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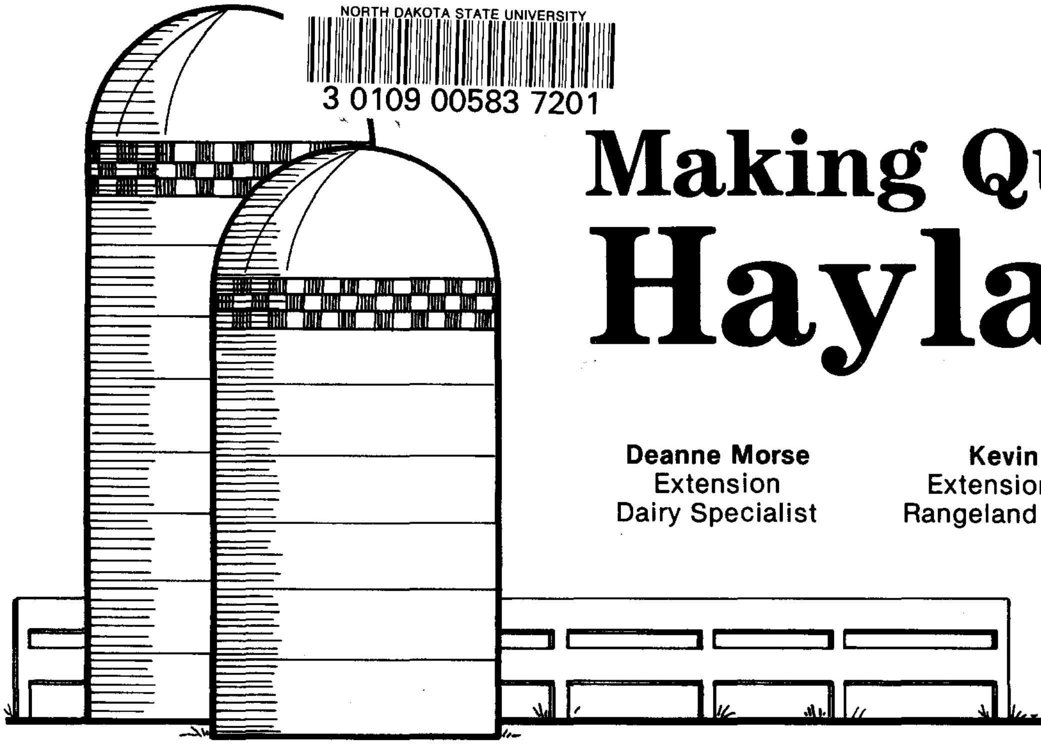

Making Quality Haylage

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Definition:

Haylage or low-moisture hay silage refers to hay put up at 40 percent to 60 percent moisture as comared with less than 15 percent for dried hay and 60 percent to 75 percent for silage.

Introduction

Management for quality forage is essential in the production of milk, meat, and wool. Forage managers should first determine the appropriate time to harvest forage. Once this is accomplished available time and labor and current weather conditions determine the best method for storage. Dry conditions at cutting time combined with no forecasted rain allow for storage in the form of dried hay. Typically, dried hay is less than 15 percent moisture and can be stored for extended periods of time. Nutrient losses from dried hay vary greatly depending on storing and feeding practices.

If precipitation occurs during the drying process, or if hay is dried inadequately, wet hay is baled. This type of hay typically is 15 to 40 percent moisture. Losses can result from molding and or burning of the bales in stored wet. Storing hay in the form of wet bales is the least desirable storage method.

The focus of this circular is management of forage in the form of haylage. When environmental conditions are adverse, an alternate method of storage should be identified and used. Under certain circumstances storage of hay as haylage is desirable. Low moisture haylage is 40 to 60 percent moisture, whereas, wilted haylage is 60 to 70 percent moisture. Direct cut forages harvested for silage have more than 70 percent moisture.

Quality Haylage Starts With:

- quality forage
- adequate moisture
- fineness of cut
- firmly packed forage

Haylage can be made from any crop that is traditionally stored as hay. ~~Ensiling~~ grasses and legumes as haylage requires moisture (40 to 60 percent) and the removal of air by packing for bacteria to work effectively . Fine chopping of haylage is critical and greatly assists the fermentation process by reducing potential areas for air.

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Making haylage out of harvested legumes and grasses is of increasing interest to producers and can be an alternate option for storing and processing forage. Reductions in moisture content necessary for production of haylage are accomplished by mowing, crushing, windrowing and drying for four to 24 hours, depending on forage moisture and weather conditions.

Advantages in processing the hay crop as haylage (low-moisture, dried high-dry matter silage) instead of high moisture or direct-cut silage, or hay include:

1. Reduction in weather associated risks.
2. Makes a palatable feed well liked by livestock.
3. Reduced storage losses.
4. Avoids objectionable odors.
5. Reduced losses due to seepage.
6. More days of suitable weather for wilting haylage than for drying hay.
7. Reduced quantities of frozen feed during cold temperatures.
8. Less dry matter losses associated with harvest compared with dry hay.
9. Less leaf (protein and dry matter) losses associated with handling.
10. Best method to harvest alfalfa after a killing frost for producers considering late October harvests.
11. Reduced wear and tear of your hay making equipment.

Some disadvantages in processing the hay crop as haylage include:

1. Requires more care in ensiling than hay to avoid mold.
2. Requires sharper knives to cut than silage.
3. Filled storage structure should occur rapidly.
4. Attention must be given to oxygen exclusion when sealing to reduce top spoilage.
5. Possible heat damage to protein.
6. Haylage is less marketable than dried hay.

Types of Forages Used for Haylage

Individual crops and mixtures used for making haylage differ with climate, soil type, and crop rotation in North Dakota. Practically any legume, grass or pasture forage can be ensiled successfully. Select the harvest time by the growth stage (maturity) of the predominant crop in the mixture. Table 1 contains a list of crops used for haylage in North Dakota by stage of maturity when the crop is recommended for harvested.

Delays in harvesting grasses after heads emerge or alfalfa after the 1/10 bloom stage decreases the quality and digestibility of the forage. Forage quality is determined largely by maturity. The protein and energy contents of forage is greatest in immature forages. As the forage matures, concentrations of protein and energy decrease, while fiber components increase. An example of this for alfalfa is shown in Table 2. Other forages follow similar trends. Neutral detergent fiber increases from 38 percent in the early bud stage to 50 percent in the

Table 1. Crops commonly used for haylage in North Dakota and recommended stage of maturity for harvesting.

Crop	Stage of Maturity
Legumes	
Alfalfa	Pre-bud to 1/10 bloom for first cutting 1/10 to 1/4 bloom for second cutting 1/4 to 1/2 bloom for third cutting
Sweetclover (and other clovers)	1/2 bloom
Perennial grasses	
Cool season grasses	Before grass heads emerge
Brome grass	Boot to early head (May 15 to June 1)
Crested wheat	Boot to early head (May 15 to June 1)
Wetland vegetation[1]	Before heads emerge
Annual grasses	
Sudangrass and sorghum (includes hybrids)	Boot to early headed
Millets	Boot to early headed
Small grains (oat, wheat, barley)	Boot to early dough stage

[1]Wetland vegetation will make better forage for livestock stored as haylage than as baled hay at any stage of maturity.

Table 2. Nutrient composition of alfalfa at various stages of growth and amount of protein and soybean meal equivalent (SBM eq) per ton of hay.

						Protein	
Growth stage	**CP**	**NE_l**	**NDF**	**ADF**	**Lignin**	**Alfalfa**	**SBM sq.**
	% of dry matter					lbs/ton	lbs needed
Early bud	23	.68	38	28	5	460	1035
Late bud	20	.65	40	29	7	400	900
Early bloom	18	.61	42	31	8	360	810
Mid bloom	17	.59	46	35	9	340	765
Full bloom	15	.56	50	37	10	300	675

Source: National Research Council. 1989. Nutrient requirements of dairy cattle. 6th rev. ed. Natl. Acad. Sci., Washington, D.C.

full bloom stage. Acid detergent fiber increases from 28 percent to 37 percent at respective stages of maturity. Lignin, a potentially non-degradable fiber faction, doubles in quantity from 5 to 10 percent between early bud and full bloom stages. As the amount of lignin increases, digestibility of fiber decreases tremendously. Not only is the lignin component not digestible, but lignin binds with other fiber components (cellulose and hemicellulose) as well as protein. Once bound to lignin, these plant components are unavailable to the animal. Each day's delay in harvesting decreases total digestibility, which means more grain must be fed to maintain high production levels.

Harvesting and Ensiling Characteristics

The quality of forage at harvesting is the first important step to producing quality haylage. Management of the forage after cutting is another necessary factor to produce high-quality forage. **IT IS ESSENTAIL TO REALIZE THAT THE BEST MANAGEMENT CANNOT CORRECT FOR LOW-QUALITY FORAGE, YET POOR MANAGEMENT CAN RUIN HIGH-QUALITY FORAGE.**

Dry Matter Content. The method for making hay-crop haylage may be classified as wilting. In the wilting procedure of harvesting forages, mow and windrow, leaving the hay dry four to 24 hours, depending on drying conditions. The crop is then harvested with a field chopper by a windrow-pickup attachment. Wilting allows partial field drying of the cut crop to contain 60 to 70 percent moisture when storing begins. If the storage structure can be filled and sealed within 18 hours from depositing the first load, begin filling when moisture content is about 50 to 60 percent. If it will take more than one day to fill and seal, start filling at 60 to 70 percent moisture. Later loads usually will be dryer. Forage with less than 50 percent moisture may be too dry to ensure good packing, increasing the risk of heat damage tremendously.

Determining Dry Matter. The amount of dry matter in a hay sample can alter its ability to be stored as haylage. Haylage ferments best between 45 and 55 percent moisture. Dry matter can be determined with a commercially manufactured hay probe according to the manufacturer's instructions.

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Another method to determine dry matter uses a scale and a microwave oven. It is best to use a scale that weighs in grams. If this is not available, use a scale that is sensitive to small amounts (i.e., quarter or half ounces). ~~The directions for scale and microwave method and an example follow~~:

1. Weigh a paper plate and record value (a).
2. Place a representative sample of forage on the plate and weigh plate and its contents (b).
3. Subtract the weight of the empty plate (a) from the weight of the plate plus the sample (b) to obtain the net weight of the original sample (c).
4. Place the filled plate into the microwave. Include a cup of water in the microwave.
5. Set the oven for 5 minutes on high temperature. When finished, reweigh, record value and return plate to microwave.
6. Set the oven for 2 minutes on high temperature. When finished, reweigh, record value, and return plate to microwave oven.
7. Repeat step 6 until little or no differences occur between the weights at two consecutive weighings. **NOTE:** if you smell a burning odor, heat for only 1 minute at a time.
8. The final weight of the plate and the sample will be the very last weight recorded (d).
9. Subtract the weight of the plate (a) from the final weight of the plate and sample (d) to determine the net final weight of the sample (e).
10. Calculate dry matter percent:
    e/c x 100. [Net final weight/net original weight] x 100.
11. Percent moisture is 100 - dry matter percent.

Example of dry matter determination:

b)	plate + sample	354 g
a)	plate	-54 g
c)	net initial sample weight	300 g
	Record of weights of plate and sample after heating	
	5 minutes	275 g
	2 minutes	254 g
	2 minutes	240 g
	2 minutes	229 g
	1 minute	225 g
	1 minute	220 g
	1 minute	219 g
	1 minute	219 g
d)	final plate and sample	219 g
a)	plate	-54 g
e)	net final sample weight	165 g

Dry matter percent 165 / 300 x 100 = 55%.
Moisture percent 100 - 55 = 45%.

Note: Odors produced may be not desirable in the house. Use this method in an open area or barn.

If the hay dry matter is greater than 60 percent, consider adding water if haylage is to be made. Otherwise, allow forage to dry for hay. If dry matter is less than 30 percent, allow forage to dry before ensiling as haylage. Once the hay is ensiled and fermented, determine dry matter before feeding to livestock. Dry matter of wet forages should be determined and rations should be adjusted at least once a month.

Length of Cut. Fineness of chopping cannot be overlooked when making haylage in either conventional or sealed silos. Fine chopping helps to exclude air because packing is tighter. This should minimize spoilage losses. A 1/4 inch cut is recommended when making haylage. As moisture content decreases below 60 percent (forage becomes drier) the shorter cut is crucial. Proper fermentation requires moisture and an absence of air. Since moisture content is lower in drier hays, a shorter cut is essential to minimize presence of air within the haylage.

Exclusion of air. Oxygen must be excluded from the haylage pile to achieve proper fermentation. Fermentation begins immediately after cutting of the green plant and must occur in order to have extended storage with minimal nutrient losses. Desirable microorganisms begin using energy from the plant material and produce acids, carbon dioxide and heat. As oxygen is depleted, anerobic (without oxygen) bacteria continue to produce acids until pH levels drop to 4 or 5. At this point fermentation stops and the ensiled feedstuff remains in a preserved state as long as air is not present. Once disturbance occurs or oxygen is allowed in, oxidation may proceed rapidly, causing heat damage (burning) by chemical oxidation of sugars in the forage. Air will penetrate the mass of haylage in sealed silos when the filling port is left open or when the unloading door is opened for feeding.

Exclusion of air in bunker and trench silos is quite challenging due to the large amount of surface area exposed to air. Special consideration should be given to storing haylage in bunker or trench silos. Key attention must be given to fineness of chop and packing of forage material. Bunker dimensions should be calculated to minimize surface area exposure. Furthermore, feeding must utilize enough of the outer exposure to minimize losses associated with spoilage.

Even distribution in the storage structure is necessary to avoid separation created by the silage blower. Fill the silo rapidly; continuously if possible. Compaction of the forage depends on considerable height of the material to provide the weight necessary to express air from the forage mass. Delays in filling will yield noticeable differences in quality. Dry matter loss by heating will occur when delays of one to two days occur between filling.

Apply a top seal of forage containing 65 to 70 percent moisture in the top 10 feet to 1/3 of the silo. Level the forage and pack it firmly to express trapped air. It is critical to reduce the amount of oxygen in the forage. Presence of air allows molds and undesirable microbes to grow, resulting in spoilage.

Finally, crown the center slightly and cover with a plastic silo cap. Hold the cap in place with weights placed around the edge of the cap. Minimizing the amount of surface exposure should minimize spoilage.

Silos for Storage

High dry matter haylages have been made successfully in conventional silo structures (upright, bunker, and trench) as well as in sealed storage. However, it is risky to plan to ensile in the conventional silo when moisture drops below 50 percent. Delays in filling may result in a moisture content (increased dry matter) too low for packing haylage. With a gas-tight silo, delays in filling do not create this problem.

STORAGE OF HAYLAGE IN PILES IS THE MOST COSTLY AND LEAST EFFICIENT METHOD OF STORAGE, AND IS NOT RECOMMENDED DUE TO UNDESIRABLE FERMENTATION. OFTEN, SPOIL AGE IS THE KEY CULPRIT IN LOWERING THE QUANTITY OF USEABLE FEED. HAYLAGE STORED IN PILES MAXIMIZES SURFACE AREA EXPOSURE AND IS DIFFICULT TO PACK SUFFICIENTLY. These two factors allow oxygen penetration into the pile resulting in inadequate fermentation (spoilage) and mold growth.

Silos confine the crop within a reasonable space and help exclude air from the crop. They are either upright or horizontal. With appropriate management, you can produce high-quality haylage by using either structure. Regardless of the structure used, the forage needs to be ensiled as rapidly as possible to prevent any excessive rise in temperature which can cause heat damage.

The surface area of the forage should be covered as soon as possible with no more then 18 hours of exposure to air. If filling is going to be interrupted for more than two days, cover with a plastic sheet until filling resumes.

Size and type of silo or storage method utilized should be suitable for your livestock feeding needs. To minimize spoilage losses, herd size and silo or bunker size must be compatible. Larger silos or bunkers will allow for greater air exposure when unloading, increasing the spoilage possibility if amount of forage fed daily is low. Small livestock operations will use less feed, making it almost impossible to keep up with the amount of spoilage that

IT IS NOT RECOMMENDED TO STORE HAYLAGE IN PILES. UNDESIRABLE FERMENTATION RESULTING IN SPOILAGE OCCURS.

can occur with large silos and bunkers. Air-tight silos with a bottom unloader and plastic bags will also minimize spoilage losses.

Upright silos are constructed from a wide variety of materials, including wood, concrete, tile, steel, and glass-coated steel. The walls and doors of new silos are usually air tight. However, older silos may have air leaks in the walls or around the doors. These should be reconditioned by a reputable silo repair company and/or calked and sealed. The drain hole should be plugged if haylage is to be stored in the silo.

Bunker and trench silos can be used successfully for storing haylage ensiled by the most careful workmanship and with rapid feeding. Haylage packs poorly in bunker silos. Poorly packed haylage will undergo excessive heating and losses. Extra effort in packing is necessary to evacuate as much air as possible and minimize losses associated with excessive heating. Moisture content should not fall below 60 percent for successful ensiling. Continuous packing with a wheel-type tractor while leveling and filling and periodic packing for two or three days after filling is desirable to form a good surface seal. Use a plastic silo cover weighted with old tires or other heavy materials. The cover will reduce surface spoilage and keep heavy rains and snow from leaching through the haylage. One of the largest factors associated with losses in a bunker silo is the total quantity of haylage stored. In general, the larger the pile the lower the percent dry matter loss.

Large plastic bags have become popular for haylage storage. There are many different silo bags made by manufacturers with some degree of quality variability among the bags. Based on results from the Dickinson Experiment Station, researchers concluded extremely low deterioration among multi-ply bags. Studies performed in Utah using two-ply bags showed a one-third increase in feed efficiency when using silo bags over large square bales. Properly bagged forage limits heating and deterioration, and increases storage efficiency. Estimated losses between one and eight percent would be expected, depending on degree of packing and moisture with plastic bags. A 9-mil plastic bag 135-ft long will hold approximately 130 tons. The bagger unit can fill a 135-ft bag in about 30 minutes.

An economic comparison of the various forage storage units indicated that concrete bunkers were the cheapest method of storage and air-tight silos were most expensive (Table 3). Plastic bags were also one of the more inexpensive storing methods with large quantities. Total investment for bagging included the cost of the bagging unit, approximately $25,000. Leasing the bagger unit will dramatically decrease the cost, but availability of the unit and expertise in using the bagger unit must be considered.

Table 3. Economic comparisons for various forage storage units at two capacities.[1]

Silo type and size	Capacity	Total investment	Ownership costs (per ton DM)
	tons DM	------ $$ ------	------- $$ -------
Metal oxygen-limiting			
20 x 80	200	82,000	67.65
25 x 90	325	113,800	57.77
Concrete oxygen-limiting			
20 x 72	170	62,000	60.18
30 x 100	510	120,000	38.82
Concrete stave			
20 x 70	155	30,250	32.20
30 x 80	425	52,500	20.38
Concrete bunker			
10 x 30 x 185	750	24,800	5.13
12 x 40 x 112	500	23,800	7.38
Bagger and bags			
5 bags	250	34,500	32.43
15 bags	750	38,000	11.91

Source: T.D. Hewitt, 1986. Dairy Herd Management 23(12): 29.

[1]These figures do not take into consideration the differences in forage loss due to spoilage, handling losses and animal waste.

The Fermentation Process Occurring In Haylage

Components of plant cells are located in two areas. The outside of the cell is the cell wall. This portion contains fibrous components: hemicellulose, cellulose, and lignin. Hemicellulose and cellulose are made of sugar units. The inside of the cell has the cell contents. This contains sugars, starches, fat, protein, non-protein nitrogen (NPN), and other non-fibrous components (Figure 1).

During the ensiling process, some bacteria are able to break down cellulose and hemicellulose to various simple sugars. Other bacteria break down simple sugars to smaller end products (acetic, lactic and butyric acids). The most desirable end products

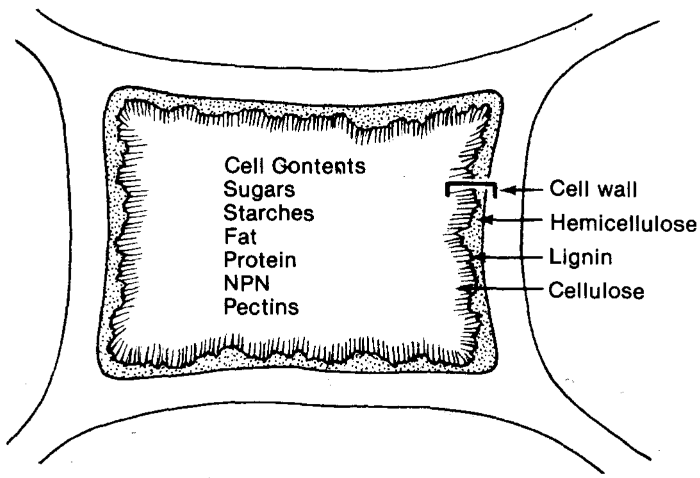

Figure 1. Plant cell fractions and chemical components.

are acetic and lactic acid. As the bacteria degrade starches and sugars to acidic and lactic acids, dry matter is lost. One of the least desirable end products is buytric acid.

It is important that bacteria responsible for production of acetic and lactic acid grow and multiply immediately after storing the forage for maximum quality haylage. Proper packing of the hay and voiding of air (oxygen) provides the environment needed by bacteria to break down fiber components and sugars. Oxygen must be removed from the haylage to maximize reproduction of acetic and lactic acid producing bacteria. Microbes (bacteria) responsible for fermentation need anaerobic (in the absence of air) conditions. As bacteria consume sugars, end products produced (acetic and lactic acid) cause the pH to drop.

Different types of bacteria thrive at various stages throughout the fermentation process. As the pH drops, acetic acid-producing bacteria reproduce rapidly. The end product of their fermentation reduces the pH further and they die off. At this point lactic acid bacteria should be producing rapidly. The net result should be a further drop in pH. If the pH does not drop sufficiently, undesirable bacteria and molds will reproduce and spoil the haylage.

A critical time during the ensiling process occurs after the initial three to five days and requires some 15 to 20 days for completion. The success of the ensiling process is determined. During these two weeks, there is a gradual increase in lactic acid as lactic acid producing bacteria break down simple sugars. The pH drops to between 3.8 to 4.2. At such acidic conditions, further bacterial action is stopped. The critical difference between silage and haylage is the effect of moisture content of the forage during this two week fermentation process. If the forage is too dry, fermentation is restricted and the pH cannot drop sufficiently. If pH of the haylage does not drop sufficiently spoilage will occur.

The last concern with the fermentation process is to maintain quality of the haylage during storage. Storage quality of all forages is essential under most management schemes. If adequate amounts of acetic and lactic acids were produced during the first four weeks of fermentation, the quality of haylage during storage will be fairly constant. If the pH did not decline rapidly or sufficiently in previous stages, increased decompositon, reduced palatability, and possible spoilage (molds) may occur.

Optimum temperature of haylage during the first few days is between 90 and 105 degrees Fahrenheit. Poorer-quality haylage is produced when temperatures are outside this range. Incomplete fermentation which may alter storing capacity can occur when temperatures are less than 85 F. At these low temperatures the primary end-product of fermentation is butyric acid, which is undesirable. At the other end of the spectrum, when temperatures are greater than 120 F heat damage is common. Heat damaged forages are characteristically brown to black in color and have a sweet tobacco aroma. Although animals eat the damaged feed readily, the feed value is reduced. Lignin binds part of the nitrogen (N), reducing availability of N. Heat damaged feeds should be evaluated and discounted for amount of unavailable N.

To Inoculate Or Not To Inoculate

The purpose of an inoculant is to increase the number of lactic and possibly acetic acid producing bacteria. Theoretically, these bacteria should reduce the time necessary for the first three to five days of ensiling. Increasing numbers of bacteria should help speed up the fermentation process. Hastening the occurrence of lactic acid producing bacteria should improve the quality of the resultant forage and reduce losses of dry matter.

The reality of the situation must be considered. A few key points must be remembered. First, the quality of harvested forage does not improve after harvesting. Second, spraying an inoculant will not make up for poor quality forage or for poor handling or storing of the forage.

The results of research trials have varied. To determine if an inoculant "works", the extent of fermentation is evaluated (final pH of the haylage). Another characteristic of haylage used to determine effectiveness of an inoculant is lactic acid content in the final product and dry matter recovery.

Researchers in Wisconsin evaluated two brands of inoculants (Table 4). Their results are representative of inoculant trials. Sometimes the inoculants are beneficial in decreasing pH, sometimes they are not. This experiment was designed to test the differences of inoculating vs. not inoculating alfalfa hay prior to putting into an upright silo for haylage. In the first year, there were some differences between inoculated and non-inoculated haylage. Cows consuming alfalfa haylage sprayed with Brand X inoculant produced more than four percent fat-corrected-milk than cows consuming untreated haylage. Cows consuming haylage sprayed with the other inoculant (Brand Y) did not perform better than those animals consuming untreated haylage. Although some benefits were observed during the first year with one brand of inoculant, no benefits were observed during the second year. In year two, cows consumed similar amounts of feed and produced similar amounts of milk regardless of inoculant presence or type.

Table 4. Silage pH, milk production (4% FCM) and composition, and dry matter intake from cows fed alfalfa silage treated with or without microbial inoculant after one and two years.

	Non treated	Brand X	Brand Y
		Year 1	
pH	5.35	4.68	4.75
4% FCM (lbs/day)	55.30	61.30	58.60
Fat, %	3.43	3.59	3.43
Protein, %	3.04	3.23	3.19
Feed intake (lbs/day)	43.40	46.50	44.50
		Year 2	
pH	4.67	4.44	4.37
4% FCM (lbs/day)	57.30	55.30	56.20
Fat, %	3.81	3.72	3.78
Protein, %	3.01	3.11	3.07
Feed intake (lbs/day)	51.60	50.90	52.90

Source: Kung et al., 1987. Journal of Dairy Science 70: 2069.

The key point to consider when evaluating whether or not you will purchase and use an inoculant is what is the benefit to you? How many pounds of milk must be produced to pay for the additional cost of purchasing and applying the inoculant? On some farms, producers may benefit from use of an inoculant for management reasons. Once a producer invests money to try a new technique, closer attention is given to management. In such instances, the benefit is from improved management and not from the inoculant.

Damaged Haylage

Spoilage occurs when fermentation of forage does not occur normally. Heat damage is a common type of spoilage. In most haylage samples, three to five percent of the crude protein (CP) can be bound to the acid detergent fiber (ADF) fraction. Under normal circumstances, if a haylage is 17.0 percent CP and five percent of the CP is bound to the ADF fraction, the feed value is only 16.1 percent CP. When heat damage occurs, the amount of CP bound to the ADF fraction is greater than five percent and can exceed 25 percent. If heat damanged protein is 12 percent of the CP, the same 17 percent CP haylage only has a 15 percent CP value. If haylage comprises a large amount of the daily feed intake for your animals, it will pay to have the acid detergent insoluble nitrogen (ADIN) determined for your forage. This can be analyzed by most labs that do wet chemistry procedures. The total protein value of a feed should be discounted for the amount of protein in the ADIN fraction.

Conclusion

Diets for livestock are centered around the production of quality forage. The first step in production of quality haylage is harvesting the forage at an immature stage. There is no method of storage that can improve poor quality forage. Managers of forage crops must pay attention to the stage of plant maturity prior to harvest and to storage details after harvest. This maximizes sustained quality of forage stored over an extended period of time.

Haylage is a viable alternative to making hay in North Dakota. Advantages of making quality haylage include reducing dry matter losses, producing a highly palatable feed, decreasing labor needed to harvest feed (no need to turn hay in field), reducing wear and tear of hay making equipment, reducing dry matter losses at feeding, and reducing losses associated with freezing (compared to silage). Depending on the method of storing haylage, additional care may be needed for structures or other farm equipment. Cattle perform best when fed balanced diets consisting of quality forage. Information about forage testing is available in circular AS-991, Know Your Forages, available through your local NDSU Extension Service office.

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