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Silage Production and Management

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SILAGE.... The product of a controlled fermentation of wet, usually green forage in the absence of air (anaerobic or oxygen-free conditions).

Silage can be made from many different crops. In North Dakota, corn is the most widely used crop for silage. Other crops commonly used include alfalfa, sweetclover, forage sorghum and sudangrass and small grains, especially oats used as a companion crop for establishment of perennial grasses and legumes.

Silage making is a method of preserving feed for livestock. The success of silage making is determined primarily by the efficiency of the fermentation process and the value of the end product as livestock feed. The nutritional value of forages preserved as silage generally is not improved.

Efficient utilization of silage by livestock depends on the stage of maturity at which the crop is harvested. Growth stage has a major influence on forage digestibility and the amount of a particular forage consumed by livestock. Various studies have shown that the best time to harvest a crop for silage is a compromise between high forage yield and forage digestibility. In addition, each crop will have an optimum growth stage for harvest depending upon its individual characteristics.

The major factors influencing the success of the ensiling process and the quality of the preserved forage include the following:

- HARVEST AT THE PROPER GROWTH STAGE
- MOISTURE CONTENT AT HARVEST
- FINENESS OF CHOP
- PACK TO EXCLUDE AIR
- COVER TO EXCLUDE OUTSIDE AIR

• Harvest at the Proper Growth Stage

The quality of the feed produced will be no better than the harvested crop. The growth stage at which first-crop forages are harvested has a major influence on forage quality. Each crop has a growth stage when forage quality and quantity are at optimum levels (Table 1). Harvesting at this growth stage will increase the potential for producing a quality silage.

• Moisture Content at Harvest

Dry matter and nutrient losses in silage depend primarily on the moisture content of the crop when placed in the silo, carbohydrate or sugar content of the forage and the exclusion of oxygen. Average losses during storage under good management have been estimated to average about 5 to 6 percent with oxygen-free and concrete stave tower silos and 15 to 20 percent when using a bunker or trench silo and an above-ground pile (Table 2).

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Table 1. Growth stage to harvest major forage crops and estimated percent moisture.

Crop	Growth stage for harvest	Est. % moisture[1]
Grass Crops:		
Corn	Hard dent, kernels glazed	70 to 65
Small grains	Late milk to early dough	75 to 70
Sorghum	Mid to hard dough	70
Sorghum-sudan	Mid to hard dough	70
Sudangrass	Mid to hard dough	70
Perennial grasses	Heading to flowering	75 to 70
Legumes:		
Alfalfa		
1-cut	25 to 50% bloom	80 to 75
2-cuts	1st cut, 10% bloom	82 to 78
	2nd cut, 50-75% bloom	75 to 70
3-cuts	Late bud to 1st flower	85 to 80
Sweetclover	10 to 20% bloom	82 to 75

[1]Field wilting required when moisture content exceeds 70% at harvest.

Table 2. Average dry matter loss of silage during storage under good management.

Silo type	% Dry matter loss Ave.	Range
Oxygen-free	5	1-11
Concrete stave	6	2-12
Bunker or trench	15	10-25
Stack	20	12-25

Silage is often described or grouped according to moisture content. The groupings include direct-cut silage (70 percent moisture or greater), wilted silage (60 to 70 percent moisture), and low-moisture silage or haylage (40 to 60 percent moisture). Another grouping noted in the literature is whole plant corn silage (62 to 68 percent moisture).

The ideal moisture content for high-moisture silage should average about 65 percent. Depending on the crop being ensiled, this will require harvesting the crop at or near physiological maturity or the crop will have to be swathed and field wilted to the desired moisture content.

Some crops are fermented more readily than others because they contain more readily available carbohydrates or sugars (Table 3) for growth and development of lactic acid-producing bacteria. Field wilting crops such as alfalfa and sweetclover which possess low levels of available carbohydrates decreases their moisture content. The sugars present become more concentrated in the cell sap causing a more active fermentation of the forage.

Low-moisture silage or haylage containing 40 to 60 percent moisture requires a well contructed silo that does not leak air. Haylage harvested at 40 to 55 percent moisture should only be stored in oxygen-free or gas-tight silos. The drier the forage the more difficult it is for self-packing to occur in conventional upright silos or for mechanically packing horizontal bunker type silos. Poorly maintained upright silos, horizontal bunkers or trenches and above-ground piles are not satisfactory for ensiling materials drier than 60 to 65 percent moisture.

Table 3. Relative levels of readily available carbohydrates in selected forage crops.

Crop	Carbohydrate availability
Corn	Very high
Small grains	High
Grass	Good
Grass-legume	Medium
Legume-grass	Fair
Legume	Poor

• Fineness of Chop

Fine, uniform chopping aids in packing to exclude air. The recommended theoretical length of cut is 1/4 to 3/8 inch. Finely chopped forage, harvested at the proper moisture content, is more dense. This material, if well distributed in the silo, improves packing. In addition, fine chopping releases more plant juices which stimulate the growth and development of desirable acid-producing bacteria.

• Pack to Exclude Air

Air within the silage mass favors the growth of undesirable bacteria in silage. Their growth and development increases the temperature within the silage. Packing is required to exclude air from the silage mass. In tower silos the silage mass packs itself, provided the forage is spread uniformly during filling. Tower silos should have lower moisture material placed in the bottom half of the silo to reduce seepage loss. The upper portion will be less dense and will pack more readily if forage moisture content is higher. Bunker, trench or above-ground stack silos require packing because the silage depth is not adequate to provide uniform compaction. The lower the daily fill rate, the greater the need for packing. Spread the chopped forage uniformly over the surface and pack continuously.

Too little packing of the silage and/or too slow a fill rate will leave too much air within the silage mass. The temperature of the silage will likely exceed the critical level of about 110°F. Studies have shown that the longer temperatures remain at or above this critical temperature the lower the protein digestibility (Table 4). The drier the silage the more incomplete the fermentation process and the greater the potential problem for increased temperatures. Also, drier silages do not pack as well as wetter silage. They possess less resistance to air infiltration and the probability of increased heating. The drier the silage the greater the temperature rise for a given unit of heat produced, resulting in increased heat damage.

Table 4. Percent protein digestibility as affected by temperature and length of storage.

Period of heating (Days)	Temperature °F		
	110	135	160
	-------- % --------		
0	69.7	69.7	69.7
3	68.7	65.8	60.2
9	68.4	64.4	50.0
18	65.2	58.6	35.8
30	65.4	49.0	30.1

Source: Alberta Agriculture - Agdex 120/25-1. 1976.

Storage losses have been classified as unavoidable and avoidable during various phases of the fermentation process and during storage and feeding (Table 5). Unavoidable losses are those losses that will result even when using good silage management practices. Unavoidable losses occur primarily during the fermentation process. These losses are those that occur during the respiration phase of the ensiling process, the losses resulting from the fermentation process and field wilting losses for grass and legume silage crops. Corn cannot be field wilted for silage, but the crop can be harvested at the proper growth stage to eliminate seepage loss. Dry matter losses by seepage in corn silage may or may not occur depending on the growth stage when harvested.

Table 5. Dry matter losses in silage during various phases of fermentation and storage.

Process	How Classified	% Loss range	Cause
Plant respiration	Unavoidable	1 - 4	Living plant cells
Aerobic respiration	Avoidable	0 ->6	Crop, filling time, silo sealing.
Fermentation	Unavoidable	3 - 8	Desirable microorganisms
Seepage loss	Avoidable[1]	3 ->7	Moisture content at harvest
Wilting loss	Unavoidable		Crop, weather, wilting time in field.
Secondary deterioriation	Avoidable	0 ->5	Crop, moisture content at harvest, environment in silo
Silage stability	Avoidable	0 ->10	Crop, unloading technique, season of year.

[1] May improve fermentation process of extremely wet material.

Avoidable losses are those related to silage management practices. Rapid, continuous filling of the silo and packing and covering to exclude air are extremely important practices to maintain dry matter losses at a minimum.

Silage crops vary in their stability once the silo is opened for feeding. During cool weather 1 to 2 inches of silage should be removed daily to prevent molds from developing. If temperatures are warm, silage removal rates of 3 inches or more daily may be required to maintain a palatable feed for livestock.

• Cover to Exclude Outside Air

Silos, especially bunkers, trenches and aboveground piles, should be covered immediately after filling is complete to exclude outside air. In general, the greater the exposed surface area in relation to the tonnage stored, the greater the need for covering the silo to prevent surface spoilage. The shallower the depth of silage, the greater the need to cover to prevent surface loss.

Silage to be carried over as a feed reserve should be covered. It's best to cover immediately after filling is complete before spoilage occurs. Plastic sheeting should be covered with a layer of insulating material such as straw, soil, or other suitable material. The insulating material prevents moisture from condensing on the top layer of silage due to the sun heating the plastic. The excess moisture increases surface spoilage by diluting the lactic acid in the silage. The insulation and/or weighted surface prevents surface air infiltration and protects the plastic from flapping in the wind and pumping air into the silage mass.

CROPS FOR SILAGE

• Corn Silage

Growing corn for silage is no different than growing corn for grain (see circular A-834, Corn Production for Grain and Silage).

Corn harvested for silage at the ideal growth stage will contain about 50 percent corn grain and cob by

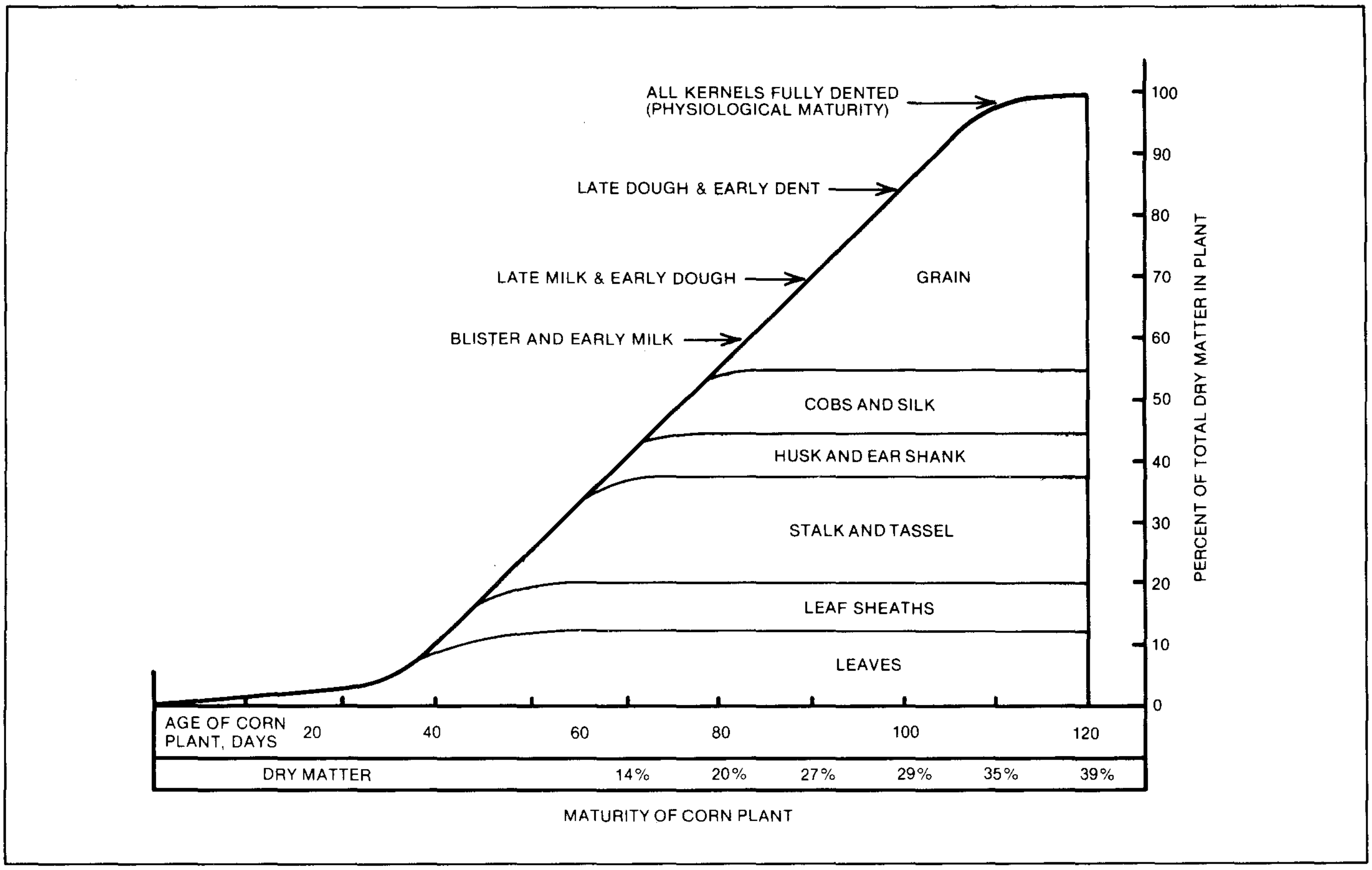

Fig. 1. Influence of growth stage on dry matter accumulation in corn.

weight. In addition, the corn and cob contain about 65 percent of the nutritive value of high quality corn silage. Therefore, select a full season hybrid with a high grain yield. DO NOT SELECT LATE-MATURING HYBRIDS AS MOISTURE CONTENT WILL USUALLY BE TOO HIGH TO PRODUCE QUALITY SILAGE.

Corn should be harvested for silage when it has reached physiological maturity. Corn at this growth stage has attained its maximum dry weight per acre, maximum forage digestibility and maximum total digestible nutrient yield per acre. The moisture content of the crop at physiological maturity is about 65 percent (Fig. 1). Under favorable growing conditions, corn harvested at the hard dent or glazed growth stage will usually be green and succulent and field losses will be low.

Physiological maturity in corn also may be determined by viewing the corn kernels. Corn that has reached this growth stage forms a "black layer" of cells near the germ end of the kernel (Fig. 2). To check for the black layer, remove several kernels from the middle of the ear, split them lengthwise or just cut off the tip. If the black layer is present, the grain is physiologically mature.

Another method sometimes used to determine when corn is ready to cut for silage is to observe the

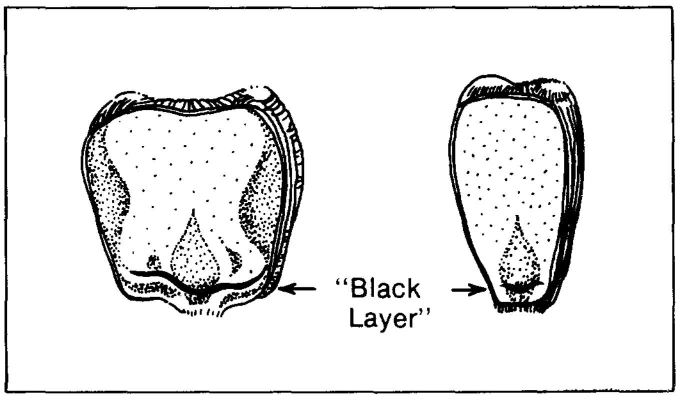

Fig. 2. Location of "black layer" in corn kernel.

"milk line" on the kernels. Break an ear of corn in two and observe the kernels opposite the germ face. The milk line forms as the kernel dries from the top down. It is the cream colored dividing line between the starchy part of the kernel and the milky dough below. Corn is ready to harvest for silage when no milk line can be observed.

• Alfalfa Silage

The growth stage and moisture content when placed in the silo are the two most important considerations when making alfalfa silage.

Growth stage when harvested, especially for the first cutting, has a major influence on nutritional quality. For each day cutting is delayed, animal intake decreases about 2 percent and forage digestibility decreases 0.3 to 0.5 percent per day. The recommended growth stages for harvest (Table 1) vary depending on the number of cuttings obtained during the growing season. These cutting schedules will provide near maximum forage yields and optimum forage quality.

Alfalfa is difficult to ensile if the crop is not wilted in the field prior to chopping. Alfalfa has a low sugar content. Field wilting to an average of 65 percent moisture or less, depending on the type of storage sturcture available, concentrates the sugars in the cell sap and provides for a more ideal fermentation.

Silage less than 60 percent moisture is difficult to pack and should not be stored in conventional upright silos, bunkers, trenches or above-ground piles. DO NOT STORE ALFALFA SILAGE IN POORLY MAINTAINED CONVENTIONAL SILOS. Bunkers, trenches and above-ground piles should always be covered or well sealed to exclude outside air when storing alfalfa silage.

Haylage, 40 to 55 percent moisture silage, should always be stored in oxygen-limiting or gas-tight silos. Silo management is very important when storing low-moisture silage in oxygen-limiting silos. Fill hatches should be closed at night, on weekends and during any interruptions in the filling process. If hatches are not closed during the entire filling period, the advantage over conventional silos will be lost. Research has shown that dry matter losses may increase a minimum of 4 percent if the top hatch is left open during filling. If the hatch is left open for several days after filling is complete, forage quality is seriously reduced due to excess heat produced and growth of undesirable microorganisms.

• Small Grain Silage

Oats is the most widely used small grain crop for silage. Forage yield data obtained at Fargo and Williston, ND show that maximum yield is obtained at about the dough stage of growth (Fig. 3). Protein composition of the forage decreases with advancing maturity to about 10 to 12 percent. Similar yields and protein contents have been obtained with barley and wheat in North Dakota tests. Highest dry matter yields have been obtained when medium to late maturing varieties are seeded.

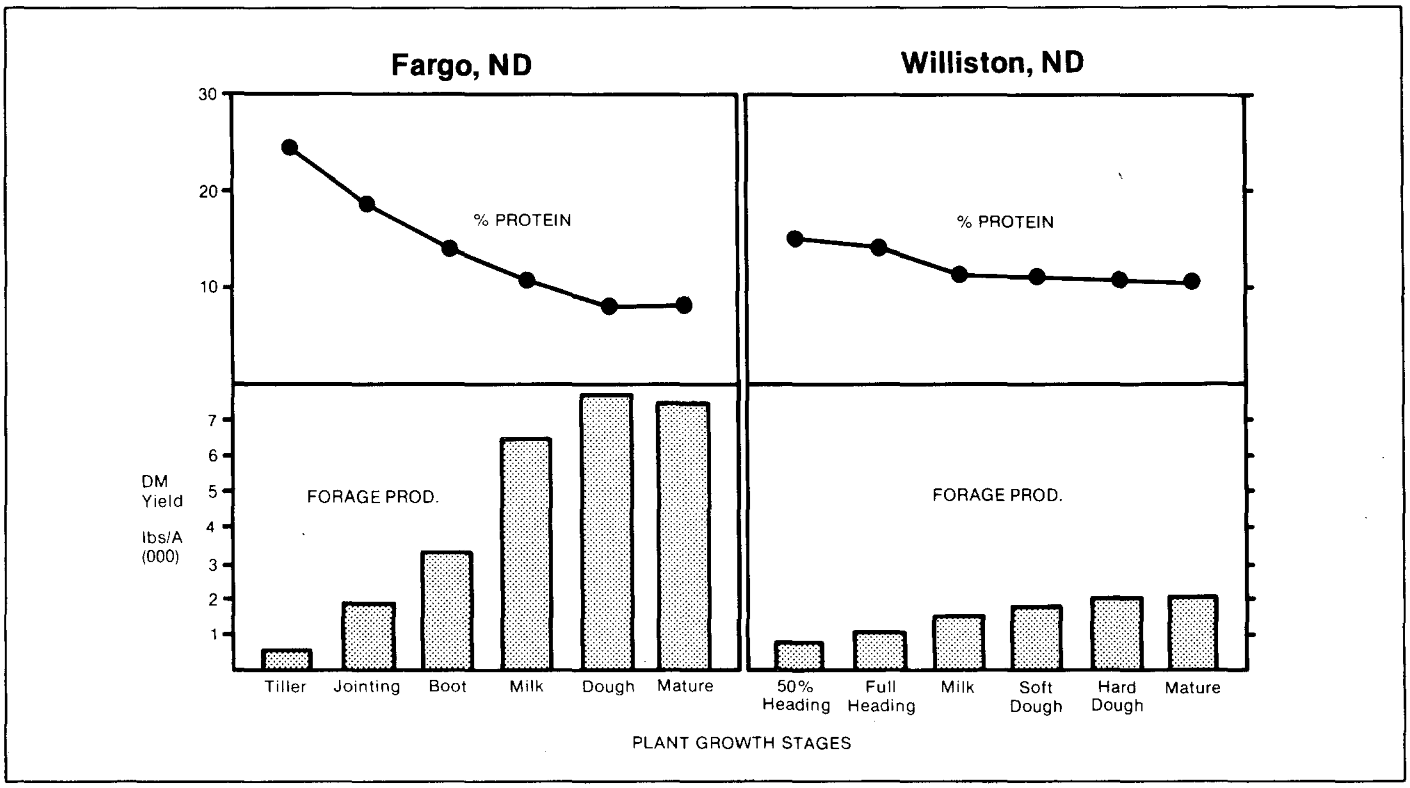

Fig. 3. Forage yield and protein content of oats harvested at various growth stages.

Oats should be harvested for silage at the late milk to early dough growth stage. The crop contains about 70 percent moisture at the dough growth stage and can be direct cut for silage. Silage cut earlier than the dough growth stage will require field wilting as the moisture content is usually 75 percent or more.

Small grains that have started to ripen will be too dry and hard to pack in the silo. Once the crop reaches the dough growth stage, optimum moisture levels will only be maintained for about four to seven days depending on weather conditions.

Fine chopping is very important when making small grain silage. The stem is hollow and requires fine chopping for more uniform packing.

• Sorghum-Sudangrass Silage

Silage made from sorghum varieties, hybrids and crosses will have a feeding value approximately 80 to 85 percent that of corn silage. In North Dakota, these forages are planted for silage on a temporary or emergency basis due to drouth, hail, winterkill and/or injury of legume stands. The forage sorghum hybrids and crosses will produce greater yields of forage than corn if plantings must be delayed due to spring and early summer drouth. Dry matter yields of forage sorghum and sudangrass compared to corn when planted during late May to early June are provided in Table 6. In general, forage sorghum hybrids and crosses are higher yielding than sudangrass varieties and hybrids.

Table 6. Dryland forage dry matter yields of forage sorghum and sudangrass varieties, hybrids, and crosses to corn when grown in wide rows.

Entry	Tons dry matter/acre[1]					
	Carrington	Dickinson	Edgeley	Fargo	Minot	Williston
Sorghum varieties & hybrids	3.2	1.9	4.5	5.9	3.7	2.8
Sorghum X sudangrass crosses	3.4	2.1	3.2	5.6	2.9	2.6
Piper sudangrass	2.2	1.0	2.2	3.8	2.2	1.9
Sudangrass hybrids	2.8	1.3	2.1	4.5	1.9	1.4
Corn all varieties	2.6	1.5	2.6	4.2	3.0	2.5

[1] Multiply yields by 3.3 to obtain silage yield at 70% moisture.

Forage sorghums should be harvested for silage at the medium to hard dough stage of growth. The crop will have approximately 70 percent moisture and can be direct-cut for silage.

Production practices for sorghum and sudangrass varieties and hybrids are discussed in circular R-762 entitled "Sorghum and Sudangrass for Forage in North Dakota".

• Sweetclover Silage

Sweetclover is sometimes stored as silage in North Dakota. It should be harvested for silage at the 10 to 20 percent bloom growth stage. Sweetclover harvested at this growth stage will have about the same feed value as alfalfa.

Sweetclover, like alfalfa, is low in sugar content and requires field wilting to concentrate the sugars in the cell sap. The crop, when harvested at the 10 to 20 percent bloom growth stage, contains about 80 percent moisture. The crop should be wilted to an average of about 65 percent moisture when placed in the silo as high moisture silage. If stored as haylage in oxygen-limiting silos, the moisture content should be between 55 to 60 percent.

Sweetclover contains a compound called coumarin. The coumarin is converted to a toxic substance in molded or spoiled silage and may cause "sweetclover bleeding disease". The toxic substance (dicoumarol) reduces the clotting power of the blood of animals. Animals consuming too much dicoumarol over time may bleed to death from slight wounds or internal hemorrhages. If animals are to be dehorned or castrated, do not feed sweetclover forage for at least three weeks prior to working cattle and at least 30 days prior to calving.

Molded or spoiled sweetclover silage can be very dangerous when fed as the only forage if high dicoumarol levels are present. Preventing mold formation in sweetclover silage is very important if high coumarin content varieties are grown.

NORGOLD is a yellow-flowered, low coumarin variety of sweetclover that can be grown to eliminate the potential danger of "sweetclover bleeding disease". ALWAYS PURCHASE CERTIFIED SEED or the benefits of growing a low coumarin variety will be lost. This is because low coumarin varieties may revert back to a high coumarin level if more than three generations away from breeders' seed.

Follow good silage management practices. Fill the silo rapidly, harvest at the proper moisture content, pack to exclude air from the silage mass, distribute the chopped forage uniformly in the silo when filling and cover to exclude outside air from entering the silage. Another alternative is to place a layer of another forage type over the sweetclover silage to reduce the potential for molding of sweetclover, then cover the silo.

ADDITIONS TO SILAGE

Various additions to silage have been suggested as methods to improve or alter the fermentation process. These materials may be referred to as ADDITIVES, CONDITIONERS and PRESERVATIVES. They are defined as follows:

- ADDITIVE - A material that adds nutrients to silage.
- CONDITIONER - A material that absorbs excess moisture from chopped forage or which increases the moisture content of excessively dry forage.
- PRESERVATIVE - A material that stimulates the fermentation process or a material that inhibits fermentation.

The benefits obtained from silage additives, conditioners and preservatives depend upon their influence on the silage fermentation process. These benefits are usually measured by the reduction in fermentation losses and/or improvement in silage quality and feeding value.

Silage additive, conditioners and preservatives function in the following ways:

- Add dry matter to reduce moisture content
- Add water to increase moisture content
- Alter the rate, amount and kind of acid production
- Acidify the silage
- Inhibit bacterial and mold growth
- Culture silage (inoculants) to stimulate acid production
- Increase nutrient content of the silage

Add Dry Matter to Reduce Moisture Content

The objectives of adding dry matter are to reduce seepage losses and provide a more suitable medium for the fermentation process. The goal of producers should be to harvest corn and sorghum for silage at the proper growth stage or at physiological maturity when plant moisture content is ideal for silage. Grasses and legumes should be wilted or dried down in the swath to an average of about 65 percent moisture or less depending on the type of storage used.

If forage crops must be harvested too wet for silage, the following guideline for dry matter addition may be used.

- Cereal grains, coarsely ground, and chopped, air dry alfalfa or grass forage will decrease the moisture content of wet forage approximately 5 percentage units for each 150 to 200 pounds of material added per ton of wet forage weight.

Add Water to Increase Moisture Content

If forage crops to be stored as silage become too dry, packing to exclude air is difficult. Under such conditions, water must be added to raise the moisture content to the desired level or severe dry matter losses will result.

- The amount of water required to increase forage moisture content 1 percentage unit is approximately 5 to 6 gallons per ton of ensiled material.

Altering the Rate, Amount and Kind of Acid Production

Acid production is essential in the keeping qualities of silage. The rate, amount and kind of acid produced is influenced by the moisture content of the chopped forage and the readily available carbohydrate content of the forage.

Corn silage harvested at the proper growth stage or at physilolgical maturity has a high level of readily available carbohydrates for lactic acid production. If legumes and grass crops are not wilted in the field to an average of 65 percent moisture or less depending on the type of storage, then the addition of a carbohydrate-rich feedstuff will enhance fermentation.

Molasses is an excellent carbohydrate or sugar source for legumes and grasses containing 75 to 80 percent moisture. For legumes, about 80 pounds of molasses per ton is required, and for grasses 40 pounds is generally used.

Cereal grains are another source of carbohydrates. These materials, when added at 150 to 200 pounds per ton of wet forage, will also reduce the moisture content of the chopped forage approximately 5 percentage units.

Acidifying the Silage

Acidifying silage, using a strong acid, has been practiced in Europe on high moisture grass silage. The purpose was to produce an immediate acid condition rather than waiting for the silage to produce its own acid. This practice is not recommended in the United States because of its high cost, the corrosive nature of the acids and low forage palatability.

Inhibit Bacteria and Mold Growth

While acid formation and the exclusion of oxygen stop bacterial growth, several chemicals used as silage preservatives also inhibit undesirable bacterial and mold growth. Acids, such as Formic and Propionic, enhance the preservation of forage. The major benefit of adding weak acids to silage appears to be in reducing spoilage in open type storage structures. Formic acid is added to hay crop silages at 0.45 percent of the wet weight or 2.25 percent of the dry matter weight. Propionic acid is added at the rate of 0.5 to 1.0 percent of the wet forage weight.

"Culturing" Silage (Inoculants)

A number of commercial products, referred to as fermentation aids and/or inoculants, are available for adding to silage at the time of ensiling. Since silage is a product resulting from the action of bacterial enzymes on the material stored, attempts have been made to alter or regulate silage fermentation through the addition of materials containing bacteria, yeasts and molds. The primary purpose for adding bacterial inoculants is to increase the number of lactic acid-producing bacteria, thus encouraging more lactic acid production and a well preserved forage mass.

Research using various bacterial inoculants indicates highly variable results. Products showing consistent, positive results indicate about a 5 percent increase in dry matter preservation. Therefore, cost of the inoculant per ton compared to the dollar value of the dry matter saved will determine the profitability of using a silage inoculant.

The addition of bacterial inoculants to corn silage harvested at the proper growth stage and moisture content has not shown consistent positive results. Results have been more positive when inoculants have been added to alfalfa, a low carbohydrate forage, and sorghum silages.

Increasing the Nutrient Content of Silage

Various materials added to silage will increase nutritive value to the extent that they themselves contain nutrients. Increasing the nutrient content of silage will greatly affect the final cost of the product produced.

Materials such as cereal grains, molasses, dry forages, limestone, urea and anhydrous ammonia are examples of nutrient additions to silage. Commercial products are also available that contain one or more of the above materials.

Limestone (calcium carbonate) is sometimes added to corn silage to increase the calcium content and extend the fermentation process. The rate frequently added is 10 to 20 pounds per ton of corn silage.

Urea and anhydrous ammonia, non-protein nitrogen (NPN) sources, are sometimes added to corn silage to increase the protein content. The various NPN sources listed in Table 7, when applied at the suggested rate per ton of stored forage, usually will increase forage protein content about 4 percentage units on a dry matter basis.

Table 7. Non-protein nitrogen sources for adding to corn silage and suggested application rates.[1]

NPN sources	Form	% Nitrogen	Application rate lbs/wet ton
Urea	dry	45	10
Mono-ammonium phosphate	dry	11	20[2]
Pre-mixed ammonia-water	liquid	20-30	17-25
Anhydrous ammonia	gas	81	6-7
Ammonia, cold flow	gas-liquid	81	6-7

[1] Commercial products should be applied at a rate to provide 5 pounds of actual nitrogen/ton of forage.

[2] Add 5 lbs dry urea to provide 5 lbs of nitrogen.

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