Some of the best quality silage ever made has come from round bales sealed in plastic. On the other hand, some of the worst silage that I have ever seen likewise came from round bales in plastic. These extremes in quality are related to procedural techniques for putting up round bale silage and problems that can occur during storage. If proper techniques are followed, excellent quality silage can be produced, especially from late summer and fall cuttings. But if bales are not managed properly, it can be a disaster resulting in total loss of the silage.

It may be easier to preserve hay crop silage in upright, trench and bunker silos than in large bales sealed in plastic. Plastic is much more susceptible to air leaks and oxygen infiltration than concrete or steel, so the ease of maintaining an oxygen-free storage environment is much less for bales surrounded by plastic than for conventional silos.

The round bale silage system, sometimes referred to as 'balage', has a number of advantages over hay and conventional silage systems:

1. Substantially reduces the risk of weather damage to the forage compared with a hay system.

2. Provides flexibility as the baler can be used for both hay and silage. Main attraction of large round bales is the ease and simplicity with which they can be mechanically handled.

3. Lower overall fixed and operating costs than other forage systems—requires less specialized equipment and no storage structures.

4. Baling requires less energy than chopping.

5. Lower field losses than round or square baled hay.

6. The system is easily expandable without a large investment.

7. Can store at a higher moisture content with less seepage loss.

8. Natural green color more likely to be maintained than in conventional structures.

9. Bales can be self-fed, eliminating the chore of daily feeding usually required with chopped silage.

Round bale silage may be a solution for small dairy operations because it can be a one man
system that helps beat weather and leaf loss and does not require investment in a large tractor, chopper and special wagons which an under 40-cow dairy can hardly afford.

There are some disadvantages that need to be considered as well:

1. Maintaining airtight storage can be a problem.
2. There may be less or incomplete fermentation, resulting in higher pH, unstable silage.
3. Potentially greater storage losses than conventional silos or hay if an airtight seal is not maintained.
4. Cost of plastic bags or wrap.
5. Increases labor requirement compared to round baled hay.
6. Disposal of considerable amounts of plastic is a nuisance at best and may become a problem as environmental regulations evolve.

A higher level of management is required for round bale silage-making. While the manager must pay more attention to details for this system to be successful, it isn't complicated. As with any other forage conservation system, keep in mind that the final product will not be any higher in quality than what is put into the bales. Harvesting the forage at the proper stage of maturity is critical. A forage crop that is over mature and low in quality may lack sufficient sugar content for good fermentation, especially if moisture content is not greatly reduced.

**PROCEDURES**

**Wilting.** Baling at the proper moisture content is more critical with balage than in conventional systems and is probably the single most important factor in round bale silage-making. Excess moisture results in improper fermentation (butyric rather than lactic acid formation) and reduces the amount of dry matter stored per bale, which greatly increases storage costs (more bags or plastic wrap per ton of dry matter). Inadequate moisture reduces the extent of fermentation and heat damage is common due to less compaction and greater entrapment of air if the crop is too dry.

Low moisture silages (40-60% moisture) have limited bacterial growth and fermentation (Noller and Thomas, 1985). Since less acid is produced, the important factor with low moisture silages is the establishment and maintenance of air-free conditions. That is why low moisture silage storage is generally confined to sealed upright silos and fine chopping and rapid filling are critical. Stacks, bunker and trench silos are seldom used because of the difficulty of obtaining sufficient compaction and maintaining air-free conditions.

Temperature rise in a tightly sealed silo is dependent upon silage dry matter (DM) content and compaction (Pitt, 1990). When oxygen is present, plant respiration occurs, breaking down plant
sugars into carbon dioxide and water and releasing heat. Aerobic and facultative anaerobic microorganisms, such as yeast, molds, and certain bacteria, can be significant sources of respiration as well. The heat produced by respiration raises the temperature of the ensiled forage. Elevated temperatures increase the rate and amount of protein breakdown (proteolysis) to soluble non-protein nitrogen (ammonia, nitrates, nitrites, free amino acids, etc.). Heating is less in more compacted forage, because compaction tends to exclude oxygen. And, since water is a good absorber of heat, temperature rise is less as moisture content increases. Silage temperatures below 90F indicate good compaction and proper DM content.

**Optimum moisture content for good round bale silage-making is 50 to 60%.** At 40 to 50% moisture, heat damage can be expected and at less than 40% moisture, burnt forage or even spontaneous combustion may occur.

**Baling.** Most large round balers can successfully bale wilted forage, but the variable chamber balers seem to do a better job than those with fixed chambers. Chain-type balers have sometimes had an advantage over belt-type since excessive slippage of belts may occur with wet forage in some machines.

Roll the bales as tightly and evenly as possible. This helps to exclude air, improves fermentation and reduces losses during feedout. If you are using bags, be sure bales are the correct size to fit the bags. Bags should fit bales snugly to minimize air space, but should be big enough to slip over the bales without difficulty. Tight, dense, uniform size bales not only provide a better fit of bags and wrap but enables stacking bales for storage. Baling ground speed should be less than speeds used in making field-cured hay. This results in tighter, more dense bales. Desired density is 10 to 15 lbs DM per cubic foot.

Keep in mind that bales containing 50 to 60% moisture will weigh about double that of dry hay bales of the same size. The typical diameter and weight of round bale silage baled at 55% moisture are: 4 ft, 800 to 1,000 lb; 5 ft, 1200 to 1600 lb; and 6 ft., 2200 to 2700 lb (adapted from Harrison and Fransen, 1991). Don't overload the strength of your baler, tractor or loader. After you have made the first bale, try to lift it with your bale handling equipment to see if the weight is acceptable. There is not much that you can do after the field has been baled and then discover that the bales are too big for the bags or too heavy for the loader or wrapper. Net or plastic twine are recommended for tying bales -- the chemical preservative in sisal twine may degrade the plastic bag or wrap.

**Storage site selection.** Choose storage locations as close to the planned feeding sites as possible. Conditions are much more favorable for moving bales in the summer than they are during the winter. Bales should be stored in a well-drained site clear of trash or sharp objects and free of as much vegetative growth as possible. Grassy areas should be mowed before bales are moved onto the site. A clean site reduces the potential for rodent damage to the bags.

Select a shady area, preferably on a north-facing slope or in the shadow of a tree line or wooded area. Solar heating of the material inside the plastic appears to be the cause of much of the deterioration of silage from early summer cuttings stored outside until winter. The farther south you go, the greater this problem. Diurnal variations in temperature cause a migration of moisture
from the tops and south-facing sides of bales to the bottoms and north-facing sides. Direct solar radiation increases temperature within the plastic during the day and vaporizes water, which then condenses primarily on the cooler north sides and bottoms of the bales at night.

In a storage trial conducted in Maryland in 1990-91, bales from each cutting were placed in bags and stored in three ways: in a barn out of direct sunlight, outside in direct sunlight and outside under a sheet of black plastic to exclude sunlight. First cutting was baled May 7, second June 11, third July 9 and fourth August 13. Feeding of the bales began in early December and continued through February.

The bales from the first three cuttings stored in the barn had considerable surface mold but were subjectively rated from 'good' to 'excellent' -- first cutting bales good, second cutting very good and excellent and third cutting excellent. First cutting bales had more surface mold than third. In all cases the balage had a good silage smell, palatability was good and the bales were totally consumed by dairy cows.

The highest rating for bales from the first three cuttings stored outside in direct sunlight was 'fair' and many were a total loss. The top and south-facing side of the bales were generally dry with considerable mold and very musty/moldy odor. The north-facing side and bottom of the bales were wet and slimy on the surface but had a reasonably good odor and cows would generally consume that portion of the bale. When silage refused by the cows was combined with bales that were unfeedable, total losses for each of the first three cuttings were estimated to be 60 to 65%.

The intent of placing a black plastic sheet over bales stored outside was to exclude sunlight, thereby reducing possible deterioration of the bags and detrimental effects of sunlight on the silage. What seemed like a good idea in theory was definitely not a good idea in reality -- all bales from the first three cuttings stored this way were a total loss. These bales had very objectionable, foul odors and often the entire surfaces of the bales were slimy. The black plastic turned out to be a superb solar heat collector. The elevated temperature levels created under the black plastic were not conducive for high quality silage. We were not able to determine whether fermentation was inhibited or if the breakdown occurred later in storage due to overheating.

The fourth cutting results were much better. All bales, whether stored inside or outside, were rated as excellent. In this case, surface mold was less of a problem on bales stored inside and moisture transfer was much less of problem in bales stored outside in direct sunlight.

Our experiences on the research farm as well as some farmer experiences indicate that under Maryland conditions, bags are not a satisfactory method of storing spring and early summer cuttings of forage for winter feeding. Use of bags or tubes in the more southern climates should probably be limited to late summer and fall cuttings or where spring and early summer cuttings will be fed within a relatively short storage period (within 1 to 2 months).

Side-by-side comparisons of bagged and wrapped balage in Maryland in 1993-94 showed wrapping to be superior to bagging but moisture migration and heat damage on the top and south-facing surfaces were still significant problems with first, second and third cuttings stored outside. Tight wrapping would be expected to exclude more air initially and to maintain a tighter
seal. And the tighter fit may minimize the pumping action of the wind as compared to a loose fitting bag.

Again, shady areas on north-facing slopes are preferred storage areas, especially in the more southern climates.

**Bale handling equipment.** Bale handling equipment ranges from spear-type devices to fork lifts and trailer-mounted sleds. Spears can be mounted on front-end loaders as well as three-point hitches. If using a tractor with a front-end loader to move bales from the field to the storage site, carrying another bale on the hitch not only increases efficiency but provides better stability of the tractor. Spears are the preferred implement for lifting bales when bagging. To move or stack bales after wrapping, moveable forks with rollers to slide under and cradle the bale or clamps which squeeze the bale while lifting are needed to avoid puncturing the plastic. Trailer-mounted sleds can be used to pick up and move several bales at a time from the field to storage site.

**Bagging**. Bag the bales at the storage site. After positioning the bales for storage, slip the bags over the bales before they are set on the ground or on top of other bales. Bagging is easiest and most efficient with two people -- one on each side of the bale. Excess air should be pushed out of the bag before sealing but it is not necessary to completely evacuate the bag. In fact, removing air with a vacuum cleaner or pump may result in punctures of the bag by plant stems and cause more harm than good.

Sealing is also easiest with two people. One person pulls and twists the end of the bag while the other ties it with a good quality twine. The twisted end should then be bent back onto itself and tied again to ensure air tightness. If bags swell up with gases for a few days after ensiling, that is a sign of a good seal. However, polyethylene plastic film used for these bags is not totally airtight, allowing the carbon dioxide formed as the fermentation process begins to be vented. Thus the bags then shrink back to bale size. If you see any bags that do not swell, check for leaks or holes and repair them.

Use good quality polyethylene bags having an ultraviolet light inhibitor. They are more expensive but allow less oxygen to infiltrate and will better withstand storage in direct sunlight. Black bags tend to weather better than white bags, but high temperatures can be a problem with black plastic. Suppliers should be willing to guarantee bags for one year.

Reuse of bags is generally not recommended. Even with good quality plastic, minor pinholes that may go undetected when examining bags can result in loss of the silage, a loss much greater than the cost of new bags. If bags are being considered for reuse, a good way to inspect them is to inflate them with a fan in a brightly lit area (outside on a bright sunny day is ideal). Then from inside with the bag over your head, look for light shining through holes. Used bags should be rolled on a bar or rod, stored in dry place protected from sun and excessive heat and kept off the floor or ground to discourage rodent damage.

Some round bale silage makers report improved results with double bagging utilizing used bags. A second bag gives added protection and further return on the investment.

**Wrapping.** Wrapping is sometimes quicker than bagging and requires less labor (Table 1), but
it means a capital expenditure for another piece of equipment. According to Garthe and Hall, a minimum of 100 bales a year should be wrapped to justify the machine cost ($6,000 to $12,000, depending upon level of sophistication).

Plastic for wrapping is usually one mil (0.001 inch) thick and should have a tackiness agent to provide proper sealing. A roll will typically cover 25 to 30 bales. Each bale requires 1.5 to 2 lb of plastic. Cost of plastic per bale is about half that for bags (Table 1). A 50 percent overlap of the plastic and wrapping twice (four layers) provides a better seal than 25 percent overlap providing four layers. As with bags, the wrap is not totally airtight and again the plastic should be guaranteed for at least one year.

**Inspect bales weekly.** Inspect the plastic weekly and patch holes as soon as they are found. With bags, wind causes loose plastic to bellow and provide an air exchange if there are holes, which usually results in spoilage of the outer layers and sometimes the entire bale in a matter of a few days. Duct tape, masking tape, etc. are not suitable for patching holes -- they usually do not adhere longer than a couple of weeks. Appropriate polyethylene tape is available from the bag or plastic wrap supplier.

**Feeding.** Livestock access to bale silage should be restricted with feeding rings or other devices to control feeding losses. If bales are simply placed on the ground with unrestricted animal access, feeding losses can be up to 50 percent. Use of a feeder ring can reduce loss to 10 percent or less. Mobile feed carts designed for unrolling or grinding bales are available, but it means a capital investment for another piece of equipment.

**COMPARATIVE COSTS TO OTHER SILAGE SYSTEMS**

Garthe and Hall compared the costs of wrapping and bagging in Pennsylvania (Table 1) to other systems. In their analysis it would cost about $52 and $30 per ton to ensile similar amounts (150 and 300 bales, respectively) of chopped forage in long tube-type bags. The cost to ensile the equivalent of 300 bales in a concrete stave silo is over $42 per ton if the silo is filled only once a year and $21 per ton if it is filled twice a year. Based on these figures the 300-bale wrapped round bale silage system is competitive in costs to the concrete stave silo system filled twice a year and considerably cheaper than the stave silo only filled once a year. This is a particular advantage for smaller dairy or livestock producers who can not justify the large capital expenditures for new or expanded facilities.

**POSSIBLE ANIMAL HEALTH CONCERNS**

One of the advantages of balage listed at the beginning of the paper is that forage can be stored at a higher moisture content without seepage loss than in tower silos. This advantage led to a deadly problem in at least one case that I am aware of.

During a period of extremely wet weather, an oats/alfalfa mixture (alfalfa underseeded in a spring oats companion crop) was apparently baled too wet for fermentation to occur. Since the crop was not wilted, it appears that starch and sugar levels were not sufficient to enable fermentation and thus the pH did not decrease. Three weeks after baling, a bale was fed to 30
Jersey cows. The bale was not apparently moldy nor did it have any other appearance to indicate that there might be a problem with this bale. However, that one bale resulted in the death of 15 of the 30 cows.

Veterinary diagnosis determined that the cause of death was ochratoxin. Ochratoxin is a mycotoxin produced by molds. It can be found on barley and oats in Scandinavia, however, its occurrence in North America is not as well documented as that of aflatoxin and several of the other mycotoxins (Buchanan-Smith and Young, 1991). The toxin destroyed the cow's kidneys.

Mycotoxins are more frequently associated with moist grains and near the surface of trench, bunker and non-sealed tower silos. While the toxins seem to be everywhere in the environment, they are usually not a problem in silage because the acids in silage prevent their development or destroy them. But in this case the pH remained at 7 after three weeks. The pH should have been 3.4 or 3.5 and the silage safe if the crop had been adequately wilted and proper fermentation taken place.

This situation is presented to illustrate possible animal health problems that can occur if proper management procedures are not followed and the forage either does not ferment or fermentation is incomplete. The balage system is not any more prone to these problems than other systems IF proper bale silage management procedures are followed.

SUMMARY

Balage can be the best or worst of systems. More attention to details is necessary but the system is not complicated. It is a flexible, lower capital cost method of preserving forage. Its use is increasing, especially on smaller farms that cannot justify investments in specialized equipment and storage structures.

If you are not presently using this system and you want to try it, go slowly at first. You may find it to be a valuable additional or alternative way to handle forage, or you may find that it will not fit in your operation at all. Trying it on a small scale is the best way to find out.

The assistance of Ivan Glick, Ag Journalist, Lancaster, PA is gratefully acknowledged in the authorship of this paper.

REFERENCES


Table 1. Comparative costs of wrapping versus bagging for two typical circumstances.

<table>
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<th>150 bales/years</th>
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<tr>
<td><strong>Inputs</strong></td>
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<tr>
<td>Plastic Price $/bale</td>
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<td>Salvage value %</td>
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<td>Size Bale weight lb DM</td>
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**Results**

<table>
<thead>
<tr>
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<th>Wrap</th>
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<tr>
<td>Plastic cost $/bale</td>
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<td>$/ton</td>
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<td>$/ton</td>
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**Total cost** $/bale 6.60 9.91 8.37 9.50
$/ton DM 22.01 33.03 27.91 31.68

Source: Garthe and Hall, 1992.

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