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College of Agricultural Sciences Cooperative Extension

Agricultural and Biological Engineering

Horizontal Silos

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A horizontal silo is a storage system where silage is piled in low (6-20 feet deep), long piles. These piles may be contained by sidewalls or inside plastic bags. The silage is not deep enough to provide "automatic" packing to exclude air and promote good ensiling. Therefore, it is necessary to mechanically pack the silage, using vehicles driving over the silage pile or in the case of bagged silage, a mechanical stuffing device to pack the silage into the bag. Filling and packing to exclude air is the key to the silage-making process. Proper equipment is necessary for both filling and unloading horizontal silos.

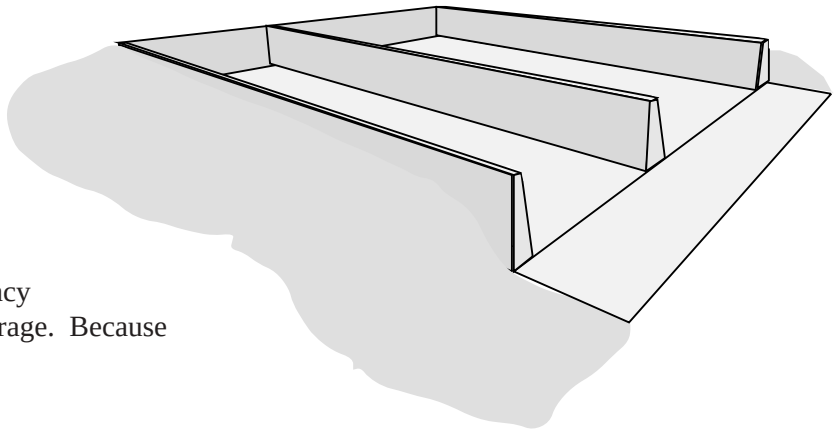
When selecting a horizontal silage storage system, consider potential water pollution and nuisance problems from silage leachate, odors, noise from the filling and emptying process, birds, and rodents. Safety for workers and visitors and machinery needs must also be considered.

Silo Types

The three main types of horizontal silos are: (a) trench or pit: a silo that is built into the ground by digging a hole or "trench" below the natural grade line, usually into a hillside; (b) bunker: a silo that is built above the natural grade line using reinforced concrete or post and plank walls; and (c) stack: a pile of silage with no structural walls to contain the material, resulting in more surface area for the same amount of silage stored. Stacks work well for emergency or temporary storage. Because of the potential for increased spoilage from the larger surface area, stacks are usually not recommended for long-term storage. With proper packing and covering, any of these can be used for storing hay crop silage, corn silage, or high moisture grains.

Horizontal silos generally cost less per stored ton than upright silos and are faster and more convenient to fill and unload. They are also more adaptable to mobile mixing and feeding systems than vertical silos. However, wind, rain, snow, birds, and rodents may cause higher storage losses. Filling horizontal silos also requires an operator with a packing machine large enough to keep up with the harvester.

Plastic silage bags and silage bales are often put into the category of horizontal silos. Silage bags are large diameter plastic tubes that are filled with silage by a special filling machine. Silage bales are round bales that have been made at a high moisture content and then tightly wrapped with plastic. Silage bales hold small amounts of silage in separate packages but add variability in the feed ration, because of variations among bags. Silage bags and bales can be used for emergency, temporary, or long-term storage. However, the plastic is not reusable, causing a disposal problem. Punctures, tears, and split seams from rodents, animals, careless handling, sharp objects on the ground or weather will result in increased spoilage.



A firm, well-drained site is essential for year-round access. Bags should be oriented north-south to promote melting of snow and drying of the sides. Provide 5 percent slope away from bags for drainage.

Construction Materials

Silo walls can be constructed with a variety of materials including concrete, wood, or earth. Reinforced concrete tends to be more durable and last longer than pressure treated wood walls, but it is usually more expensive. Wooden walls can allow more air to enter the silo if not properly sealed. Earthen walls are low cost, especially when the silo is below grade. However, these walls will need annual maintenance and can result in dirt and other debris getting into the silage. For long-term use, trench silos should have permanent walls and floors.

Concrete or asphalt placed on a well-drained and compacted sub-base provide a long lasting floor surface. Place the floor to drain rain and melting snow away from the working face and direct leachate from the silage for easy collection and disposal. Slope floors 1 to 2 feet per 100 feet toward the silo entrance with a center crown of 4 to 6 inches or about 1/4 inch per foot. For some sites, it may be more convenient to slope the floor to one side 4 to 6 inches.

Air entrained ready-mix concrete makes durable paving. Specify a minimum compressive strength of 3500 psi and limit water to 6 gal/cu yd or less. Place the mix at least 5 inches thick on 6 mil polyfilm over a well compacted base and damp cure for five days.

Asphalt will stand up to both the attack of acidic effluent and mechanical wear and tear. It can be placed in one day and requires no lengthy curing period making it especially attractive for repair situations. Large quantities of leaking fuel or oils from vehicles can soften asphalt materials. Place asphalt with coarse aggregate over a well-drained and compacted gravel base in two separate lifts to provide a 6 inch thickness. A concrete apron where vehicles enter the silo will protect the asphalt from crumbling.

Earth floors are not very satisfactory for silos except in an emergency. However, a crushed rock floor 4 to 6 inches thick, using 3/4 to 1-1/2 inch material, topped with 1 to 2 inches of wetted-in fine limestone will provide a good semi-permanent floor.

Construction of a horizontal silo can be done in incremental steps. A stack with a gravel floor can be converted to a bunker silo by adding a concrete or asphalt floor and walls.

Silos that are partially or completely below ground level need to consider ground water exclusion and control. Use water-tight construction joints to prevent the flow of liquids either into or out of the silo. Also consider how precipitation running off the cover will be directed away from the silo area.

Location

When locating horizontal silos, consider:

- access for vehicles bringing silage from fields or the highway
- location of existing and planned feed storages
- travel routes for feed delivery vehicles
- space for maneuvering
- safety for pedestrians, other farm workers and visitors
- drainage of runoff from the pile cover
- potential for polluting surface and ground water resources (surface flow, wells, sink holes, and other potential paths to ground water
- homes and property lines
- future expansion

Determining Size

The capacity and dimensions of a horizontal silo are determined by the total amount of feed to be stored and the expected daily feed removal rate. Feed-out rate is a management variable that determines exposure time of the working face to air. Longer exposure to air (slower feed-out rates) increases the likelihood of aerobic spoilage, depending on the silage aerobic stability, density of the silage, and degree of face disturbance during feed-out. A minimum feed-out rate of 6 inches per day is recommended to reduce dry matter loss. This is especially critical during hot weather. Therefore, to hold 360 days of feed, a total silo length of 180 feet is needed. This can be accomplished with a single long silo, multiple shorter silos, or by feeding a wider silo in narrower “slices.”

Building more silos that are narrower allows much greater freedom in feed inventory use. A second silo makes feeding fermented feed during harvest easier. With a properly-sized silo, a single cutting of hay can be harvested, covered, and fermented without having to open the silo to put in another cutting. This also allows cuttings to be kept separate for different feed rations. Perhaps one larger silo could be used for first cutting, since it often represents about 40 percent of the year’s yield. Fill the larger one first for winter feed, and then fill smaller silos for summer use. Another option is building a silo for hay crop silage no larger than can be filled in three full working days.

A good application for silage bags may be to hold second and third cuttings, that are about half the volume of first cutting, where the herd size does not permit multiple bunker silos.

To determine the silo dimensions, first calculate the pounds of dry matter (DM) for each silage ingredient to be fed per day. Next, determine the depth of the silo to be designed. Deeper silos expose less surface area and therefore have less spoilage but need larger walls to withstand the higher pressures. Recommendations are to use a minimum depth of 8 feet and a maximum depth of 20 feet**. Do not plan silo depth higher than the unloading equipment can reach.** Undermining a silage pile is a dangerous practice. The resulting overhanging material can suddenly break loose and crush or suffocate the person unloading the silo.

Finally, determine the width by dividing the daily usage (lb. DM) by average dry matter density (lb. DM per cubic foot, see table), removal rate (ft), and depth (ft) [Width (ft) = DM per day (lb.) ÷ Density (lb./ft^3) ÷ Removal per day (ft) ÷ Depth (ft)]. This will give the total width in feet of the silage face needed.

The length of the silo is then determined by dividing the total amount of dry matter to be stored in the silo (lb. DM) by average dry matter density (lb. DM/ ft^3), width (ft), and depth (ft) [Length (ft) = Total DM (lb.) ÷ Density (lb./ft^3) ÷ Width (ft) ÷ Depth (ft)].

Table 1. Average dry matter density (lb. DM per cubic foot).

FEED	DM lb./ cubic foot
alfalfa silage	12
corn silage	14
ground ear corn	33
whole shelled corn	39
ground shelled corn	42

Filling and Packing

Wheel-type tractors have proven to be an effective method for placing and packing silage in horizontal silos. While track vehicles provide more stability, the flotation from the tracks result in less compaction. A bucket, fork, or blade is required to move and spread the silage. A tractor with a low mounted blade is usually more stable than a bucket or fork on a loader frame. Special precautions should be taken to minimize the risk of serious injury or death to the operator and damage to the equipment due to overturns. The tractor must have roll-over protection and a seat belt that is used. (see safety sidebar)

Wedge filling is preferred to filling the silo in shallow layers the entire length. Start in the rear of the silo and build a triangular wedge across the width of the silo. Then progressively layer and pack silage over this wedge. Wedge filling exposes less surface area than does layering the entire silo, leading to less dry matter loss and better final quality. Thinner layers of silage fill and more trips over the pile with packing equipment will increase compaction.

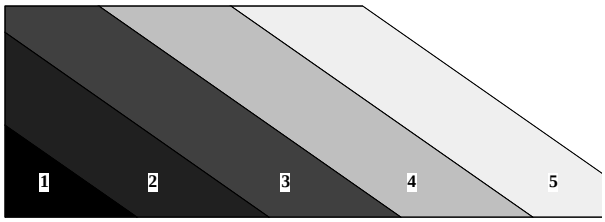


Figure 1. Wedge filling method.

To ensure proper packing, maintain an adequate packing intensity. Packing intensity can be defined as the weight of the packing tractor(s) in tons divided by the tons of wet silage packed per hour, assuming the packing equipment runs continuously. Sizing packing equipment to maintain a packing intensity of 0.5 is recommended. Therefore, the rule of thumb is that a tractor can pack about twice its weight in silage per hour. For example, to pack 20 tons of wet silage an hour would require 10 tons of packing equipment. By using a larger packing vehicle or multiple vehicles, this packing intensity can be maintained for higher harvest rates. Plan to crown the top of the silage about 1/8th of its width. This will promote drainage of precipitation to the sides of the silo.

Covering

Horizontal silos should be covered immediately after filling to prevent dry matter loss. An additional advantage is that the cover stops rainwater from seeping through the silo and creating more leachate. Install the cover material to assure that precipitation running over the top does not run down between the silage and the inside of the wall. Use 4 mil plastic covers for storage periods less than 120 days, and 6 mil for greater than 120 days. Black plastic is suggested to be suitable north of the Mason-Dixon line, while white has advantages in the sunny south.

Covering a large horizontal silo is not a trivial matter, but the time and effort is an investment in quality silage. Secure the cover in place to prevent removal by the wind and also to prevent “waves” or “ripples.” A cover that is held in place but responds to wind by billowing or rippling will actually pump air into the top of the silo. Hold silo covers in place with weights such as tires placed side by side, slab wood, patio blocks, lime bags that are opened and fed with the silage, or a layer of limestone or manure solids. Pay close attention to edges and seams. Place tires or

other weights next to each other, or use a continuous layer of old silage, limestone, etc. It may be necessary to tie the weights together to prevent them from sliding on steep slopes. Place weights so they do not damage the plastic.

Covering and uncovering a horizontal silo is a challenge considering the large numbers of tires or other weighted material and large amounts of plastic that must be handled. Provide a convenient area for storing tires and for disposing of plastic covering material. They should be out of the way and not interfere with regular traffic. Cutting tires in half will reduce the total number needed, allow them to be stacked in a nested fashion, and will reduce trapped water that creates a breeding ground for insects.

Normally, plastic covering material is not reusable; therefore, a method of disposal or recycling is needed. While landfilling or burning are most common, opportunities for recycling are now becoming available. Contamination of the plastic with silage and dirt and its bulkiness complicate recycling. Two fact sheets concerning recycling of agricultural plastics are listed at the end of this fact sheet.

Length of Cut

As far as the cow is concerned, hay crop silage can't be cut too long. However, when it comes to filling the silo, this longer fiber is harder to pack. Recommended theoretical length of cut (TLC) for hay crop silage is 3/8-1/2 inch. TLC for corn silage should be 3/8 inch - 1 inch. TLC longer than 1/2 inch may result in cob wafers, requiring a kernel processor. These recommendations are a compromise between an adequate length for the cow and the ability of the silage to be packed. Longer lengths of cut require more care and attention when packing the silo to get high quality feedstuffs at feeding. Maintain sharp cutter knives, a close shear bar, and a packing intensity of 0.5 (i.e. at least 1 ton of packing equipment running continuously for every 2 tons of forage stored per hour).

Moisture

Silage must be harvested at the proper moisture content to enhance packing and provide moisture for the fermentation process. Moisture content of wilted hay crop silage or corn silage should be 65 to 70 percent when placed in horizontal silos. Dry matter determinations during filling and feed out can be accomplished using a Koster tester or a microwave oven and a scale. (See fact sheet I 106 *Determining Forage Moisture Content with a Microwave Oven*)

Pollution Control

Silage is more than a nutrient-rich foodstuff. It can also be a pollutant. The silage-making and storing process can result in liquid effluents or leachate, gases, malodors, undesirable microorganisms, and waste or spoiled silage.

The most important characteristics of silage effluent are: 1) its corrosive effects, 2) its high polluting strength, and 3) its poisonous gas-forming ability. Silage effluent has a high biochemical oxygen demand (BOD). This means if it is allowed to enter a water supply it removes a large portion of the available oxygen from the water, causing septic conditions and fish kills. The potency of uncontrolled effluent not only severely pollutes water, it will also burn or kill vegetation if applied at full strength or allowed to run directly onto crops from a leaching silo. Properly ensiled silage will not produce high levels of leachate. However, even small amounts of leachate can accumulate and result in large flows from large silos.

Include silage leachate collection and disposal with the overall waste management planning for the farmstead. Common disposal practices include: 1) diluting leachate with equal parts of milking center wastewater or barnyard runoff before using it for irrigation, and 2) diverting to an open -top liquid manure storage. However, **DO NOT** add effluent to storage tanks, reception pits or sumps located inside livestock buildings, other enclosed spaces, or any covered underground manure storage. Silage effluent, especially when mixed with manure can produce poisonous gases that result in almost instant death to humans and/or animals. Whatever the control system, it must also have a regular maintenance schedule to ensure it will continue to function correctly. Your county conservation district or the Natural Resource Conservation Service (NRCS) are sources of design information and assistance for proper handling of silage effluent.

Rodent Control

Steps can be taken to limit the appeal of horizontal silos to rodents. A narrow trench, about one foot deep, filled with medium-sized gravel and built around building foundations and slabs, will discourage rodents from burrowing. When they attempt to burrow into the gravel, it will collapse as they dig. Keep the silo

area clean, well mowed and free of loose piles of used plastic, jumbles of tires, piles of rotting silage and tall vegetation. Nearby abandoned vehicles and buildings may provide a home for rodents within easy commuting distance to the silo.

Birds may also enjoy feeding at a horizontal silo. Covering the feeding face of the silo will cut down the accessibility of feed to the birds.

Unloading

It is important to keep the material at the unloading face of a horizontal silo as dense as possible. If designed properly, the removal rate should be approximately 6 inches per day. Maintaining a high quality silage face is critical in limiting dry matter loss as the silo is emptied. Mechanical unloaders, which carve away the face of horizontal silos and transfer the silage to transport vehicles, maintain a uniform surface. However, they are an extra investment and may be slower than a bucket loader. A front-end loader is the most common method of removing silage. A tractor with a raised loader bucket full of silage is especially unstable. Use a loader tractor with wide spaced wheels and a ROPS. To maintain a smoother unloading face, remove silage by pulling downward with the loader bucket. Lifting upward on the silage face with a loader will loosen more silage, allowing oxygen to be introduced deeper into the silage.

In silos that are too wide to remove a full 6 inches per day off the entire face, it may be better to remove the silage in narrow "slices." There will be spoilage along the exposed surface where the slice is made, but since this surface is not regularly disturbed, this loss may be less than that across the entire face when only a small amount is removed daily.

Control unloading hazards by not building silos deeper than unloading equipment can reach. If the equipment cannot reach the top of the pile, an overhanging mass of silage may result. The undermining and eventual collapse of these overhangs has resulted in fatalities.

Safety Tips

Children and visitors should be kept away from horizontal silos: silos are not playgrounds. It is particularly important to keep unnecessary people away during harvest and feeding when large machines are unloading and packing silage or loading mixer wagons. The operator may not be looking for people and may accidentally run over them. Also, plan travel routes for vehicles delivering silage so they are away from areas that unsuspecting pedestrians, especially children, are likely to occupy.

Filling and packing of horizontal silos requires special care and attention to reduce the risk of accidents and severe injury. Maneuvering machinery on and around loose silage requires mature, experienced operators using proper equipment. Always keep front-end loaders and forks as low as possible. Raised front end loaders and forks create a severe risk of overturn especially when the bucket is full or when the tractor is on an incline or soft material. (see sidebar below)

Safety First When Working in Horizontal Silos

Special precautions should be taken to minimize the risk of serious injury or death to the operator and damage to the equipment due to overturns.

1) Use only tractors equipped with an approved roll-over protection frame or cab, and require the operator to use seat belts for both safety and comfort. A tractor with a ROPS cab offers the most protection.

2) Only mature, experienced operators should be allowed to operate the packing tractor or unloading tractors and forage wagons on the silage.

3) Use low clearance, wide front-end tractors (not tricycle type) with the wheels extended for maximum stability. The use of dual tires will also increase stability.

4) Adding weights to the tractor will assist in packing and can provide stability. Add weights to both the front and rear of the tractor to maintain safe weight distribution. Avoid rear wheel weights that will interfere with packing close to the walls of a silo.

5) Wheel-type tractors should not be driven on silage surfaces with slopes steeper than 4 to 1 (1 foot of rise in 4 foot of run).

6) Back up or drive down slopes to avoid the risk of a rear overturn.

7) Distribute silage in uniform 6 inch layers for even packing and to help prevent soft spots.

8) Front wheel assist drive tractors can provide extra traction and stability for packing and towing on the silage.

Conclusion

Proper design of horizontal silos can offer a low-cost storage alternative for dairy feeds. However, no matter which type of silo, construction method, or construction material, the final quality of silage removed is dependent on good management practices. The best design can fail due to poor management. The following eight items are major points to be addressed: 1) fill as rapidly as possible, 2) ensile at correct moisture, 3) keep harvester knives sharp and cut at correct length, 4) spread silage in thin layers and pack immediately, 5) keep safety in mind when working in or around a silo, 6) cover and seal the silo the day you finish filling, 7) maintain a smooth silo face and remove an adequate thickness daily, 8) maintain silo walls and floors to assure minimal air and water infiltration.

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For a copy of our Fact Sheet listing or Idea Plan listing contact:
Agricultural and Biological Engineering Extension
246 Agricultural Engineering Building
University Park, PA 16802
(814) 865-7685 FAX (814) 863-1031 or email mxh16@psu.edu.

Additional Reading

Below are fact sheets available from Agricultural and Biological Engineering, 246 Agricultural Engineering, University Park, PA, 16802
(814) 865-7685 FAX: (814) 863-1031
email: mxh16@psu.edu.
C-8 *Recycling Used Agricultural Plastics*
C-22 *Recycling Your Used Agricultural Plastics*
E-34 *Tractor Overturn Hazards*
H-70 *Silo Capacities*
H-72 *Site Evaluation for Dairy Housing Systems*
H-73 *Planning Feeding Systems For Expansion*
H-74 *Feed Center Design and Components*
H-75 *Bulk Storage*
I-106 *Determining Moisture Content with a Microwave Oven*
I-107 *Forage Losses = Economic Losses, So Minimize Them*

Circulars and "for sale" publications are available from Publication Distribution Center, 112 Agricultural Administration Building, University Park, PA 16802, (814) 865-6713. Call for current pricing and availability.

Extension Circular 396 *Harvesting and Utilizing Silage*
MWPS-7 *Dairy Freestall Housing and Equipment* $20.00
NRAES-01 *Pole and Post Buildings* $6.00
NRAES-38 *Dairy Feeding Systems Proceedings* $25.00
NRAES-67 *Silage Production - For Seed to Animal* $25.00