Silage management today, significant money, made or lost

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Abstract

This paper reports the significant economic impact growers and livestock producers can gain or lose in managing silages, especially corn silage. Examples are discussed on how starch levels in corn silage can be elevated by altering management practices such as hybrid selection, growing, harvesting, processing and harvesting higher. Economic returns from packing, covering and feeding silages are discussed. Depending on previous management level and the number of practices a producer might be able to improve, the value made or lost could be greater than $30.00 per ton.

Key Words: corn, silage, management, economic

Introduction

This applied paper presents information demonstrating the importance of silage management today and the significant economic impact it can have on any enterprise growing, buying or feeding silage. The primary silage discussed will be corn silage since it is the king of forages in many geographic regions of the Northwest. The percentage of corn silage in dairy diets has increased in recent years as improved silage hybrids and management have demonstrated the positive influence higher levels of excellent corn silage can have on lowering feed costs. The discussions in this paper centered on silage losses and their economic impact can generally be applied to most fermented silages.

After 30 years of working in the animal forage area, I began to review what we had discovered which was worthwhile in terms of impacting the bottom line of operations utilizing corn silage in their operations. For the past 4 years I have been asked to teach the forages portion at the Southern Great Plains Dairy Consortium in Clovis New Mexico. This paper contains methods I utilize to teach students the importance and value of excellent silage management. It is critical for those students and the readers here to understand the economic values cited in this paper, when tied back to management practices, are not identical in every silage and management situation. Numerous variables, constantly changing, make it impossible to state any value is the correct one in every case.

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Variation in Silages

The first concept I teach is no two silages are, or have ever been, the same. Like snowflakes, each silage is totally unique. With snowflakes, the primary variables are temperature and humidity. With silages, you encounter ever-changing natural occurring microflora (epiphytes) living on plants harvested for silage. These microbial numbers change day to day, hour by hour based on temperature, humidity and sunlight. There will be multiple genus and species of lactic acid bacteria as well as other types of bacteria, yeasts, and fungi. Within each species, each strain will have different growth rates based on initial population, temperature, moisture, packing density, nutrient composition of the crop and pH sensitivity. Each plant will have a unique microbial profile and in 10,000 tons of corn silage there could be over 10 million plants. These plants are harvested over many hours or days. No two silages are ever packed or covered exactly the same nor is the feeding management identical. In addition, silage starch and fiber digestibility can increase, during the first 5 months of storage, Hallada et al. (2008).

The Value of One Point of Starch in Corn Silage

The high content and digestibility of starch in corn silage is one of the most attractive aspects of feeding it. Nutritionists closely monitor starch content of the silage they are feeding and if asked what percent of corn silage they would like to have as starch you most commonly hear "Above 30%, 35% is better". What are the economic advantages of improving starch content of corn silage and how can we accomplish the task? I use steam flaked corn (SFC) as a basis for the value determination. I do so because in well managed corn silage the digestibility of the starch is similar to starch digestibility in SFC. I correct the value of the SFC to a dry matter basis (82% DM) so I can determine cost per pound, dry matter basis. At the time this paper was written, the price for SFC in the Magic Valley of Idaho was $265.00/ton. This calculates to $.16 per pound, dry matter basis. A year ago the cost of SFC was $330.00 per ton which placed the value per pound at $.20. Should SFC drop to $230.00/ton with a bumper corn crop this fall the price per pound would be $.14 per pound of dry matter starch. Well managed corn silage is about 65% moisture, 35% dry matter or 700 pounds of dry matter per ton. If we are to change any fraction by 1%, it requires we change it by 7 dry matter pounds per ton (700 X .01). At $265.00/ton, 7 pounds of starch is worth $1.12 per ton ($.16 X 7). A year ago that value was $1.40 and should the price of SFC drop in the future to $230.00/ton the value would be $1.00/ton. If we could increase the starch content of corn silage by 5 percentage units (ex; 28% to 33%) it would increase the value of that corn silage by $5.60 per ton ($1.12 X 5 - current price for SFC at $265.00/ton). I feel by improved hybrid decisions and improving management, many operations utilizing corn silage could increase starch content 5 percentage units or more.

Management to Improve Starch Content or Digestion

Step one in increasing starch content in corn silage is selecting hybrids which provide the most potential for starch. In other words, maximize grain content. All hybrids are not created equal. A good silage hybrid must be an excellent grain hybrid if the goal is to maximize starch content. While one grain or silage plot will not provide you adequate reliable data, combining data from a number of plots, hopefully 20 or more, will begin to separate hybrids on nutrient parameters. A hybrid which has one bushel grain advantage per acre, yielding 30 tons of silage per acre at 65% moisture would add 1 pound more dry matter starch per ton of silage. Should grain yield be improved 7 bushels per acre, certainly possible with diligent pre-plant study, the result would translate to 1 additional percentage unit of starch in the corn silage.

When a producer purchases a bag of corn seed, the grain or silage yield is not printed on the bag. The reason is because where and how those seeds are planted, nurtured and harvested will greatly influence grain and starch yield as well as whole plant silage yield. To cover all agronomic management necessary to achieve maximum yields is well beyond the scope of this paper, I will cover one very important period. In much of the Northwest, the most common factor influencing grain or silage yield would be water or heat stress two weeks before to two weeks following tasseling of the corn. During this month period, corn will utilize half the water required during the entire growing season. A grower may not be able to totally control this type of stress, even on irrigated acres. It is, however, a critical period growers must be well aware of and manage through to the best of their ability. Stress during this period could cause yield reductions of 6-8 percent per day, equivalent to at least 1 percentage unit of starch lost for every day of significant stress.

Maturity differences in the corn kernel at the time of harvest significantly influence starch content. Once a hybrid begins to dent (not all hybrids dent), starch deposition begins first at the outer portion of the kernel and moves towards the cob. The process will vary in length with weather, especially temperature (cooler temperatures would slow starch fill). In most areas starch deposition occurs in 3-5 weeks. While the number can vary due to planting and growing conditions, we would desire 25% starch in the corn silage at 1/3 starch line. A number of trials conducted by DuPont Pioneer have shown an average of six units of starch gained from 1/3 starch line to 2/3 starch line. Many research articles refer to what I refer to as starch line as "milk line". In warmer areas of Washington, Oregon, Idaho and Utah given normal heat, it requires about one week to move starch from 1/3 to 2/3. Thus, whole plant corn silage is gaining about 1 percentage unit of starch per day. The recommended maturity for corn silage is 2/3 starch line. Because of the physiological structure of a corn kernel (germ portion in the lower kernel) corn will contain 90-95% of the starch deposited in the kernel at 3/4 starch line. This stage of maturity usually places the harvested silage close to the desired whole plant moisture content of 65%, necessary for adequate packing of the silage. Attention needs to be given to the plant maturity as the harvest grows near. The most serious management mistake would be harvest before adequate starch deposition has occurred. Every year during my career I observed fields chopped when the starch line was less than 1/3 down the kernel. In those cases, the end user could be giving up 8-10 percentage units of starch. At the current price of SFC those utilizing corn silage harvested early could be losing $9-$12 per ton in starch value.

Proper kernel processing (KP) is a critical area of management which requires close observation during all of the harvesting period. Researchers have shown processed corn silage to have higher starch digestibility, Bal et al. (2000), Schwab et al. (2002). Some KP research has shown little influence on intake or lactation performance, Dhiman et al. (2000). Most consulting nutritionists feel proper KP is an absolute necessity to achieve optimum animal performance in animals fed corn silage. Forage samples can be collected and sent to a laboratory to determine the degree of processing but if one is monitoring KP during harvest a more rapid determination is required. It is a common practice for consultants at DuPont Pioneer to fill a 32 ounce cup with corn silage, fresh cut or fermented and count the number of undamaged kernels in that sample (replicate procedure 3 times). The ideal number of whole kernels would be zero. Any number higher indicates possible reduced starch digestibility. The economic impact of improper processing is difficult to determine precisely because starch digestibility in unprocessed kernels will; increase in digestibility over the first 5 months, Hallada et al. (2008). It is also difficult to determine the economic impact since the number of unprocessed kernels is different in every situation. In addition, maturity of the kernel is not a constant. Many consulting nutritionists feel the reduction in starch digestibility in poorly processed corn silage could be 5-10 percentage units. Schwab et al. (2002) reported starch digestibility difference of 4.5 units (92.9 vs. 97.4) between unprocessed and processed corn silage.

It is possible to concentrate starch content in corn silage by raising the cutting height of the corn at harvest. Most studies have been conducted raising the cutting height by 12-14 inches. Kung et al. (2008) conducted a study raising the cutting height of one hybrid 14.2 inches which added 1.99 units of starch in the resulting silage. Wu and Roth (2005) summarized 11 studies in which corn silage was cut an average of 12.5 inches higher, raising starch levels 1.8 units. Whole plant yield was lowered an average of 7 %. In lactation studies milk fat has been reported to be lower. The economics of high cutting corn silage need to be evaluated closely. I am aware of several dairy producers who high cut corn silage to some degree and feel it is a favorable management tool. I do not feel high cut corn is for everyone but some utilize it very successfully.

Value of Dry Matter Losses in Silage

There will be dry matter losses when utilizing silage. From an applied and teaching standpoint I want students to understand there are losses which will be variable across location, moisture content, temperature, silo type, packing density, silo covering management and feedout management. These variables should be reviewed carefully to determine if it is possible to reduce dry matter losses. It is important students understand where they occur, how we can reduce them and perhaps most importantly, appreciate, and be able to calculate estimated value of the losses. Table one shows the range of these losses and primary management required to reduce them. With current high feed prices, the value of these losses deserves discussion. Because no two silages are identical, it is impossible to place exact value on losses we incur in producing and feeding silages. I have read articles which calculate the losses based solely on the value of the silage after it is placed in the storage unit. They would say if the value of the silage is $50.00/ton once stored and we lose 20%, the value of the loss is $10.00 /ton or $.50 per point of loss. If nutrient analysis were identical for silage before and after losses occurred, we could assume dry matter lost was the same as the silage which remains. This, of course, is not the case. The reason is that during respiration, fermentation, top spoilage and aerobic microbial activity on re-exposure to oxygen microbes utilize the components of the silage which are most valuable as a feed. They would include sugars, other non-structural carbohydrates, proteins, and organic acids. All of these nutrients have very high digestibility, near 100%. The microorganisms creating losses do not utilize cellulose, hemicellulose or lignin. What value can we place on these losses? I feel a unit of loss, 7 pounds of dry matter per ton for silage is as valuable as 7 pounds of starch. Earlier in this paper we placed the current value of 1 point of starch at $1.12/ton. Through better silage management, reducing dry matter loss 5 percentage units would increase the value $5.60 per ton ($1.12 x 5).

Table 1. Typical losses in silage by phase and management required to reduce them.

Silage Phase	**%**	**Management To Reduce Losses**
Respiration	1-8	Proper moisture content, rapid fill, excellent packing (increase density)
Fermentation	2-6	Use of a **proven** homo fermentative additive (Lactobacillus plantarum, Lactobacillus casei, Enterococcus faecium, several Pediococcus species)
Effluent	0-2	Harvest the crop below 70% moisture
Surface	1-8	Excellent packing (low porosity), cover the silage quickly using high quality plastic, consider the use of oxygen barrier films, seal sides and ends well, adequate tires or gravel bags to secure plastic, monitor condition of plastic, keep cover close to face and sealed
Aerobic	1-10	Excellent packing, low porosity, proper moisture content, use of a **proven** heterofermentave additive (Lactobacillus buchneri)
Feeding	1-10	Proper removal rate; 6-18 inches per day), clean perpendicular face, use of silage rake or defacer, keep loose silage cleaned up
Total Losses	**6-44**	

Respiration Loss

Respiration occurs from the time the crop is harvested until it achieves an anaerobic phase. Prior to that, live plant cells and aerobic micro-organisms convert water soluble carbohydrates to carbon dioxide and water producing heat in the process. Additional gases may be produced from enzymatic proteolysis of proteins. Proper moisture content, 65% is usually considered ideal, improves packing and reduces the length of this phase. Excellent and **rapid** covering of the silage are critical to eliminating oxygen as quickly as possible. This phase will continue as long as oxygen is present or until the source of water soluble carbohydrates are depleted. If excellent management practices are utilized this phase should be relatively short and the associated dry matter losses kept to a minimum (1-2 units). Silage which is too dry, not packed well or has delayed or poor covering could increase dry matter loss significantly (double digits).

Fermentation Loss

The fermentation phase begins once the silage has achieved an anaerobic state (no oxygen). Anaerobic micro-organisms convert water soluble carbohydrates to organic acids (lactic acid the primary) lowering pH to the point further microbial activity is inhibited. Variables which influence fermentation length would be moisture content, temperature, buffering capacity of the silage and naturally occurring micro-organisms present on the crop. Dry matter loss should be relatively small (1-4%). The addition of a proven Homofermentative bacterial inoculant can generate a rapid and more efficient fermentation which can lower dry matter loss by 1-2 units.

Effluent Loss

Effluent or seepage is the result of harvesting a silage crop too wet. In the dryer portions of the Northwest, we usually are able to harvest crops below 70% moisture so seepage is not a common problem. In portions of the region where we have higher rainfall and cooler temperatures requiring harvest at lower dry matter content may induce a problem in crops such as alfalfa and grass silages. In terms of dry matter loss, effluent loss is usually between 0-2%.

Surface or Top Loss

Covering bunkers in the Pacific Northwest is now the standard practice. Without a cover, 75% of the top 12 inches can be lost and the remaining forage have reduced digestibility. Negative effects due to oxygen penetration can extent down 30 inches where nearly 25% of the dry matter can be lost (Bolsen 1997). It is critical to apply the cover as quickly as possible; every hour delay will reduce dry matter recovery. Bolsen et al, (1993) covered bunkers either immediately or after 7 days. Delayed covering in small bunkers increased dry matter loss in the top 13 inches by nearly 8 units (89.3% vs. 81.4%). If covering a bunker, plastic should cover side walls such that the other edge can be pulled over the top several feet. This will reduce loss on the shoulders of the silage. Plastic seams should have adequate overlap (3-4 feet). Utilizing oxygen barrier (OB) film can reduce dry matter loss if applied quickly and properly. Borreani et al. (2007) reported significant reduction in dry matter loss using OB film. The edges and ends of all plastic must be sealed tightly. Adequate tires or gravel bags to secure plastic must be placed such that damage to one spot in the plastic does not allow oxygen to travel excessively under the cover. Limit the plastic removed ahead of the feeding face to 3 days or less. Though most now cover silage, top spoilage is still one area many operations utilizing silage could look to improve. Such improvements could gain 3-5 units of dry matter recovery.

Aerobic Loss

Silage will have to be re-exposed to oxygen once feeding begins. Loss incurred during this period can be variable and significant. Roth and Undersander (1995) reported up to 30% dry matter loss can occur from the exposed face, exposed top surface at the face and loose silage. Because this can be a significant potential loss, best possible management tools should be applied at the time the silage is placed in the storage unit. It begins with the proper moisture content at harvest, the speed of fill and the degree of packing (increased density, low porosity). The primary goal is to reduce porosity, the ability of oxygen to penetrate exposed material. Table 2 shows the relationship of dry matter loss as influenced by silage density reported by Ruppel (1992). This study was done in the Eastern United States with alfalfa silage.

Table 2. Dry matter loss as influenced by silage density.

Density (lbs DM/ft^3)	DM Loss, 180 days (%)
10	20.2
14	16.8
15	15.9
16	15.1
18	13.1
22	10.0

These data suggest for every pound of density we can improve, we reduce about 1 unit of dry matter loss. In bunkers, the most common density found is about 14 lbs DM/ft^3 but can range from less than 10 to 20. If we improve density 14 to 17 lbs ft^3, dry matter loss should be reduced by 3 percentage units. It is possible to have equal density but not the same porosity. Proper moisture content (65-70%) is the best way to achieve the desired effect of higher density and lower porosity **IF** we are able to rapidly fill a silo and achieve proper packing weight and time.

The rate of silage removal is a very significant variable. Higher removal rates are desired because they reduce the effect of oxygen, or more correctly, yeasts and molds which in the presence of oxygen convert water soluble carbohydrates to CO^2, heat and H_2O. Pitt and Muck (1993) found dry matter loss was 3% at the recommended removal rate of 6 inches per day for 35% dry matter silage with a density of 14 lbs DM/ft^3. Dry matter loss was reduced as density increased.

Two important facts every operation utilizing silage should consider. The first is density in a silage bag, bunker or pile is not a constant. You could have 17 lbs DM/ft^3 at the bottom and a density of 13 lbs DM/ft^3 near the top. This is almost always, the case. The second is that losses on the face are not constant. Temperature would be the primary variable since it influences yeast and mold activity. Face losses will be less in lower temperatures (below 40 degrees), than in the heat of summer (95 degrees). Design and size of bunkers should be such that removal rates match the lowest density and the time of year aerobic losses are most likely to occur (summer). I prefer removal rates of 12 inches a day.

The use of a heterofermentative (Lactobacillus buchneri) inoculant has been demonstrated to be beneficial on stability of silage on re-exposure to oxygen Kleinschmit et al. (2005), Schmidt and Kung (2010), Tabacco et al. (2011). Improved stability is not a constant as it would vary with temperature, humidity and soluble carbohydrate availability. Improved stability of 30 hours has been reported (Man et al. 2009).

Aerobic losses are variable but with excellent management in proper moisture, proper packing, optimum removal rates and the use of a proven heterofermentative inoculant, many operations could reduce dry matter loss by 3-5 percentage units.

Feedout Loss

The face of the silage should be maintained as a smooth surface which is perpendicular to the floor in bunker, trench, and drive-over pile silos. This will minimize the square feet of surface exposed to oxygen. Use of a silage rake or defacer will disturb less of the pile, leave a better surface, and blend the silage top to bottom better than using a front end loader. If silage is moved to a blending area or commodity pad the silage is re-mixed with oxygen for a longer period of time. The use of a proven L. buchneri can reduce dry matter loss during ration mixing and time in a feed bunk. Loose silage should be picked up at all times. Excellent management at feedout could improve dry matter recovery 1-2 percentage units.

Summary

The first point of this paper is that no two silages are ever the same. Because this is true, it is impossible to say the use of any one product or management decision will result in the same result every time. In recent years with the price of all animal feeds increasing significantly, the nutritive components of the initial silage crop and how much is lost prior to feeding have very significant economic impact. Starch content in corn silage may be improved through hybrid selection, how stress free the crop is grown, maturity at which it is harvested, degree of processing and increasing the height at which it is harvested. Each of these 5 tools might be capable of raising starch 1-3 percentage units for a total potential starch increase of 5-15 units. Basing the value on steam flaked corn, this could improve the value of corn silage $5.60-$16.80 per ton. This is significant from an economic viewpoint. How many producers are maximizing returns fully? This paper also discussed loss in silage and products and management which might reduce silage loss as much as possible. These losses come from microbial utilization of the most digestible components in the silage with nothing of value created in the process (CO_2, heat, water). Economic return of reducing losses is very significant. Areas where proven products or improved management can reduce loss are fermentation (1-2 percentage units), surface loss (top spoilage 3-5 percentage units), aerobic loss (face, 3-5 percentage units) and feedout (1-2 percentage units). These 4 areas represent potential for lowering dry matter loss by 8-14 percentage units. Based on steam flaked corn, this represents a potential increase in the value per ton from $8.96 - $15.68. Question; Are we achieving maximum return from the silage produced and fed? Combining adding starch and lowering dry matter loss, the potential value added or lost per ton would be $14.30-$32.48 per ton. A single operation may already have excellent management in many of the areas discussed. In today's world of extremely tight profit margins, every operation should review all phases of silage management every year to determine where improvements might be possible. Adding 2 units of starch and reducing dry matter loss 2 percentage units on an operation producing 20,000 tons of silage, the economic value, as calculated in this paper, would be approaching $90,000. Significant money! Made or lost?

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