SILAGE FOR BEEF CATTLE
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GARBAGE IN, GARBAGE OUT: THE IMPACTS OF SILAGE MANAGEMENT

Andy Skidmore, PhD
Technical Services - Ruminant
Lallemand Animal Nutrition
askidmore@lallemand.com

Andrew Skidmore, DVM, PhD, of Findlay, Ohio, serves as a member of the technical service team for Lallemand Animal Nutrition.

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.

His passion for the cattle industry has spanned over 35 years and several industry organizational leadership roles. Most recently Skidmore was the secretary and Reproduction Award Director of the Dairy Cattle Reproduction Council, and a Federation of Animal Science Societies scientific advisory committee member for the American Dairy Science Association.

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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