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Growth Through Agricultural Progress

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Making and Feeding Hay-Crop Silage

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Hay-crop silage is made by fermenting any moist hay or pasture crop—a true grass, a legume, a green cereal, or any combination of these.

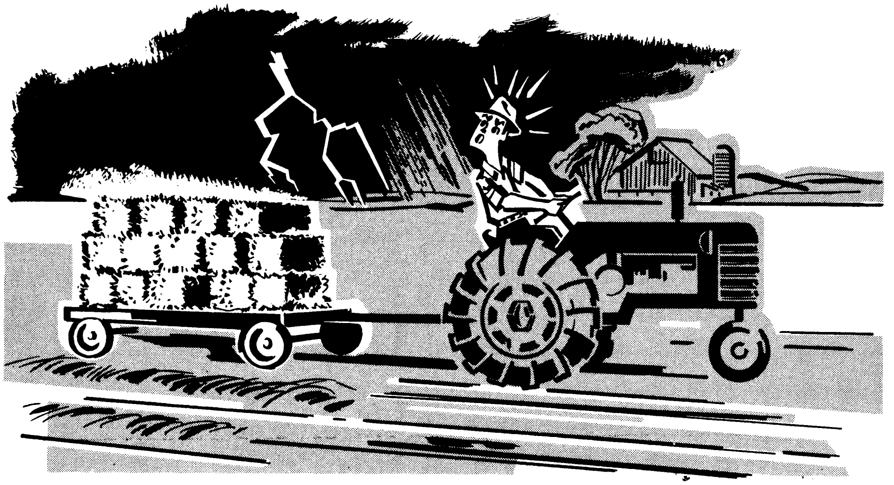
Making a hay crop into silage has these advantages:

- High-quality forage that might otherwise be harvested as hay of inferior quality, or lost because of inclement weather, can be preserved.
- The protein in homegrown forages can be preserved, thus reducing requirements for purchased high-protein supplements.
- A high proportion of the carotene is preserved, thus insuring against vitamin A deficiency.
- Little additional equipment expense is required for farms already producing corn silage. On these farms, silos can be used 2 or 3 months when they would otherwise be idle.
- Hay-crop silage is well adapted to fully mechanized storing and feeding and self-feeding.
- More dry matter is conserved by ensiling than by field curing the same crop.
- Silage is well adapted to a system of saving excess spring-pasture growth for a pasture supplement during midsummer.
- Crops can be harvested earlier—at their most nutritious stage.
- Siloing destroys weed seeds and reduces fire hazard.

The ensiling process *will not* improve the quality of the harvested forage.

Some disadvantages of hay-crop silage are:

- Storing a ton of a crop as silage requires the handling of two to four times more weight than storing it as hay.
- Additional equipment is needed if corn silage is not already being produced.
- Silages made from high-moisture crops that have received no wilting or preservative often have an offensive odor.
- Animals' dry-matter consumption of some silages—especially those from direct-cut crops—is less than that of good hay. Therefore, silage is not as satisfactory as hay when it is the only forage in a ration.



HAY CROPS FOR SILAGE

Individual crops and mixtures used for making silage differ with climate, soil type, and crop rotation. Practically any hay or pasture crop forage can be successfully ensiled. Select the harvesttime by the stage of maturity of the predominant crop in a mixture. The best time for silage-crop harvesting is generally the same as that for hay.

The following shows the stage of maturity at which hay crops should be harvested for silage:

Crops	*Stage of maturity*
Alfalfa	1/10 to 1/4 bloom.
Perennial grasses	Grass heads emerged before bloom.
Small grains	Boot stage.
Clovers	1/2 bloom.
Soybeans	Seeds forming in pods.
Lespedeza	First seeds forming.
Millets	Boot to early headed.
Sudan grass	Boot to early headed.

Delays in harvesting beyond the early heading stage in grasses or first-bloom stage in alfalfa decrease palatability and digestibility of the forage. Each day's delay decreases digestibility about 0.5 percent. Each decrease means that more grain must be fed to maintain high production levels. Late harvesting of the first cutting often reduces the yields of subsequent cuttings. Therefore, nothing is gained in terms of total tonnage obtained.

The lower moisture content of mature crops reduces seepage losses and the amount of weight to be handled. However, these advantages are not sufficient to justify a delay in harvesting.

GENERAL PRINCIPLES

Harvesting and filling

The methods of making hay-crop silage may be classified as either wilting or direct cut. Wilting allows partial field drying of the cut crop so that it contains 60 to 70 percent of moisture when stored. Direct cutting allows no field drying. The crop is ensiled with its moisture content unchanged.

Each step in silage making may be accomplished in more than one way. The procedure is basically the same in all systems.

In the wilting procedure, mowing and windrowing are followed by harvesting with a field chopper having a windrow-pickup attachment. If the crop is to be direct cut, the standing crop is harvested with a field chopper having a sickle attachment. In either case the chopper is followed by a truck or wagon into which the chopper delivers the chopped forage. Harvesting unchopped forage with a buck rake or heavy-duty hayloader is possible but is not a common practice.

Storing forage

Chopped forage is stored in tower silos by raising it to the top of the silo with a silage blower or elevator. If a bunker or trench silo is used, the loaded truck or wagon may be driven into the silo and dumped directly. Or a blower or elevator may be used. If a preservative is to be added to the forage, it usually is added at the blower or elevator or spread on each load just before or after being dumped.

Distributing and packing

In tower silos distributing and packing is done by hand or with the aid of a mechanical rotary distributor at the top of the silo or, sometimes, dispensed with. In bunker or trench silos distributing and packing usually is done with a tractor equipped with a blade or scoop. A wheel-type tractor does a more solid packing job, but a crawler-type tractor is sometimes used because it is faster and more convenient.

Well-packed silage will not be damaged as much as loosely packed silage by small air leaks in silo walls or the top seal.

Sealing the surface

An improperly sealed silo can waste the labor and expense of getting a crop into the silo. The top layer of silage should be sealed as soon as possible after filling is completed. A weighted plastic sheet is usually best. A layer of soil, wet sawdust, limestone, or waste forage is good weighting material.

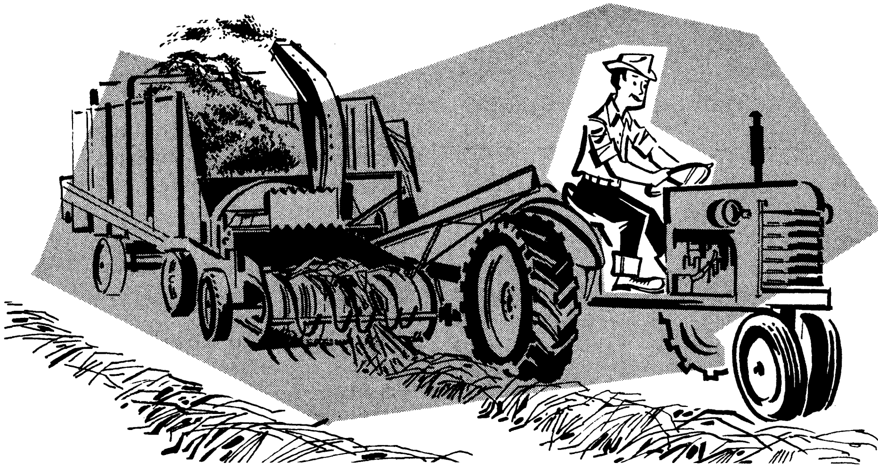
How silage is formed

Silage is formed by bacterial activity and other chemical changes in green forage stored in the absence of air. If air is not excluded from a moist stored forage crop, it will mold, rot, and become useless. Sealing the crop from the air prevents this damage.

Bacteria that grow in the absence of oxygen produce organic acids by fermenting the sugars and other carbohydrates in the crop. The organic acids formed stop further bacterial action and preserve the silage.

Silages sealed against oxygen differ in quality. These differences depend on the amount and type of acids formed by the fermentation and the amount of protein breakdown. Chemical composition of the plant, tightness of the air seal, type of chopping, and speed of filling affect fermentation.

Silage that has undergone ideal fermentation contains a predominance of lactic acid; little, if any, butyric acid; and small amounts of ammonia. Crude protein values alone are of little value as indicators of silage quality. They do not show how much true protein remains and how much has been changed to a low-value ammonia form. Crude protein values remain about the same during ensiling, even though the silage may be poorly preserved and much of the true protein changed to a low-value form—ammonia.



MAKING WILTED SILAGE

When wilting crops for silage, reduce the moisture content to 60 to 70 percent by partial field drying. On a bright, hot day, mown forage may wilt properly in 2 or 3 hours; during cool, cloudy periods, wilting may require 2 or 3 days.

You can estimate moisture content by a squeeze test. Squeeze a handful of chopped forage into a ball and hold it 20 to 30 seconds. Then quickly release your grip. The condition of the ball shows about how much moisture it contains. Following is a guide for estimating moisture content:

Condition of forage ball	*Approximate moisture content*
Ball holds shape, considerable free juice	Over 75 percent
Ball holds shape, little free juice	70 to 75 percent
Ball falls apart, no free juice	60 to 70 percent
Ball falls apart readily	Below 60 percent

The moisture content of individual loads is not so important that the harvesting operation must be halted occasionally to allow time for drying. Some loads with a slightly higher or lower moisture content than that recommended may be put into the silo occasionally without affecting the overall quality of the silage.

Plan ahead so you do not lose time in waiting for the crop to wilt and do not allow the wilting to become excessive. Mowing and raking in separate operations is the simplest method. This method allows you to vary the speed of wilting by raking at the proper time. Windrowed forage wilts more slowly.

You can combine the mowing and windrowing operations by using a windrowing attachment, mounting a rake and mower on the same tractor, or using a special mowing-windrowing machine.

Because a considerably longer wilting period is required when windrows are made soon after cutting, accurate planning is required to reduce weather risks. Time required for wilting is reduced to a minimum by using a hay conditioner and leaving the crop in the swath to wilt.

Efficient harvesting requires that the forage harvester be operated at full capacity. Chopping forage with a direct-cutting machine is less efficient than chopping wilted forage from the windrow because—

• Extra power is required to handle the moist crop.

• Some crops cannot be fed into a direct-cut machine fast enough to keep it loaded to capacity, since groundspeed and width of cut are limited.

Table 1 shows results of comparisons between the time required to harvest alfalfa as wilted-windrowed forage and the time required to harvest it as direct-cut forage. The comparisons were made at the Agricultural Research Center, Beltsville, Md., under different crop conditions over a 4-year period. It was found that crops were chopped from windrows twice as fast as from the standing position.

TABLE 1.—*Time required to harvest alfalfa as wilted forage and as direct-cut forage*

[Average results obtained by Agricultural Engineering Research Division, Agricultural Research Service, Beltsville, Md., 1955 through 1958]

WILTED FORAGE [1]

Machinery used in harvesting	Man (or machine) hours per ton of dry matter
Method A	
7-foot mower	0. 49
7-foot rake	. 43
5-foot forage harvester with windrow attachment	. 33
Silo filler	. 27
Total	1. 52
Method B	
7-foot mower-rake	0. 59
5-foot forage harvester with windrow attachment	. 33
Silo filler	. 27
Total	1. 19
Method C	
12-foot mower-windrower	0. 20
5-foot forage harvester with windrow attachment	. 33
Silo filler	. 27
Total	. 80

DIRECT-CUT FORAGE [2]

5-foot forage harvester	0. 66
Silo filler	. 34
Total	1. 00

[1] Moisture content: 65.5 percent. Yield: 0.82 ton of dry matter per acre from 75.6 acres.

[2] Moisture content: 75 percent. Yield: 0.76 ton of dry matter per acre from 29.4 acres.

When mowing and raking are combined (method B), total labor and machinery requirements for harvest of wilted forage approach those for direct-cut forage. But when a windrower is used (method C), requirements for wilted forage are less than those for direct-cut forage.

When a high-yielding crop is being harvested, a relatively slow groundspeed will load a direct-cut machine to capacity. Some of these comparisons were made on alfalfa yielding 8 tons per acre of 78-percent-moisture forage. Even in this heavy crop, when it was easy to keep the direct-cut harvester fully loaded, 60 percent more acres per hour were harvested by windrowing and wilting to 62-percent moisture.

Reducing moisture content of the forage by delaying harvest until the crop is in an advanced stage of maturity should be avoided because it produces less palatable forage of lower nutrient content. This forage is also more difficult to pack and may become moldy if wilted to a moisture content as low as 60 percent.

Excluding air from wilted silage is more difficult than with direct-cut silage. The lighter, wilted silage will not pack as tightly in the silo. This places more emphasis on a tight silo, rapid filling, good distribution and packing, and short chopping (harvester set for ½-inch cut or less). These conditions can best be met in tower silos; with experience, however, it is possible to use bunker and trench silos successfully for wilted silage. It is recommended that at least the top half of tower silos be tramped to pack the crop tightly enough to eliminate air pockets. Using unwilted forage for the last two or three loads also will aid in packing.

Crops may be wilted even more before storage when using a gastight silo in good condition. High-density packing is not required to keep air out of silage in these structures because the silo serves as the seal. When gastight silos are used, the moisture content may be reduced to 40 to 50 percent. Do not wilt beyond this point since no benefits in terms of preservation or silage quality will be gained, and the additional wilting will increase weather damage and leaf losses during harvesting.

Ensiling wilted crops results in little or no seepage loss.

The reduced weight of wilted silage makes it easier to handle than high-moisture silage. The amount of dry matter in 100 tons of wilted, 65-percent-moisture crop and in 175 tons of fresh, 80-percent-moisture crop is the same—35 tons. The wilted crop contains 65 tons of water, the fresh crop 140 tons—a difference of 75 tons of water.

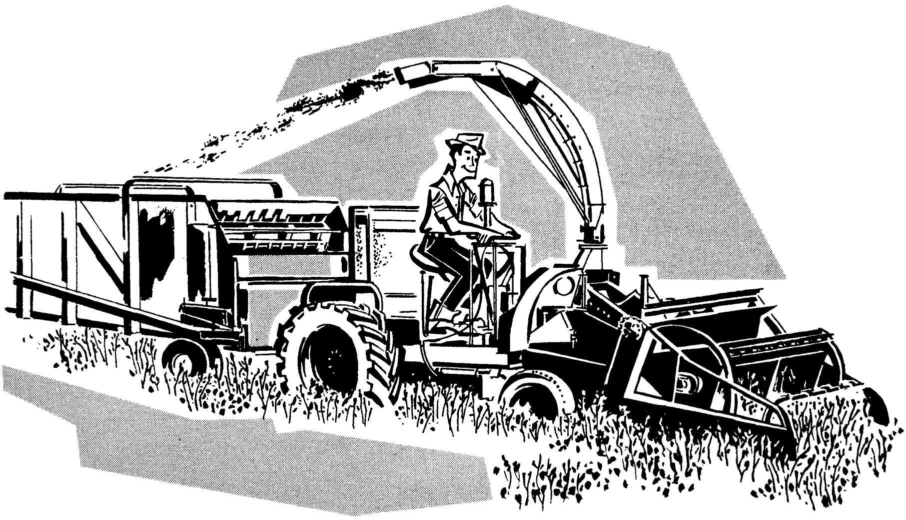
However, making wilted silage by partial field curing is affected more by weather conditions than is the direct-cut method.

MAKING DIRECT-CUT SILAGE

First-cutting forage crops, cut at the recommended stage of maturity, often contain 75 to 85 percent of moisture. By the direct-cut method, a forage harvester with mower-bar attachment cuts the crop, chops it, and blows it into a trailing wagon or truck, which transports it to the silo. Thus, the moisture content is practically as high when stored as when cut.

High-moisture silage has two basic disadvantages:

- The extra water increases the problems of handling, seepage, and silo pressures. Extra reinforcement should be added to silos when storing high-moisture silage.
- Fermentation of wet silage produces too much of the weak



acids, such as butyric acid. Weak-acid, high-ammonia fermentations result in foul-smelling, unpalatable silage.

This tendency toward poor fermentation is not consistent. Excellent fermentation sometimes occurs in high-moisture silage; the reason for this is not clear. Because the fermentation of untreated high-moisture forage is unpredictable, many farmers add preservative materials, although they often are not needed. Additives should do at least one of these things to be of help:

- Provide fermentable carbohydrates.
- Furnish additional acids directly to increase acid conditions.
- Specifically inhibit the undesirable types of bacteria.
- Directly or indirectly reduce the amount of oxygen present.
- Reduce the average moisture content of the silage.
- Absorb some seepage that might otherwise be lost.

Adding 60 to 100 pounds of molasses per ton of fresh forage will increase the percent of fermentable carbohydrates. This generally produces a silage that is sufficiently acid and of good quality. Because molasses must be diluted with water to obtain the proper rate of flow at the blower, water is added to an already high-moisture silage. This increases the seepage losses.

Adding 100 to 300 pounds of dry, ground grains or dried-pulp products to direct-cut forage on the load or at the blower will absorb much of the excess moisture and provide a source of carbohydrates. Although these feeds increase the feeding value of the silage, 15 to 20 percent of the feeding value of the added grain may be lost during the fermentation process.

Table 2 shows that when 1 ton of 80-percent-moisture, high-quality forage is stored, you must add 300 pounds of ground grain or pulp product to avoid seepage losses by reducing the moisture content to about 70 percent. The result is that about 40 percent of the stored dry matter is feedstuff preservative.

Feedstuffs are not usually added at rates higher than 200 pounds per ton of forage. Reasons are the initial expense, storage losses of the added feed, and difficulty in efficiently using a silage that contains more than 30 percent of grain or pulp products.

Chemical preservatives thoroughly mixed with the chopped forage generally produce desirable fermentation and good silage but add nothing directly to the feeding value of the silage.

A chemical may be added to decrease the growth of bacteria that produce undesirable changes. This encourages the development of desirable organisms and produces a good-smelling, palatable silage. Sodium-metabisulfite and Kylage[1] are typical of this type of chemical preservative. They are most conveniently added at the blower during storage.

Direct-cut forage should be chopped to a ¾-inch cut and should be leveled and tramped especially well at the edges for at least the top third of the silo.

[1] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guaranty or warranty of the product named and does not signify that this product is approved to the exclusion of other comparable products.

TABLE 2.—*Effect of adding feedstuff preservatives on moisture content of forage originally containing 80 percent of moisture*

Pounds of preservative added per ton of forage	Pounds of dry matter in each ton stored			Percentage of total as—		Average moisture of ensiled material (percentage)
	Forage	Grain	Total	Forage	Grain	
None	400	--------	400	100. 0	--------	80. 0
100	382	86	468	81. 6	18. 4	76. 6
150	374	128	502	74. 8	25. 2	74. 9
200	366	166	532	69. 0	31. 0	73. 4
250	360	202	562	63. 4	36. 6	71. 9
300	352	238	590	59. 7	40. 3	70. 5
350	346	272	618	55. 9	44. 1	69. 1

Comparison of Harvesting Methods

The advantages and disadvantages of wilting and direct cutting may be summarized as follows:

WILTING

Advantages

Less weight to store and feed.
Faster harvesting.
Reduces seepage losses.
No expense of added preservatives.
Pleasant odor.
High dry-matter intake by animals.

Disadvantages

Possibility of weather damage is increased.
Requires more exacting management.
Requires an additional field operation.
Possibility of damage to chopper by stones is increased.

DIRECT CUTTING

Advantages

One operation from field to silo.
Less chance of field losses.
Less chance of damage to chopper by stones.
Packs more easily.

Disadvantages

Additional water must be handled and fed.
Expense of preservatives.
Objectionable odors.
Low dry-matter intake by animals.
Increased seepage; increased dry-matter loss.

TYPES OF SILOS

Silos confine the crop within a reasonable space and aid in excluding air from the crop. They are either upright or horizontal.

You can produce high-quality feed by using either type of structure if air has been properly excluded. Both wilted and direct-cut forage should be ensiled as rapidly as possible to prevent an excessive rise in temperature, which is evidence of air damage.

The surface area of the forage should not be exposed to air more than 12 to 18 hours before being covered with at least a foot of fresh forage. If filling must be interrupted for more than 2 days, level the silage and seal it with a plastic sheet weighted with wet forage until filling is resumed.

Upright silos

Permanent.—Satisfactory upright silos are constructed from a wide variety of materials, including wood, concrete, tile, steel, and glass-coated steel.

Inside walls and doors should be smooth and free from cracks and holes which might be a source of air leaks. Lining the doors on the inside of the silo with plastic sheeting or asphalt paper gives added protection against air leaks.

The structure should be designed or reinforced to withstand the high pressures associated with hay-crop silages. Adequated drainage should be provided to prevent saturation of the forage at the bottom of the silo and to relieve the pressure of excessive seepage. Feeding from upright silos can be made completely automatic by the use of mechanical top unloaders, conveyors, and bunks.

Immediately after filling is completed, seal the silo by—

- Carefully placing on top of the silage a sheet of plastic that covers the forage and extends several inches up the silo wall. Weight the sheet with 1 to 2 feet of direct-cut forage or wet sawdust. Generally this provides a satisfactory airtight seal.
- Inserting in the upper 2 to 3 feet of the silo a commercially made pastic sleeve. Partially fill the sleeve with direct-cut forage and tie the free end securely. The sleeve is pressed against the smooth silo wall by the weight of enclosed forage.
- Carefully installing a commercially prefabricated silo cap on the exposed surface of the silage. Fill the cap tube with water to keep it pressed against the silo walls.

Temporary.—Snow fence with a lining of reinforced waterproof paper or plastic, or heavy galvanized wire fence with such a lining, makes a useful temporary silo. Additional labor and care are required in properly constructing and packing this temporary stack. Height of the silo should not exceed the diameter by more than 4 feet.

Gastight Silos

Gastight steel silos equipped with mechanical unloaders are available.

Air cannot reach forage stored in these silos as long as they remain sealed, and the originally included air is soon used by respiration and fermentation of the forage. Therefore, hay-crop forage may be ensiled in gastight silos without distributing or tramping, and at moisture contents of 40 to 60 percent.

These structures are especially well suited to intermittent filling or feeding. The mechanical unloader at the bottom of the silo will allow completely mechanized feeding if it is used in conjunction with a conveyor system.

Because the sealing materials are not well protected and are easily punctured or torn, temporary upright silos are difficult to keep airtight. However, if handled carefully, they may provide excellent storage.

Horizontal silos

Trenches, bunkers, and stacks are inexpensive but require greater skill in filling and sealing than do upright silos because of the large area of forage susceptible to damage caused by surface exposure.

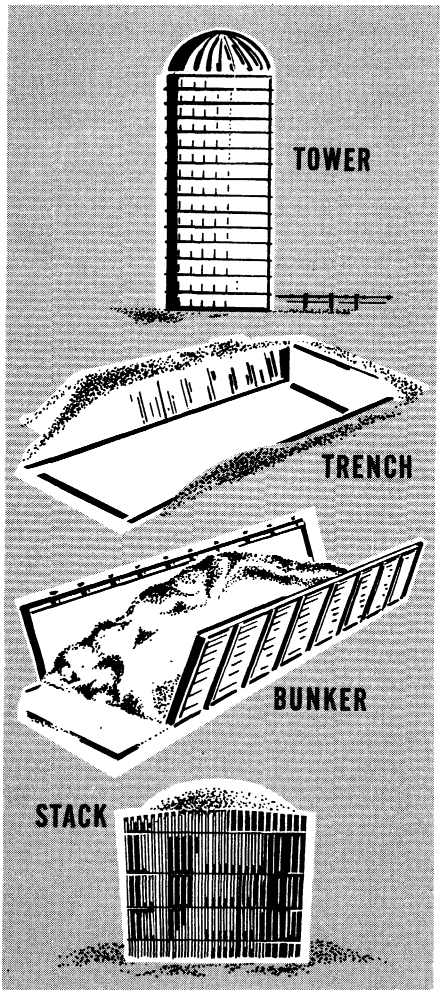
Horizontal silos can be used for self-feeding by installing a portable feed gate at one end of the silage.

Trench silos, as the name implies, are simply trenches dug in the ground. They are located on sloping land so that one end is at ground level to allow drainage and access by machinery. The sidewalls may have no lining or may be lined with concrete, wood, or masonry blocks. The type of lining depends on the soil type.

Bunker silos are built with most of the floor at or above ground level. Thus the sidewalls—concrete or wood—require support, which may consist of posts or braces or both. Many combinations of materials and elevations are possible. A floor of concrete is best for both trenches and bunkers. Without a concrete floor, a serious mud problem is almost inevitable.

Stack silos that have no sidewalls or floors require no silo construction at all. Sealing the silage depends entirely on the surface sealing material applied after the stack is built. An adequate seal is difficult to achieve because material used to weight the seal on steeply sloping sides does not stay in place. This difficulty is reduced if the sides have a gentle slope.

Proper drainage in and around the structure and a dry approach to the silo are important and should be considered in placing and constructing all horizontal silos. Bunker silos can be used to an advantage in poorly drained areas where trenches would be unsatisfactory. The floor of the horizontal silo should be crowned and sloped enough to provide adequate drainage. Silo walls should be of tight construction and sloped 1 to 2 inches per foot of depth to make packing easy. Earth walls of trenches should be cut smoothly



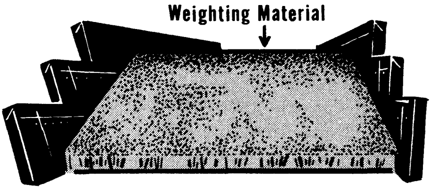
and sloped 4 to 5 inches per foot of depth to reduce soil cave-in.

Continuous packing with a tractor, preferably wheel type, throughout the filling operation is necessary to help exclude air.

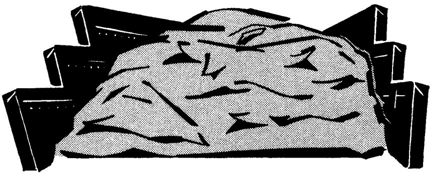
The exposed surface of the silage should be covered with an airtight seal immediately after filling. Plastic sheeting does an excellent job if properly applied. The entire surface of the plastic must be weighted with sawdust or some similar material. This prevents air from moving under the seal if it is accidentally punctured. If weighting material is not provided, one break in the plastic will cause the entire surface to spoil. Be sure to apply extra weighting material at the edges to provide firm contact between the covering material and the wall.

Many failures of horizontal structures may be blamed on failure to provide an adequate airtight seal and on slow or interrupted filling. Exceptionally large bunkers or trenches should be filled from the sides and sealed in sections to prevent surface areas from being exposed to air for prolonged periods.

GOOD COVERING



POOR



Comparison of Types of Silos

The advantages and disadvantages of upright and horizontal silos may be summarized as follows:

UPRIGHT

Advantages

Small surface area exposed.
Adapted to mechanical unloading.
Occupies small area.
Can be conveniently located without regard to terrain.
Feed and feeder are protected during bad weather.
Sufficient packing is more easily attained.

Disadvantages

Greater vertical pressure increases seepage problem.
Relatively high initial investment.
Requires elevating equipment or blower.
Self-feeding is more difficult.

HORIZONTAL

Advantages

Low initial cost.
Reduced seepage losses.
Relatively adaptable to self-feeding.
Minimum machinery for filling.

Disadvantages

Greater surface area susceptible to exposure.
Satisfactory crop preservation is more dependent on managerial skill and care.
Air exclusion is more directly dependent on distribution, packing, and sealing.

CALCULATING SILO REQUIREMENTS

Upright silos

To calculate the size of silo that will fit your needs, you must know how much feed will be required each day and how long the silage feeding period will be.

The estimates in table 3 will be helpful in choosing the proper size of upright silo. Generally, the greater the silo diameter the lower the cost of space for storing each ton of silage.

A minimum depth of silage must be removed from the silo each day, so that spoilage will not occur during the feeding period. This depth is 2 inches in winter and 3 inches in summer. The weight of this depth depends on the diameter of the silo and on air temperature. Therefore, in deciding on the size of a silo, decide first on the pounds of silage to be fed each day—multiply the number of animals by the average number of pounds to be fed to each animal. Then find a value in column 1 of table 3 that is about equal to this amount. The corresponding value in column 2 will be the maximum safe silo diameter for this rate of feeding.

TABLE 3.—*Estimates of minimum rates of silage feeding and tower silo capacities*

Minimum daily use in winter and summer	Diameter	Contents of silo if height is—										
		30 feet	32 feet	34 feet	36 feet	38 feet	40 feet	42 feet	44 feet	46 feet	48 feet	50 feet
Pounds	*Feet*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
846 1,274	12	75	81	87	93	100	106	113	119	126	132	138
1,152 1,732	14	102	110	118	127	136	145	153	162	171	180	188
1,508 2,259	16	133	144	115	166	178	189	200	212	224	235	246
1,908 2,862	18	-----	-----	196	210	225	239	254	269	283	297	312
2,354 3,352	20	-----	-----	-----	259	277	295	313	332	350	367	385
2,848 4,275	22	-----	-----	-----	-----	336	357	374	401	423	444	465
3,393 5,085	24	-----	-----	-----	-----	-----	425	451	478	503	528	554
3,978 5,972	26	-----	-----	-----	-----	-----	499	529	560	591	620	650
4,617 6,926	28	-----	-----	-----	-----	-----	579	614	650	685	719	754
5,301 7,947	30	-----	-----	-----	-----	-----	664	705	746	786	826	865

The amount of silage fed per animal per day depends on the palatability of silage and other feeds in the ration. A 1,000-pound cow will often eat 70 to 90 pounds of good-quality silage containing 72 percent of moisture if no other forage is being fed. Usually, however, you should feed some hay to obtain maximum forage consumption, and this will reduce silage requirements. For example, feeding 5 pounds of hay would reduce the daily requirement of hay-crop silage by about 16 pounds.

After the safe diameter has been determined, the height of the silo needed may be calculated from the total amount of forage to be stored.

To calculate the number of tons of silage to be stored, multiply pounds of silage fed per day by days in feeding period and then by 1.15; divide the result by 2,000. This formula allows 15 percent for storage losses. The height of silo needed to store this amount may then be determined along the appropriate safe-diameter line in table 3.

The estimates in table 3 are intended to apply to silage having 70 to 74 percent of moisture. More or less moisture will increase or decrease the capacity in terms of total weight, but the capacity for true feed—tons of dry matter—is not affected much by these differences.

To plan a feeding program you may need to know the amount of *settled* silage remaining in a silo. The values in table 4 are estimates of the silage remaining below specified depths in silos of different diameters. These tonnages apply most closely to silage having 70 to 74 percent of moisture, but the weights of dry matter would be about the same for silages having other moisture contents.

Horizontal silos

The minimum safe cross-section size for trenches and bunkers depends on the amount to be used per day. Table 5 may be used to estimate width and depth of these silos.

TABLE 4.—*Estimates of tons of settled silage remaining in tower silos*

Silo diameter (feet) ⇨	10	12	14	16	18	20
⇩ Depth of settled silage (feet)	Estimated tons of settled silage					
20	35	50	68	89	113	139
22	39	56	76	100	126	156
24	43	62	85	110	140	173
26	47	68	93	121	154	190
28	52	74	101	132	167	206
30	56	80	110	143	181	224
32	60	87	118	154	195	241
34	65	93	126	165	209	258
36	--------	--------	135	176	223	275
38	--------	--------	143	187	237	292
40	--------	--------	152	198	251	310
42	--------	--------	--------	209	265	327
44	--------	--------	--------	220	279	344

TABLE 5.—*Estimates of capacity of bunker and trench silos*

Average width (feet) ⇨ / Depth (feet) ⇩	10	12	14	16	18	20	22
	Estimated capacity (tons per foot of length) [1]						
4	0. 80	0. 96	1. 12	1. 28	1. 44	1. 60	1. 76
5	1. 00	1. 20	1. 40	1. 60	1. 80	2. 00	2. 20
6	1. 20	1. 44	1. 68	1. 92	2. 16	2. 40	2. 64
7	1. 40	1. 68	1. 96	2. 24	2. 52	2. 80	3. 08
8	1. 60	1. 92	2. 24	2. 56	2. 88	3. 20	3. 52
9	1. 80	2. 16	2. 52	2. 88	3. 24	3. 60	3. 96
10	2. 00	2. 40	2. 80	3. 20	3. 60	4. 00	4. 40
11	2. 20	2. 64	3. 08	3. 52	3. 96	4. 40	4. 84
12	2. 40	2. 88	3. 36	3. 84	4. 32	4. 80	5. 28

[1] Based on average initial density of 40 pounds per cubic foot. This may also be regarded as the minimum amount of silage fed per day.

The values shown in the table represent the tons of silage present in a linear foot of silos of different widths and depths. Silage requirements for 5 days should not exceed the amount of silage in 1 linear foot of silo. Assuming that the proper width and depth have been selected, a silo 1 foot long for each 5 days of the feeding period should provide the proper space.

Settled, direct-cut silage from well-packed trenches and bunkers has averaged at least 45 pounds per cubic foot at the Agricultural Research Center, Beltsville, Md. Thus, the content of settled silage may be calculated by multiplying width in feet by length in feet by depth in feet by 45; the result equals content in pounds.

SILAGE LOSSES

The loss of weight occurring during the storage period seldom corresponds exactly to a loss in feed nutrients because water may account for much of the change. Therefore, storage losses are more properly expressed in terms of dry matter.

The amount of silage dry matter fed is never as great as the amount stored. This difference is lost through seepage or spoilage, or leaves the silo as a gas.

You should recognize and learn to reduce these losses. They increase expense in time, labor, and equipment and reduce feeding value of the remaining silage.

Seepage losses

Dry-matter losses in seepage are caused by soluble nutrients flushed out of the silo in the excess water of the stored crop, in water formed by the fermentation process, or (if the silo is not well protected) in rainwater. Wilted silage stored at the recommended moisture content and protected from rain should have little or no seepage loss.

Seepage losses of forages stored in tower silos usually are 0 to 14 percent of the stored dry matter, the losses depending on the moisture content, species, maturity of the stored forage, length of cut, and depth of the silage mass. The following guide shows average seepage losses from forage stored in tower silos:

Percent moisture in stored forage	*Dry matter lost in seepage*
	Percent of stored dry matter
80	12 to 15
75	5 to 8
70	0 to 2
65	0

Seepage losses in horizontal silos are less because vertical pressures are much less in shallow silage. Failure to protect the silage from the leaching effects of rain will increase losses from seepage.

Top-spoilage losses

Top spoilage in any structure is generally caused by exposing forage to air. Since silos of the horizontal type have a much larger surface area than those of the upright type, forage stored in them is more susceptible to large-scale top-spoilage losses.

It is possible to practically eliminate top-spoilage losses in any silo by carefully applying an airtight seal immediately after filling the silo.

Gas losses

Gas losses during the storage period are largely due to the respiration of plant material soon after ensiling, to the necessary bacterial action in the fermentation process, and to the undesirable action of micro-organisms caused by prolonged exposure and infiltration of air into the silage. This loss can be kept to a minimum only if air is excluded from the silage as soon as possible.

You cannot see the extent of this loss. For instance, you might notice that there are only 3 or 4 inches of spoilage on an uncovered horizontal silo and decide that the expense and labor involved in applying a proper seal are more costly than the loss of this small amount of silage. However, the silo will also have an excessive *invisible* loss. These gas losses have been reduced about 4 pounds of dry matter for each square foot of surface sealed. This saving alone repays the investment of 2 or 3 cents for sealing. Improved silage quality is an added benefit.

Example showing value of a cover

If you fill each of two bunkers with 200 tons of 80-percent-moisture forage, you will have 40 tons of dry matter stored in each for feeding during the winter.

For purposes of illustration, let us assume that you apply a cover to *one* of the bunkers.

Initially each silo has a potential for providing the silage needed by a 40-cow milking herd for 250 days—40 pounds of silage (8 pounds of dry matter) per cow per day. This would be in addition to the hay and grain necessary to meet the nutrient requirements of the herd.

Table 6 shows estimates of losses, based on experimental observation, that would probably occur in the two silos.

The extra dry matter preserved in the covered bunker was enough to feed this herd 43 days. More than half of the extra dry matter was preserved by reducing gas losses, which are invisible.

Replacement of the additional dry matter lost in the uncovered bunker would require the purchase of 8 tons of hay, cost of which would be about $300. In contrast to this expense is the cost of a cover—about $40.

Efficiency of bunkers

With proper sealing procedures, bunkers are as efficient for preserving direct-cut (high-moisture) forage as are tower silos. Table 7 shows results from a comparison of these two types of storage. A reduction in seepage losses (as compared with the tower silo) and very low spoilage losses were responsible for the good job done by the bunker.

SILAGE QUALITY

"Silage quality" is a broad term referring to appearance, odor, chemical constituents, and (indirectly) feeding value.

Chemical characteristics

To a great extent quality depends on the crop that was ensiled, but the type of fermentation that develops also has an effect. If an active, desirable fermentation has taken

TABLE 6.—*Recovery and losses of dry matter for forage stored in covered and uncovered bunker silos*

[Example based on 200 tons of 80-percent-moisture forage (40 tons of dry matter) stored in each of two silos. Initially each silo has a potential for providing the silage needed by a 40-cow milking herd for 250 days]

Recoveries and losses	Percent of dry matter stored		Equivalent in days of feeding [1]	
	Covered silo	Uncovered silo	Covered silo	Uncovered silo
Dry matter recovered	79. 9	57. 9	200	157
Dry matter lost:				
Spoilage	1. 7	6. 2	4	15
Seepage	7. 0	16. 0	18	40
Gas	11. 4	19. 9	28	50
Total lost	20. 1	42. 1	50	105

[1] "Day of feeding"=1,600 pounds of silage—40 pounds of silage (8 pounds of dry matter) for each of 40 cows.

TABLE 7.—*Recovery and loss of dry matter stored in bunker and tower silos* [1]

Type of silo	Recovered (good silage)	Lost		
		Spoilage	Seepage	Invisible
	Percent	*Percent*	*Percent*	*Percent*
Bunker	85. 2	0. 5	3. 8	10. 5
Tower	77. 9	0	8. 4	13. 7

[1] Forage was direct-cut and treated with sodium-metabisulfite.

place, the silage will be highly acid (low pH value), contain considerable lactic acid and little if any butyric acid, and show relatively small amounts of ammonia. These fermentation characteristics are usually associated with good odor and with animal acceptance.

A relatively inactice fermentation may result from well-wilted forage. Such silage will not be very acid (higher pH value) but will contain only small amounts of butyric acid or ammonia. Such silage is of good quality because of the absence of undesirable fermentation products.

Silages from high-moisture forage that do not become highly acid (low pH) usually develop high levels of butyric acid and ammonia, have an unpleasant odor, and are not consumed well by livestock. These characteristics are signs of poor quality.

Odor and appearance

The chemical values referred to above are usually not available on a farm basis, but poor-quality silage can be recognized by its slimy, dark appearance, its strong odor, and its nonacid taste. Silage that has been overheated by air contamination is dark brown—and nearly black in places. Although such silage has a pleasant odor (somewhat like the odor of tobacco), and cattle eat it readily, it is low in digestible nutrient content, particularly protein.

Feeding value

The feeding value of any forage depends on its digestible nutrient content and on the maximum amount that an animal will consume (acceptability).

Fortunately, forages high in nutrient content tend to be highly acceptable, but both factors need to be considered in determining feeding value.

Digestible Nutrient Content.—The content of digestible nutrients in silage depends to a great extent on the content in the original crop. No ensiling method improves forage—but some methods are more desirable than others because they allow less change in composition than others.

Silage contains on a percent composition basis slightly less crude protein than the original forage, and less nitrogen-free extract; it contains more crude fiber and crude fat. Extensive leaching or poor air exclusion intensifies these differences.

Digestibility of silage is generally less than that of the original crop. This is due in part to lower nitrogen-free extract and higher crude fiber content. Digestibility of crude protein is usually maintained; but if the silage becomes overheated, protein digestibility will be greatly lowered.

Part of the original true protein is converted to nonprotein, ammonialike compounds in the silo. Cows can use a limited amount of this converted protein, but in poorly preserved silage the conversion may be so great that usable true protein becomes a limiting factor. Crude protein values in silage generally reflect the *level* of protein in the original crop, but this fact tells us nothing about the digestibility of the protein or about the amount of it that is still true protein.

The acids are produced at the expense of available carbohydrates. Since both the acids and the carbohydrates are valuable nutrients, there is little net change in digestible nutrient content.

Some silages are much higher in carotene content than others, but almost any hay-crop silage contains enough to meet animal requirements. Differences in carotene level above requirements are of little practical importance.

Acceptability.—Forage is usually a cheaper source of digestible nutrients than grain. Therefore a ration consisting solely of forage would be the most profitable one if animals would eat enough of it to meet their nutrient requirements.

One way to increase the acceptability of forage is to feed early-cut forage and to feed both silage and hay. Another is to feed silage that is free of mold and spoilage, relatively high in dry matter, and low in butyric acid and ammonia.

Cattle will eat high-moisture silage in greater amounts (more pounds) than they will eat hay or wilted silage. But this does not mean that they are getting the maximum amount of dry matter; the opposite is likely to be true. The low proportion of dry matter in high-moisture silage is a fact that must be taken into account by dairymen who depend on silage as a major source of nutrients.

A 1,000-pound cow may eat 100 pounds per day of silage containing 80 percent of moisture when that is the only forage she has. However, this forage dry-matter intake (20 pounds per day) is low and will support only a low or moderate level of milk production. Dry-matter intake could be increased by offering some hay or by making a drier silage. For example, 5 to 15 pounds of good-quality hay may be fed in addition to silage if the moisture content of the silage is more than 60 percent.

The grain content of a high-moisture silage preserved with dry ground feedstuffs affects the feeding value of the silage. This silage would be palatable and high in nutrient content, but feeding it would result in decreased intake of forage dry matter and probably lower profits.

HAY-CROP SILAGE AND HAY

Dry matter from good hay and dry matter from good silage are about equal in content of digestible nutrients. However, the amount of hay that can be replaced by silage without reducing nutrient intake is limited by acceptability of the silages. To maintain a high level of forage nutrient intake, feed some additional hay. When wilted silage is used, less hay will be needed.

The ratio of hay and silage required for maximum forage consumption is not very exact and may range between 1 to 1 and 1 to 10 on a weight basis. Practically, this means that a farmer can make hay during only the most favorable weather periods and still remain within these ratios in his feeding program.

HAY-CROP SILAGE AND CORN SILAGE

The nutrient content of hay-crop plants is basically different from that of corn plants, but one type of silage may replace the other on a dry-matter basis if the grain ration is adjusted to meet nutritional requirements.

Corn silage contains more digestible energy than hay-crop silage but less digestible protein. Therefore, if you substitute hay-crop silage for corn silage, you should feed more energy in the grain ration, but you may reduce the protein content of the grain ration.

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