage at low inclusions. In general, corn silage contains 50% forage and 50% grain and is commonly added at 5 to 15% of diet DM in finishing diets. Please note that all proportions discussed in this paper are inclusions on a DM basis in diets. With silage containing 34 to 38% DM (62 to 66% moisture), then proportion in the diet on a DM basis is quite different than proportions on an as-fed basis and conversion is needed when adding ingredients to mix the final diet. Most nutritionists feed silage assuming it were 100% forage whereas inclusion should probably be considered on an equal NDF basis to other forages, or assuming it is 50% forage given that the corn content is about 50% on a DM basis. Another consideration is that the grain is very wet high-moisture corn in silage.

With more distillers grains supply and expensive grain years ago, we researched feeding corn silage at greater than usual (i.e., roughage source only) inclusions and the impact on performance and economics of feedlot cattle. Many feedyards in the Midwest are farmer-feeder operations that own their own cattle and crop ground. If priced correctly and shrink is managed, silage is one of the most economical sources of energy which lead to research to maximize inclusion. In addition, numerous technologies may further benefit silage use such as hybrid selection and traits, kernel processing, and different combinations with grain and distillers grains. Lastly, recent laboratory and performance data suggest that the protein in silage is mostly degradable and the RUP content is considerably lower than previously thought (approximately 10% of CP as RUP). This paper will focus on recent research on corn silage inclusion, impact of hybrids, and kernel processing.

CORN SILAGE INCLUSION

Past research focused on increasing corn silage and replacing corn grain, which was economical at inclusions of 40 to 60% when grain was expensive. The perception was that if grain is cheap, then feeding elevated amounts of corn silage was not economical. However, some yards tend to use silage to "grow"calves as well for a period of 40 to 70 days before stepping them down on silage and up on grain. A silage growing program will normally contain 70% silage or more in the diet.

We have contained numerous experiments in the past 7 years evaluating elevated amounts of silage for finishing cattle. In 5 experiments that compared 15% inclusion to 45% inclusion for finishing cattle, ADG decreased by 5.2% or 0.2 lb/d (Table 1). In some studies with yearlings, cattle fed 45% silage tended to eat more, with less impact on ADG. In calf-fed studies, feeding 45% silage either resulted in no change in intake or slight decrease compared to feeding 15% so no significant change in DMI. However, feed conversion is consistently poorer with F:G being 6.7% greater for cattle fed 45% silage compared to 15%. In almost all studies (except one discussed later), cattle were fed the same days which resulted in cattle being marketed with slightly lower marbling scores and fatness. Despite being economical, no producers have adopted this practice of elevating silage inclusions. Managing the inventory needed in large operations is a limitation, and in general, producers and nutritionists focus on feed conversion. At times, the focus on F:G is at the expense of profitability or cost of gain.

Many feedyards are open to growing cattle for a period prior to finishing. We wanted to evaluate feeding 45% corn silage (on average) by feeding 75% silage for the first half of the feeding period and 15% silage for the second half of finishing, and compare to feeding either 15% or 45% silage continuously over the whole feeding period (Ovinge et al., 2018 Midwest ASAS abstract). In addition, cattle fed 45% silage were consistently less fat than cattle fed 15% silage. Therefore, ultrasound was used and we attempted to slaughter cattle at equal fatness by feeding cattle on the treatments with elevated silage 28 days longer. Cattle fed 75/15 or 45% silage had similar intake, ADG, and F:G to one another (Table 2). However, both treatments resulted in lower ADG and poorer (i.e., greater) F:G than cattle fed 15% silage. Because cattle fed 75/15 or 45% silage continuously were fed 28 days longer to get to similar fatness, HCW was greater for those treatments compared to feeding 15% to get to the same fatness.

BROWN MIDRIB CORN SILAGE

If cattle are going to be fed 45% silage in feedlot diets, other technologies may be beneficial if fiber digestion can be improved. One example would be use of brown midrib corn silage hybrids. Hilscher et al. (2018a) evaluated feeding a brown midrib hybrid or a brown midrib with a softer endosperm compared to a control hybrid on performance. At 15% inclusion, the softer endosperm brown midrib hybrid increased gain compared to the other 2 hybrids, but not a large impact due to the brown midrib trait at 15% inclusion (Table 3). However, at 45% inclusion, feeding either brown midrib hybrid increased gain compared to the control hybrid with variable impacts on F:G. In a growing study, the response to brown midrib hybrids improving performance was different than what was observed in the finishing trial. Cattle fed either brown midrib hybrid had dramatically greater intakes compared to control (Table 4). As a result of a 3 lb greater daily DMI, ADG was increased by 0.6 lb/d but no differences were observed in F:G across the 3 silage hybrid treatments. Feeding brown midrib silage growing diets with 80% silage inclusion increases fiber digestion (Table 5) which increases passage, increases DMI, increases ADG, but does not impact F:G in silage growing programs. The reason is that when 80% silage-based diets are fed, intake is limited by gut fill. In finishing diets where intake is limited more by energy, then intake may increase but doesn't appear as dramatic as growing diets. In a followup finishing study with 40% silage inclusion, feeding the same brown midrib hybrids increased DMI by 1.1 to 1.5 lb/d, increased ADG by 0.35 to 0.40 lb/d, and improved F:G by 4.6% compared to a control hybrid (Table 6). Those cattle were very big yearlings consuming an average of over 30 lb of DM daily.

KERNEL PROCESSING

In the same study evaluating brown midrib hybrids at 40% inclusion, hybrids were kernel processed or not and the interaction between hybrid and kernel processing was evaluated. No interaction was observed between kernel processing and hybrid. A typical energy response was observed for kernel processing whereby ADG was not impacted by kernel processing silage and feeding it at 40% inclusion. However, steers fed silage that was kernel processed ate less feed to get the same ADG, resulting in a

2.9% improvement in F:G (Table 7). These data suggest that kernel processing of silage is worth about 7.25% improvement in F:G assuming the entire change in F:G is due to improving the silage fed at 40% of the diet (2.9%/0.4). A different recent growing silage study that evaluated kernel processing with silage inclusion of 80% of diet DM suggests a 6.6% improvement in the silage due to kernel processing (data unpublished).

CONCLUSION

If corn silage is priced correctly, then feeding 2 or 3 times more silage to finishing cattle will result in poorer feed conversion by about 5%. This is dependent on silage hybrids and kernel processing. If more silage is going to be used during finishing, having sufficient bypass protein from distillers grains is important. Most of these studies used 20% or more distillers grains on a DM basis. If producers don't want to use 45% silage, but want to grow cattle on high-silage diets and step them down halfway through, then performance is the same as if feeding 45% silage continuously. In addition, cattle can be fed a bit longer and to heavier weights prior to getting too fat. Those economics get complex and need to be explored by individual operations.

For more information on our research program, please visit our beef website (beef.unl.edu).

TABLE 1.

Effect of 15% or 45% corn silage (DM basis) on performance and carcass characteristics across 5 experiments.

	Treatment1		
Item	15	45	P-Value
Pens, n	58	58	
Performance			
DMI, lb/day	24.5	24.9	0.17
ADG, lb[2]	3.86	3.66	<0.01
Feed:Gain[2]	6.29	6.71	<0.01
Carcass Characteristics			
HCW, lb	865	861	0.40
Marbling Score[3]	458	446	0.02
Backfat Thickness, in	0.555	0.537	0.07

[1] Across 5 experiments, 22 pens of yearlings, 36 pens of calf-feds. Diets fed with either 20 or 40% distillers grains.

[2]Calculated from hot carcass weight, adjusted to a common 63% dressing percentage

[3]Marbling Score 400-Small00, 500 = Modest00

TABLE 2.

Effect of growing cattle on corn silage at 75% followed by 15% compared to cattle fed 15% or 45% continuously, with cattle fed elevated silage longer to equal fatness (Ovinge et al., 2018a Midwest ASAS abstract).

	Treatment1			
Item	15	45	75/15	P-Value[2]
Pens, n	12	12	12	
DOF, d	153	181	181	
Performance				
DMI, lb/day	23.7	23.6	23.0	0.09
ADG, lb[3]	4.02[a]	3.82[b]	3.73[b]	<0.01
Feed:Gain[3]	5.88[a]	6.18[b]	6.17[b]	<0.01
Carcass Characteristics				
HCW, lb	829[a]	877[b]	866[b]	<0.01
Dressing Percentage	62.73[a]	61.65[b]	61.75[b]	<0.01
LM Area, in^2	13.13[a]	13.51a[b]	13.64[b]	0.05
Marbling Score[4]	460	480	473	0.32
Backfat Thickness, in	0.53[a]	0.60[b]	0.55[ab]	0.05
Liver Abscesses, %[5]	6.25	2.08	3.13	-

[a,b]Means with different superscripts differ ($P < 0.05$).

[1] Treatments were 15% silage inclusion, 45% silage inclusion, and 75 to 15% silage inclusion

[2] P-value for the main effect of corn silage inclusion

[3] Calculated from hot carcass weight, adjusted to a common 63% dressing percentage

[4] Marbling Score 400-Small00, 500 = Modest00

[5] Liver abscess data did not converge

TABLE 3.

The effects of silage inclusion and silage hybrid on feedlot performance and carcass characteristics in calf fed steers (Hilscher et al., 2018a Beef Report).

	Treatments1									
	15% corn silage			45% corn silage						
	CON	BM^{3}	BM^{3}-Exp	CON	BM^{3}	BM^{3}-EXP	sem	Int.[2]	Concen-tration[3]	Hybrid[4]
Feedlot performance										
DMI, lb/d	21.5	22.1	21.8	22.3	22.4	23.0	0.3	0.19	< 0.01	0.11
ADG5, lb	3.73^{b}	3.73^{b}	3.88^{a}	3.49^{c}	3.67^{b}	3.68^{b}	0.04	0.05	< 0.01	< 0.01
Feed:Gain[6]	5.77^{b}	5.92^{c}	5.63^{a}	6.38^{e}	6.09^{d}	6.26^{e}	-	0.01	< 0.01	0.45
Carcass Characteristics										
HCW, lb	882^{b}	880^{b}	898^{a}	855^{c}	875^{b}	877^{b}	4.3	0.04	<0.01	< 0.01
Dress, %	64.05^{b}	64.15^{a,b}	64.64^{a}	62.75^{c}	63.89^{b}	63.87^{b}	0.19	0.03	< 0.01	< 0.01
12th rib fat, in	0.56	0.55	0.59	0.47	0.49	0.52	0.02	0.76	< 0.01	0.23
Marbling score	451	455	475	413	425	443	10.0	0.90	< 0.01	0.03

[a,b,c,d,e] Means with different superscripts differ ($P < 0.05$).

[1] Treatments were control (CON; hybrid-TMR2R720), a bm3 hybrid (BM3; hybrid-F15579S2), and an experimental bm3 hybrid (BM3-EXP; hybrid-F15578XT) with a softer endosperm

[2] Silage Concentration × Silage hybrid interaction

[3] Fixed effect of silage concentration

[4] Fixed effect of silage hybrid

[5] Final BW calculated based on HCW / common dressing percent of 63.8%

[6] F:G was analyzed as gain to feed.

[7] Marbling score 400 = small00, 500 = modest00

TABLE 4

Effects of feeding two different bm3 corn silage hybrids on growing steer performance (Hilscher et al., 2018b).

	Treatments				
Variable	**CON**	**BM3**	**BM3-EXP**	**sem**	**P-value**
Initial BW, lb	714	713	714	0.7	0.80
Ending BW, lb	989b	1035a	1032a	4.9	< 0.01
DMI, lb/d	21.2b	24.0a	24.1a	0.2	< 0.01
ADG, lb	3.62b	4.23a	4.19a	0.06	< 0.01
Feed:Gain2	5.86	5.67	5.74	-	0.26

[a,b,c] Means with different superscripts differ ($P < 0.05$).

[1] Treatments were control (CON; hybrid-TMR2R720), a bm3 hybrid (BM3; hybrid-F15579S2), and an experimental bm3 hybrid (BM3-EXP; hybrid-F15578XT) with a softer endosperm.

[2] Feed:Gain was analyzed as gain to feed, the reciprocal of feed:gain.

TABLE 5.

Effects of feeding two different bm³ corn silage hybrids on intake and digestibility of nutrients (Hilscher et al., 2018[c]).

	Treatments[1]				
Item	**Control**	**BM3**	**BM3-EXP**	**SEM**	**P-Value**
DM					
Intake, lb/d	15.0	16.5	16.2	1.1	0.11
Digestibility, %	64.5	67.7	69.0	1.6	0.11
OM					
Intake, lb/d	13.8	15.1	15.1	1.0	0.11
Digestibility, %	66.8[b]	70.0[ab]	71.6[a]	1.4	0.05
NDF					
Intake, lb/d	5.9	6.5	6.1	0.4	0.08
Digestibility, %	45.3[b]	57.8[a]	57.0[a]	2.2	<0.01

[1] Treatments were control (CON; hybrid-TMR2R720), a bm3 hybrid (BM3; hybrid-F15579S2), and an experimental bm3 hybrid (BM3-EXP; hybrid-F15578XT) with a softer endosperm.

[a,b,c] Means with different superscripts differ (P < 0.05).

TABLE 6

Main effect of corn silage hybrid on cattle performance and carcass characteristics with silage fed at 40% of diet DM to finishing yearlings (Ovinge et al., 2018b beef report).

	Treatment1				
Item	**Control**	**bm3**	**bm3-EXP**	**SEM**	**P-Value2**
Pens	12	12	12		
Performance					
Initial BW, lb	882	882	882	11.8	1.00
Final BW, lb[3]	1310[a]	1347[ab]	1354[b]	13.7	0.07
DMI, lb/day	31.3[a]	32.4[b]	32.8[b]	0.33	0.01
ADG, lb[3]	4.12[a]	4.47[b]	4.54[b]	0.058	0.01
Feed:Gain[3]	7.58[a]	7.24[b]	7.22[b]	-	0.04
Carcass Characteristics					
HCW, lb	826[a]	849[ab]	853[b]	8.7	0.07
LM Area, in²	12.5	12.5	12.5	0.09	0.99
Marbling Score[4]	476[a]	516[b]	511[b]	7.1	0.01
Backfat Thickness, in	0.54	0.58	0.56	0.015	0.20
Liver Abscesses, %	9.09	4.73	6.46	2.86	0.56

[a,b]Means with different superscripts differ (P < 0.05).
[1]Treatments were control (CON; hybrid-TMF2H708), a bm3 hybrid (bm3; hybrid-F15579S2), and an experimental bm3 hybrid (bm3-EXP; hybrid-F15578XT) with a softer endosperm
[2] P-value for the main effect of corn silage hybrid
[3] Calculated from hot carcass weight, adjusted to a common 63% dressing percentage
[4] Marbling Score 400-Small00, 500 = Modest00

TABLE 7.

Main effect of kernel processing of corn silage when fed at 40% of diet DM on growth performance and carcass characteristics (Ovinge et al., 2018b beef report)

	Treatment1		SEM	
Item	**KP**	**+KP**	**-**	**P-value[2]**
Pens, n	18	18		
Performance				
Initial BW, lb	882	882	9.6	0.99
Final BW, lb[3]	1337	1338	11.2	0.96
DMI, lb/day	32.6	31.8	0.27	0.04
ADG, lb[3]	4.38	4.38	0.047	0.93
Feed:Gain[3]	7.45	7.24	-	0.10
Carcass Characteristics				
HCW, lb	842	843	7.1	0.96
LM Area, in[2]	12.5	12.5	0.07	0.78
Marbling Score[4]	501	501	5.9	0.97
Backfat Thickness, in	0.56	0.56	0.012	0.70
Liver Abscesses, %	4.60	9.23	2.32	0.34

[1] Treatments were not kernel processed (-KP) or kernel processed (+KP)
[2] P-Value for the main effect of kernel processing
[3] Calculated from hot carcass weight, adjusted to a common 63% dressing percentage
[4] Marbling Score 400 = Small 00, 500 = Modest 00

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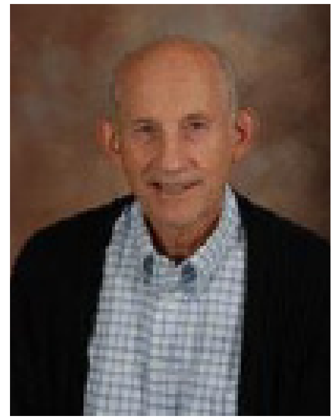
ACCURATELY PRICING CORN SILAGE



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Of course, the economics are important. The biology is essential to be able to do the economics, but the biology alone without economics is not especially important to producers. Here is our attempt to put economics to the biology that has been presented.

There are 2 very important issues that need to be addressed. First is the price of the corn grain to use for pricing the corn silage in the field and second is valuing the manure.

We will discuss pricing assuming the silage is being purchased from a corn producer, realizing many cattle operations will also have a farming operation. The principle is the same. Most corn producers don't want to price the corn in September because on average, it is the lowest price of the year. Corn price increases from harvest through the next Spring and Summer.

However, the grain must be stored until that time of higher price. Storage costs increase from about $0.30/bu for the first month, plus about $0.03 for each additional month. Corn price increases about 15% to a peak in April to July. The cost of storage is about equal to the price increase from harvest to Spring. If you cut silage, you pay the storage cost in the silo. Therefore, it is logical to price corn in the field based on the price of grain at harvest. For our calculations, we used September futures price (April 2) minus the basis $3.73/bu. ($4.12-0.39).

In the past, corn producers have charged for the plant nutrients (N & P) removed in the forage portion of the corn plant when silage is harvested. That is logical, but the same producers have not wanted to pay for the nutrients in the manure resulting from the feeding of the silage. Table 1 shows the nutrients in the manure from feeding 45% silage in a finisher. That includes the nutrients from the other ingredients in the diet. Further, Rick Koelsch (UNL Beef Watch) has reported the following benefits to manure over commercial fertilizer: increased crop yields, increased soil microbial mass, decreased N losses, increased water stable soil aggregates and increased soil carbon. Therefore, it seems logical that the corn producer should pay for the manure returned to the fields from which the silage was cut. The manure would supply about 4 times the P level needed for plant growth. The three options to accommodate the P are shown in Table 2. Rotating fields each of the 4 years is most economical. However, silage is usually cut from fields close to the feedlot to minimize silage hauling expense. Therefore, hauling manure every fourth year may be the most practical solution and the one we will use for silage pricing.

In a fairly intensive study over 2 years, Row et al. (2016) measured the effect of silage dry matter on grain yield. Grain yield is maximized at black layer and silage was 42.2% dry matter (Table 3). That may be a bit dry for good silage packing, therefore we propose using 38% dry matter for silage harvest. Based on the data of Row et al. (2016), the silage yield of that harvested at 38% dry matter, will be 94% of that at black layer.

Based on the previous assumptions, the pricing of silage in the field is presented in Table 4. Table 5 then shows the further calculations of the price of silage to the feed bunk. Depending upon value placed on manure and amount of silage shrink, the price of silage to the feed bunk is 68 to 78% the price of the corn grain after grain storage.

A 4-trial summary is presented in Table 6. The data are adjusted to equal final carcass weights so 5 more days were required to finish the 45% silage-fed steers. The 45% silage-fed steers gained slower and less efficiently than those fed 15% silage, but net income was more than $13 greater for the 45% silage-fed steers because of the lower cost of silage compared to grain.

The use of DG in the diet is important to the cattle performance as well as the economics. Burken et al. (2015) fed 4 combinations of DG and silage. The 45% silage diet decreased gain and efficiency and the 40% level of DG tended to increase gain and efficiency (Table 7). There was not a clear interaction indicating 20% DG was probably sufficient. Economics were better for 45% silage-fed steers and best when fed with 40% DG ($19 advantage to 15:20 diet).

Ovinge et al. (2019) compared systems for feeding higher levels of silage. Feeding 75% silage followed by 15% was similar in performance to 45% silage throughout the finishing period (Table 8). Economics favored feeding the higher level of silage. Somewhat more silage was fed with the continuous 45% level feeding which helped the economics. The 45% level of silage feeding was more than $50 more economical than feeding 15% silage.

Silage has excellent value in grower diets. As shown by Watson (this conference), meeting the protein requirement is very important. The availability of distillers grains (DG) at reasonable prices affords the opportunity to provide economical diets based on corn silage and distillers grains. Two experiments have been conducted where DG was the supplement. While we cannot compare them directly, it may be a useful observation. In one experiment, 15% DG was fed and in the other, 21% DG was fed. The additional level of DG adds both protein (RUP) and energy to the diet (Table 9). Calves gained more rapidly and efficiently when fed 21% DG and cost of gain was more than $6/cwt less. This illustrates the opportunity for using DG and silage for growing cattle.

In the Ovinge et al. (2019) experiment, the calves were fed three levels of silage during the first 70 days (growing period), 15, 45 and 75%. This is a time of efficient gains and feed: gain was less than 5 with only a small decline for the 75% silage-fed calves (Table 10). Cost of gain was $5/cwt less for the calves fed 75% silage. The silage had 96% the feeding value of the grain.

Assuming 72% TDN in the silage and 88% in the corn and 114% for DG, the cost per pound of TDN is presented in Table 11. Clearly, silage and DG are the economical sources of energy and the DG supplies protein (RUP) in addition.

Based on the calculations presented, it seems that corn silage is an economical feedstuff in both finishing and growing diets. The important issues for consideration are: pricing grain at time of silage harvest for silage pricing, pricing grain after storage cost for feeding the grain, accounting for fertilizer value of the manure and minimizing shrink. A final point is that of the use of a cover crop after silage harvest. This is good for the soil and potentially an economic source of forage. The cover crop can be planted early enough to get good Fall growth and with good Spring growth can be grazed or harvested. We will leave the economics of that to others.

TABLE 1.
Manure from 45% Silage Diet[1]

	45% Silage
DMI, lb.	3821
OMI, lb.	3608
Forage (silage)OMI	812
Silage DMI, lb. (ton)	1719 (.86)
Manure, tons	1.88 (.879)[2]
N excreted, lb.	96
N manure, lb. (ton sil)	48 (21.2)[3]
P excreted, lb.	16.8
P manure, lb. (ton sil)	15.1 (6.68)[3]

[1]45% corn silage, 40% DGS, 15% corn
[2]tons/ton 38 dm silage
[3]lb/ton 38% dm silage

TABLE 2.
Options for Manure Credit

- Rotate silage fields every 4 years to distribute P
  Increased hauling distance for silage?
  Full credit for manure
  Silage cost 52-55% corn price

- Spread manure 1 year in 4 to only replace silage removal of P
  One fourth credit for manure
  One fourth hauling expense
  Silage cost 70 to 74% corn price

- Spread manure annually on a P basis
  One fourth credit for manure
  Hauling expense ≈ manure credit
  Silage cost 76 to 80.4% corn price

TABLE 3.
Effect of Silage Dry Matter on Yield[1]

	Weeks from Black layer		
	-1	**0**	**+1**
Percent Grain	50.9	52.3	53.5
Grain Yield, bu	237	252	252
Silage Dry Matter	38.1	42.2	43.3

[1]Row et al. 2016

TABLE 4.
Corn Price in Field

- Corn price † fall to summer= $.47/bu (10 year average)
- Corn price increase ≈ storage cost
- Fall basis, Eastern NE ≈ $.39/bu
- Therefore, current cash for September = $3.73/bu
- Harvest, haul, dry, loss ≈ $.47/bu
- Net in field = $3.26
- 263 bu yield = $857/ac, 6.22 tons dm
- 12.1 ton dm silage at 42% dm (black layer)
- 11.35 ton dm at 38% dm (6% yield drag)
- $28.69/ton 38% dm silage in field

TABLE 5.
Silage Price to Feed Bank

	Manure[1]
Silage price in field	$28.69
Residue fertilizer value	$+1.93
Manure fertilizer value	$-3.63
Net Silage Price in field	$26.99
Manure spread cost	$.50
Harvest, haul, pack	$11.00
Storage	$2.00
Net Silage price to feedyard	$40.49
10% Shrink	$44.99 (68.0%)[3]
15% Shrink	$47.63 (72.0%)[3]
10% Shrink, no manure value	$49.02 (74.0%)[3]
15% Shrink, no manure value	$51.91 (78.4%)[3]
10% Shrink, equal fert. value[2]	$46.88 (70.8%)[3]
15% Shrink, equal fert. value[2]	$49.63 (75.0%)[3]

[1] Replacing plant nutrients in silage with manure 1 year in 4
[2] Manure value equal to fertilizer value of nutrients in silage forage.
[3] Percentage of corn prices ($4.12/bu)

TABLE 6.
Four Trial Summary

	Corn Silage	
	15%	**45%**
Initial wt	866	866
Final wt	1403	1403
DOF	136	141
DMI, lb.	26.68	27.10
ADG	4.02	3.81
F:G	6.64	7.11
Net, $	6.49	19.75

TABLE 7.
Silage and DG Levels[1]

	Silage: DG			
	15:20	**45:20**	**15:40**	**45:40**
DMI	26.1	26.9	26.4	26.7
ADG	4.26	4.19	4.42	4.22
Feed:Gain	6.13	6.42	5.98	6.33
Net, $	54.73	65.96	56.32	73.71

[1]Burken et al. (2015)

TABLE 8.
Finishing Systems[1]

	Silage Level		
	15%	**45%**	**75/15%**
DMI	23.7	23.6	23.0
ADG	4.02	3.82	3.73
Feed:Gain	5.88	6.18	6.17
Net, $	27.02	83.64	64.47

[1]Ovinge et al. (2019)

TABLE 9.
Level of DG with Silage Grower

	Hilscher et al.	Ovinge et al.
DG, % dm	15	21
Initial BW	714	698
DMI	21.2	20.3
ADG	3.62	4.17
Feed:Gain	5.86	4.98
Cost of Gain, $/cwt	51.63	45.22

TABLE 10.
Level of Silage in Grower[1]

	Silage Level, %		
	15	45	75
Initial BW	699	701	698
DMI	23.8	23.0	20.3
ADG	4.98	4.75	4.17
Feed:Gain[2]	4.85	4.95	4.98
Cost of Gain, $	50.25	47.62	45.22

[1]Ovinge et al. (2019)
[2]Silage = 96% value of grain

TABLE 11.
Cost/Unit TDN (Grower)

Silage, 10% loss	$.082/lb. TDN
Silage, 15% loss	$.087/lb. TDN
Corn grain ($4.12/bu (.087)	$.099/lb. TDN
DGS (=corn)	$.076/lb. TDN
Hay ($70/ton)	$.0859/lb. TDN
Hay ($80/ton)	$.0960/lb. TDN

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