SMALL-SCALE SILAGE PRODUCTION

A RESOURCE FOR SUBSISTENCE AND HOBBY FARMERS

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Image above: Epstein, D. (Photographer). (2011). Silage barrel. *[Web Photo]. Retrieved from http://bioponica.org*

BACKGROUND

Silage

Silage is fodder, typically fed to ruminants, consisting of undried vegetation stored in an airtight environment, which leads to its fermentation. Through this lactic acid fermentation, the incorporated crops avoid spoilage and retain nutritional value. For a subsistence dairy farmer, who normally faces "a serious decline in milk production during dry or cold periods [due to] seasonal scarcity of fresh, succulent, nutritious feed," silage on a smaller-than-conventional scale enables availability of economical and high-quality feed year round (Van Peursem, 1962). In this way, adequate animal health and production can be maintained outside the growing season.

Silage has benefits over both grain and hay feeds. For example, corn silage provides "50 to 60% more nutrients per acre for beef cattle than harvesting the grain alone" (Sewell & Wheaton, 1993). Silage's advantages over hay include one tenth of the storage space requirement, fewer weather-related harvesting restrictions, less than 10% dry matter loss as opposed to 30% potential with hay, reduction in harmful nitrates via fermentation by about 50%, storage up to 3 years without deterioration, and potential incorporation of less desirable vegetation like corn stover (Food and Agriculture Organization [FAO]).

The airtight, anaerobic storage required by silage, i.e. a silo, exists in many forms including conventional upright silos, plastic bags, 55-gallon drums, and covered trenches. A well-packed, well-sealed silo filled quickly is key to reduce losses via spoilage and leakage. Packing ought to occur after each layer of material is added and, in case vegetation has settled a few days after packing, more may need to be added to completely fill the silo (Van Peursem, 1962).

Lactic acid fermentation

Forage plants begin their transformation into silage via cellular respiration as indigenous microorganisms consume the available oxygen, which will be present to some degree regardless of well the silo is packed. The amount of oxygen available in the silo determines how long this

Equipment and supplies referenced in this document are widely available in the United States; however, in less industrialized areas, locally-available alternatives may be of equal effectiveness and significantly more affordable. Even in cases where using such alternatives may mean sacrificing a little, in terms of silage quantity or quality, this can still be markedly more economical than acquiring the items specified. For example, using banana or palm tree leaves to cover a pit silo may be only slightly less ideal than a waterproof tarp.

phase lasts. Ideally, very little cellular respiration will occur because this phase results in an undesirable temperature increase and nutrient losses (FAO). Too much oxygen, in fact, will lead to the vegetation spoiling entirely, eliminating its value as feed. For this reason, oxygen must be excluded - as best as possible - from the silage at all points from initial packing, through storage, until it is ultimately fed. Oxygen, and therefore cellular respiration, can be limited by ensuring that there are no leaks in the silo, that vegetation is ensiled at the appropriate moisture content and chopped to an appropriate particle size, and that the silo is filled and sealed quickly and packed well (FAO).

After the available oxygen is depleted, lactic acid fermentation - an anaerobic process - can begin. In the case of silage, a desirable fermentation is the biochemical conversion of water-soluble carbohydrates, i.e. sugars, from the ensiled vegetation into cellular energy and lactic acid by anaerobic bacteria. Undesirable fermentations can produce alcohol or acetic acid, resulting in "up to a 24% loss of the original sugar" (Muck, 2000). "Lactic acid is the preferred product of fermentation because it is a strong acid ... [it] contains almost the same energy as the original crop sugars, and it can be fermented by rumen microorganisms" (Muck, 2000). The types and numbers of indigenous lactic acid-producing bacteria, the silage temperature, and "the sugar content of the crop" determine how effectively these bacteria cause fermentation to occur (Muck, 2000).

Correct dry matter content, or - conversely - moisture content, is vital to an effective fermentation. Vegetation with too much moisture increases the amount of lactic acid needed to complete

Corn is a highly productive silage crop. [1]

Walk-behind brush mowers are effective for small operations. [2]

If well packed, 55 gallon drums make excellent silos. [3]

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[1] *Růžička, F. (Photographer). (2012).* Corn. *[Web Photo]. Retrieved from* http://www.sxc.hu/photo/1403336

[2] *Agustin, H. (Photographer). (2010).* Brush mower. *[Web Photo]. Retrieved from* http://agustinmachines.blogspot.com/2010/03/brush-mower.html

[3] *Epstein, D. (Photographer). (2011).* Silo. *[Web Photo]. Retrieved from* http://bioponica.org

fermentation, resulting in a longer fermentation period and a lower-quality product; however, vegetation with too little moisture will not pack well, trapping oxygen, and causing spoilage (FAO). In an adequate silo with a properly ensiled crop, the environment is one that "eliminates spoilage from the growth of yeasts, molds, and adverse bacteria while maintaining essential proteins and nutrients" (FAO).

Gases are produced during the fermentation process that can be dangerous to human health. A Peace Corps document (ACTION, 1977) recommended swinging "a piece of canvas, a tree branch, a burlap bag, or something to agitate the air and dilute gases that may be present with oxygen from the air" before entering a silo, especially a large one like a pit silo. "A victim of silo gas should be moved into fresh air as soon as possible, ... artificial respiration should be applied, and [the victim should be] taken to a physician immediately" (ACTION, 1977).

Additives

In addition to an oxygen-free environment, a low pH is necessary to prevent spoilage by undesirable bacteria, yeasts, and molds (Muck, 2000). pH is lowered naturally as microorganisms convert carbohydrates to acids; however, there are additives - often called "inoculants" - sold in many areas that can sometimes hasten the lowering of pH. Sewell and Wheaton (1993) found that, for *corn* silage, "there is no reliable evidence that adding enzymes, yeast cultures, antibiotics or acid forming bacteria to improve silage quality is economical. ... The improvement, if any, has not paid for the cost of the additive in most cases." This is because indigenous populations of lactic acid-producing bacteria are already very high on corn harvested at the appropriate time, resulting in a good natural fermentation, high in lactic acid; however, inoculants may aid fermentation in corn crops harvested before maturity, while overly dry, or immediately following a killing frost (Muck, 2000). While studies show inoculants improving fermentation only 40% of the time in corn silage, they have improved hay-crop silages two thirds of the time (Muck, 2000). This suggests that research-backed additives may be worth a trial in hay-crop silages to determine their profitability.

Most, if not all, inoculants contain lactic acid-producing bacteria but not all have the same number of live bacteria per application, the same strains of bacteria, or the same effectiveness on a particular silage crop (Muck, 2000). In order, *Lactobacillus plantarum*, other *Lactobacillus* or *Pediococcus* species, and *Enterococcus faecium* are the most common types of bacteria in commercial inoculants; "be skeptical of products that contain other species" (Muck, 2000). Inoculants should contain at least 100,000 lactic acid-producing bacteria per gram of crop or 90 billion per ton and they ought to be labeled for the type of crop being ensiled (Muck, 2000). These products are sold in dry or liquid forms, both of which have strengths and weaknesses in terms of storage and ease of use; the focus should be on the user's capability to uniformly and thoroughly suffuse the inoculant into the crop (Muck, 2000).

Silages with less than 50% moisture content require supplemental water "to prevent the formation of tobacco-brown silage" (Sewell & Wheaton, 1993) by increasing the overall moisture content to between 60 and 65% (Grant & Stock, 1994). Seven gallons of water, distributed evenly throughout the silage, are needed "per ton of silage for each 1% increase in moisture content" (Grant & Stock, 1994). Take care that any water used in conjunction with inoculants or silage is not chlorinated, as chlorine can kill off desirable bacteria (Muck, 2000). Silages with more than 70% moisture content, e.g. because poor weather precluded wilting, can be adjusted to the 60 to 65% range "by adding 5 to 15% of dry hay" uniformly throughout the silage (ACTION, 1977).

A 1962 publication (Van Peursem) targeting subsistence farmers suggested that, if accessible, molasses diluted with water ought to be added to all silages at a rate of "10 kilograms per metric ton" to increase palatability, nutritive value, and - in the case of low-sugar crops - "as an aid to the essential fermentation." Undiluted whey will have a similar effect (ACTION, 1977).

Crops

Choice of crop and planting options will be dependent on specific circumstances; however, under optimal growing conditions, corn (*Zea mays*) "produces more energy per acre than any other [silage] crop" (FAO). Other mainstream silage crops include sorghum (*Sorghum bicolor*), small grains such as oats (*Avena sativa*), rye (*Secale cereale*), wheat (*Triticum* spp.), pearl millet (*Pennisetum glaucum*), triticale (× *Triticosecale*), and barley (*Hordeum* spp.), and legumes like alfalfa (*Medicago* spp.), peas (*Pisum sativum*), fava beans (*Vicia faba*), and sweet clover (*Melilotus officinalis*) (Saskatchewan Ministry of Agriculture; USDA, 2013). Alternative silage crops include sunflowers (*Helianthus annuus*) in areas with a short growing season and Jerusalem artichoke (*Helianthus tuberosus*) tops - a perennial crop - in areas with wet springs, where annual soil preparation is problematic (Cheeke, 2005; USDA, 2013). With few to no exceptions, any fodder can be successfully ensiled, from wetland vegetation through yard clippings. Avoid fodder to which herbicides or pesticides have been recently applied (Scharabok, 2002).

As previously discussed, it is important to ensile vegetation at the correct dry matter content; for hay crops, the ideal is 42% dry matter and, for corn it is 34% dry matter (Seglar, 2003). In attempting to achieve this level, "most grasses should be cut after the heads have emerged but before the plants have started to bloom" (ACTION, 1977). Outside of unexpected circumstances like drought, "corn should be harvested for silage after the grain is well dented but before the leaves turn brown and dry;" this corresponds with "maximum percentage of grain" and optimal dry matter content (Sewell & Wheaton, 1993). Another indicator of appropriate corn crop maturity is "the presence of a dark colored [or black] layer at the base of the grain," at which point the whole corn plant "should be harvested by cutting it 10 to 12 centimeters from the ground" (FAO). "Check for black layer development by splitting kernels lengthwise or by cutting off the tip of the kernel" (Grant & Stock, 1994). Harvesting just a couple weeks early "will often result in a 20% reduction in dry matter yield," while harvesting late can cause equally significant yield losses and increased mold risk (Grant & Stock, 1994). Nutrient digestibility can also be decreased by late harvest (FAO).

Sorghum has been bred in two different directions. Some varieties are meant to maximize grain production, while others are meant to maximize forage; however, all sorghums, including sorghum-sudangrass hybrids, are typically "more drought tolerant and adapted to a wider range of soils than corn" (Sewell & Wheaton, 1993). Grain sorghum varieties tend to yield higher digestible energy than forage varieties but all types have a higher-than-desirable moisture content at harvest (Grant & Stock, 1994). Ideal dry matter content for sorghums is just above 30% but this may not occur without post-harvest wilting or delaying the harvest until after a frost (Grant & Stock, 1994).

Packing the silo well is largely determined by the ensiled vegetation's size. Whereas tender, leafy material like green pasture grasses are sufficiently small to pack well, large, fibrous plants like corn or sorghum require chopping, which releases plant sugars and enables greater compaction, fitting more silage in the silo and better displacing air (FAO). Grant and Stock (1994) offer data showing "a 14% increase in dry matter storage with the finer chop, indicating that finer silage chop results in firmer packing in the silo." Sewell and Wheaton (1993) suggest chopping corn silage "½ to ¾ inch long, irrespective of maturity and moisture level." Sorghum should be chopped to ½ inch and long hay should be chopped no smaller than a ¼ inch (Schroeder, 2004).

Ensiled crops low in sugar are "more likely to rot than ferment;" however, as previously mentioned, sugar sources like molasses may be added to resolve the problem (Lane, 1999). Low-sugar crops "include mature C4 pasture grasses harvested in the rains, legumes in general, and possibly tree fodder" (Lane, 1999). Excluding corn and sorghum, tropical grasses are low-sugar plants (Yami, 2008).

More than one crop may be successfully ensiled together, specifically by adding especially high or especially low-quality vegetation into a good base like corn or alfalfa, until the added materials comprise up to 30% of the silage (FAO; Van Peursem, 1962). Another cause for blending crops may be to fix incorrect moisture content, e.g. incorporating sorghum - a consistently high-moisture crop - into an overly dry corn crop (Grant & Stock, 1994) or adding grain between the layers of silage during filling to "help absorb excess moisture" (Scharabok, 2002).

Evaluating

After sufficient fermentation has occurred, silage can be evaluated for quality in a number of ways. The chart below offers targets for silage constituents.

COMPONENT	TARGET for CORN	TARGET for ALFALFA
pH	< 4.0	< 4.5
Lactic acid	> 3%	> 2%
Acetic acid	< 3%	< 2%
Propionic acid	< 1%	
Butyric acid	< 0.1%	
Ethanol	< 0.5%	0
Ammonia nitrogen	< 10%	< 15%
Yeast, mold, *Bacillus*	< 100,000 CFU (colony forming units)/gram	
Mycotoxins	0 parts per million	
Temperature	< 20°F above ambient temperature	
Appearance	No visible mold	
Color	Green, yellow-green, or brown-green	
Smell	Pleasant smell; not rancid, not like vinegar or alcohol	

COMPONENT	TARGET for CORN	TARGET for ALFALFA
Texture	Not slimy	
Density (wet)	43 pounds/foot^3	37 pounds/foot^3

(Seglar, 2003; FAO; Van Peursem, 1962)

Many of these indicators will require professional analysis, which can be beneficial if available, but others can be discerned by the layperson with a pH meter, a thermometer, or simply their senses of sight, smell, and touch. While temperature ought to be measured during silage's cellular respiration phase to identify overheating, all other indicators will be observed after "adequate fermentation, usually in 3 weeks" (FAO). Silage density is less of a concern with small silos than it is for large ones.

Odors and colors are helpful gauges of fermentation. The chart below offers some criteria signaling undesirable fermentations.

FEATURE	SIGNIFICANCE
Rancid odor	Clostridial fermentation
Musty odor	Moldy silage
Tobacco odor	Heat damaged silage
Vinegar odor	High acetic acid level
Alcohol odor	High ethanol content from yeast fermentation
Sharp, sweet odor	High propionic acid level
Orange color	Bacterial growth
Red color	*Fusarium* fungus growth
Brown to black colors	Excessive heating
White color	Secondary mold growth
Yellowish color	High acetic acid level

(Schroeder & Crawford, 2010; FAO)

Feeding

Because silage is typically a high-quality feed, it is usually fed to livestock that have high nutrient requirements such as young animals and dairy animals. However, other livestock can profitably utilize silage, especially if elements of their normal ration - hay, for example - have become more expensive, or to avoid health problems related to low-quality forage. While it is most commonly fed to ruminants and horses, silage can also be valuable in hog rations (Pickett, Foster, Hollandbeck, 1965).

Livestock generally enjoy silage, but some considerations must be made to feed it successfully. Any portion of the silage to be fed that is obviously spoiled or moldy must be disposed of; this will usually be the layer most exposed to air (Van Peursem, 1962). Silage should be fed within hours of opening the silo but, if it must be fed out over several days, the silo should be resealed or covered as best as possible to minimize drying, air exposure, and the corresponding dry matter losses (FAO; Van Peursem, 1962). If livestock do not initially consume silage, they may do so once its odor has weakened; if not, "some incentive, such as molasses or fresh forage mixed with the silage will help" (Yami, 2008). Lastly, "feed bunks must be cleaned out to prevent any remaining silage, which will spoil, contaminating the next feed out" (FAO).

Silage particle size, usually determined by the length of the chopped fodder, affects both consumption and animal health (Grant & Stock, 1994). Large plants like corn and sorghum should be chopped no smaller than ⅜ inch in order to provide sufficient saliva production and dietary fiber to avoid health problems (Grant & Stock, 1994; Seglar, 2003). Unlike corn, sorghum grain has a tough seed coat, meaning "relatively large amounts may pass through cattle undigested. Therefore, consider rolling the grain sorghum as it is put in or taken out of the silo" or harvest the plants early when the seed coats are softer (Grant & Stock, 1994).

The feed value of silage is dictated by the nutritional and phenological attributes of the crop ensiled and the effectiveness of the fermentation (Grant & Stock, 1994; Sewell & Wheaton, 1993). While corn, under optimal conditions, offers the greatest energy production and average daily gains of any silage crop, it is important to recognize its deficiencies in protein, calcium, phosphorus, and vitamin A (FAO; Sewell & Wheaton, 1993). For a 500-pound steer, "a full feed of corn silage would need to be supplemented with 1.5 pounds of a 40% protein supplement[,] a free-choice mixture of equal parts dicalcium phosphate and trace mineralized salt[, and] 15,000 IU of vitamin A per head daily" (Sewell & Wheaton, 1993). Sewell and Wheaton (1993) also suggest that antibiotics and growth stimulants "are usually profitable" and that less than 50% of the protein supplement should be "derived from urea."

Corn silage is safe and easy to transition to and from (Sewell & Wheaton, 1993). If it is employed as a fiber supplement to high-grain rations, 5 to 10 pounds per head per day should provide adequate roughage to avoid associated health problems (Sewell & Wheaton, 1993). A 500-pound steer will eat between 25 and 35 pounds of corn silage daily; however, make sure to consider the dry matter content of the silage before determining how much to feed per day if feed is not free choice (Sewell & Wheaton, 1993).

LOW-INVESTMENT APPROACHES TO SILAGE

Determining dry matter

The most simplistic method of estimating the dry matter content and the corresponding moisture content of plants to be ensiled is what the Food and Agriculture Organization calls a "grab test," in which a handful of forage - chopped to the appropriate length - is squeezed tightly for 25 seconds. Upon quickly releasing one's grip on the ball of forage, its reaction must be observed; the chart below will help interpret the ball's response.

DRY MATTER CONTENT	RESPONSE UPON RELEASE
Less than 25%	Ball holds shape with considerable free juice
25 to 30%	Ball holds shape with very little free juice
30 to 40%	Ball unfurls slowly with no free juice
More than 40%	Ball unfurls quickly

(FAO)

Evaluations of dry matter and crop maturity should be conducted "at the beginning of silage harvest. Several procedures could be used, including oven drying, laboratory analysis, and use of small electric moisture testers. All methods require gathering a representative sample..." (Grant & Stock, 1994). Employing a food dehydrator or oven to discover the dry matter content requires that the operator:

1. Weigh the container that will hold the sample.
2. Weigh the sample and subtract the weight of the container.
3. Dehydrate the sample.
4. Weigh the dehydrated sample and subtract the weight of the container.

5. Divide the weight of the dehydrated sample by the weight of the hydrated sample. The result is the dry matter content, e.g. a 0.2 total means 20% dry matter
6. Subtract the dry matter content, e.g. 0.2, from 1 to find the moisture content, e.g. 0.8 is 80% moisture.

Harvesting

Harvesting can take many forms depending on the resources available to a farmer and the crop to be ensiled. Harvesting equipment can mean a machete, a scythe or sickle, or a lawn, brush, or sickle bar mower. On a larger scale, custom harvesters may be hired in some areas to reap the crop. Tree fodder could require stripping branches by hand. In most cases, except when using a bagging mower, crops will need collected, usually by raking.

The small-scale producer has a few options for turning thick, fibrous plants like corn and sorghum into masses of chopped vegetation, ready for ensiling. These options include custom harvesting, where available, or chopping plants in the field with a brush mower then collecting the clippings. Farmers with less than ¼ acre or those who harvest multiple times over the course of the growing season might consider chopping plants by hand with a large knife (FAO; Yami, 2008). A fourth option discussed among small producers is to chop the plants - after cutting them near ground level to remove them from the field - by feeding them through wood chippers or hammer mills (*Wood chipper*, 2010). Regardless of the method, the crop must be processed in batches that are small enough to harvest, chop, and ensile within one day; otherwise, "it will become moldy or [too] dry" (FAO).

While corn can be harvested at its optimal moisture content, freshly cut hay crops often contain high moisture levels of 75 to 85% at harvest (Schroeder, 2004). To lower the moisture content, hay crops can be "cut and left to wilt" for a length of time primarily determined by the weather (Schroeder, 2004). For example, hay is ready to harvest within minutes after harvesting during a dry spell while it may take up to 3 days if harvested during rains (ACTION, 1977). "Under ideal drying temperatures of late spring and early summer [in the north-central United States], four to six hours are usually adequate to reduce moisture levels to around 65%" (Schroeder, 2004). "The most common problem encountered in making wilted silage is that producers allow too much wilting to occur before ensiling[, resulting in heating,] reduced digestibility as well as higher harvest and storage losses" (Schroeder, 2004). Wilting has progressed too far if "leaves become dry and curled;" instead, the crop ought to wilt until "leaves and stem become limp" (ACTION, 1977).

Bag silage

Advantages of using plastic bags as silos include their low cost, avoidance of seepage losses and air exposure, flexibility in production and storage, and ease of handling (FAO). Small batches of silage may be produced as resources allow and their size simplifies handling and feeding (FAO). Because the acid produced is confined to the bag, silage quality is kept high despite "poorer compaction than that [of silos packed] with silage machinery" (FAO). Because the whole bag is fed out to the animal, the rest of the silage, which is in other bags, is not exposed to air and therefore remains unspoiled (FAO). There are disadvantages to bag silos though, which include ease of puncturing - especially if stiff lengths of vegetation are ensiled, penetrability by pests, and the disposal of used bags (FAO).

Correct storage protects the bags' thin plastic from penetration or degradation. If stored outdoors, the "site should be cleared of stubble and sharp objects;" a tarp can be laid over the ground as an extra precaution and herbicides can be employed on nearby weeds to eliminate shelters for rodents and insects, who may damage the silage bags (Schroeder, 2004). Alternatively, concrete, asphalt, gravel, or dirt surfaces can be used (FAO). To avoid water damage, only "well graded and well drained" surfaces should be used (FAO). A site with around-the-clock shade helps "avoid temperature fluctuations which can degrade both the [silage] and the plastic" (Schroeder, 2004). "Alternatively, the bags can be stored in a pit and covered" (Yami, 2008). If stored indoors, the bags should be stacked somewhere they will not be damaged by pests (Yami, 2008). "After emptying, the bags must be carefully washed, dried and stored in a safe place for reuse if not damaged" (Yami, 2008).

Rodents, birds, insects, children, livestock, pets, and chemicals are all threats to bag silos (FAO). Some pests can be kept away, if bag silos are isolated from other feed sources (FAO). "Inspect the bags on a regular basis" and, if necessary, repair holes with tape, tar, or mastic; extensive damage will require re-bagging of silage (FAO). "Number and date the bags for easy identification and recall of materials bagged" (FAO).

The few references available about ensiling in relatively small bags suggest similar methods. First, start with the highest-quality, damage-free bags available (Lane, 1999). Starting with more expensive, higher-quality bags is economical as the bags can be washed and reused from season to season (Scharabok, 2002). Bags can range in size from "strong plastic shopping bags" (Lane, 1999) through very large, heavy-duty trash bags manufactured for construction debris. For small shopping bags, like those available in many grocery stores, the second step is to carefully fill the bags "so as to avoid making any holes" (Lane, 1999). "Gently but firmly squeeze the bag by hand to expel air" (Yami, 2008). Tying the two handles of the shopping bag into a knot will "not result in an air-tight closure;" instead, "while compressed[,] the neck of the bag [must be] twisted then turned over and tied with twine" (Lane, 1999). From here, the bag silo is placed, upside down, into a second shopping bag, which is then sealed (Lane, 1999). The process is repeated in a third shopping bag so that "each bag of silage [is] triple wrapped, and seams which might be expected to leak air [are] doubly protected" (Lane, 1999).

For large bags, the second step is to line a receptacle, e.g. a trash can, with 2 of the bags (Jernigan). The receptacle will help facilitate packing and avoid stretching or tearing the plastic during packing (Yami, 2008). Holes should be punched in the bottom of the receptacle "to prevent a vacuum lock between the bags and the can" (Scharabok, 2002). Third, fill the bag, compacting each layer by stepping into the receptacle or by using "a heavy object or board that is slightly smaller than the mouth of the barrel" (Jernigan). Make sure to leave enough room at the top so that the bag can be tied (FAO). Once full, twist the neck of the inner bag, "fold it over and then tie securely;" "do the same with the outer bag," sealing it around the inner bag (Scharabok, 2002). Twine makes a sturdy fastening; for best results, wind the twine around the neck a few times before knotting (FAO). Lower the receptacle onto its side to remove the filled bag (Jernigan).

Receptacle silage

Fodder ensiled in a receptacle like a large plastic container or 55-gallon drum follows the concepts described above for bagged silage, e.g. pack silos well and seal tightly, except that there is less concern of rodent infiltration during storage because of the receptacle's hard exterior. Specialty vacuums exist to remove air from drums, which will help ensure a more desirable, i.e. anaerobic, environment. A receptacle may be lined with a bag, e.g. a heavy-duty trash bag, if preferred.

Pit silage

These silos "consist of trenches or pits dug into the soil" (Bartholomew, du Plessis & Macdonald). The pit walls can be unlined, or lined with brick, concrete, or tarp (Bartholomew, du Plessis & Macdonald). In comparison with above-ground silos, pit silos "are never damaged by storm or fire [and] require less reinforcing" (ACTION, 1977). While pit silos can be a highly economical way to store silage, they have distinct disadvantages. Those pit silos with earthen walls will lose silage liquid and the essential acid it contains as "it seeps out through the bottom of the pit as effluent" (Yami, 2008). Water damage from rain, floods, poor drainage, and high water tables is inevitable if the silo is poorly sited (ACTION, 1977).

Construction of pit silos mandates only a few general principles, which conform to those discussed throughout this paper, e.g. reducing air exposure and achieving good compaction. Round pits and sidewalls that are "straight and smooth" encourage uniform compaction and avoidance of air pockets (ACTION, 1977). If the soil is too loose to form walls, like in places with deep sand, a pit silo cannot be properly dug; instead, a tank or cistern would need to be built into the ground (ACTION, 1977). As with all outdoor silos, shade will help minimize silage quality degradation and minimize drying once the silo is opened for feeding (ACTION, 1977). The silo will need to be of sufficient depth that 2 to 4 inches of silage can be removed from the surface daily to avoid spoilage (ACTION, 1977).

Pits should be prepared for filling just before the harvest because of the tendency for walls to collapse if the pit remains empty (ACTION, 1977). Like with all silos, each layer of silage should be packed to exclude air; sidewalls, where air pockets are likely to form, ought to receive special attention during packing (ACTION, 1977). Care must be taken to avoid unintentionally pushing soil into the silo when filling, compacting, or feeding, as this will reduce the silage's palatability (ACTION, 1977). A properly sited, well-constructed pit silo can last for years and, if a pit is to be reused, "all rotten and moldy silage should be removed [and sidewalls] should be straightened if portions have fallen in during the preceding rainy season" (ACTION, 1977). As for termite damage, "experience and studies have indicated that termites will not eat well preserved silage" (ACTION, 1977).

CONCLUSION

Silage is a feed option that can make nutritious green fodder available in times when it would otherwise be unobtainable. Through lactic acid fermentation, silage effectively conserves fresh feed in times of oversupply to be fed in times of scarcity. Almost any fodder crop can be successfully ensiled, though some - like those with insufficient fermentable sugar, moisture content, or indigenous bacteria - may dictate the use of additives. With sufficient information and some minor equipment investments, subsistence and hobby farmers can produce high-quality silage on a appropriately sized scale.

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