

Silage storage

9.0	Introduction	219
9.1	Storage systems for forage-harvested (chopped) silage	220
9.2	Designing bunkers and pits	227
9.3	Filling and compacting silage in bunkers, pits and buns	231
9.4	Sealing bunkers, pits and buns	232
9.5	Storage systems for baled silage	234
9.6	Location and maintenance of stored bales	240
9.7	Plastics used for silage	241
9.8	Storage losses	244
9.9	Drought (or long-term) storage	249
9.10	Appendices	250

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In this chapter

9.0	Introduction	219
9.1	Storage systems for forage-harvested (chopped) silage	220
9.1.1	Silage buns or stacks	220
9.1.2	Portable clamps or walls	221
9.1.3	Above-ground bunkers or clamps	222
9.1.4	In-ground pits	223
9.1.5	Stretchable bag system	225
9.1.6	Tower silos	226
9.2	Designing bunkers and pits	227
9.2.1	Location	227
9.2.2	Dimensions and storage capacity	228
9.2.3	Construction	230
9.3	Filling and compacting silage in bunkers, pits and buns	231
9.4	Sealing bunkers, pits and buns	232
9.5	Storage systems for baled silage	234
9.5.1	Bulk storage above-ground	234
9.5.2	Individual above-ground bale storage	237
9.5.3	Bales stored in pits	239
9.6	Location and maintenance of stored bales	240
9.7	Plastics used for silage	241
9.7.1	Plastic sheeting	241
9.7.2	Stretchwrap plastic film	242
9.7.3	Silage tapes	243
9.8	Storage losses	244
9.8.1	Effluent	244
9.8.2	Respiration and aerobic spoilage	245
9.8.3	Fermentation	248
9.9	Drought (or long-term) storage	249
9.10	Appendices	250
9.A1	Spoilage losses with forage-harvested silages – likely causes and solutions	250
9.A2	Spoilage losses with baled silage – likely causes and solutions	251

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The Key Issues

Successful storage depends on:

1. Producing an airtight storage unit as quickly as possible after completion of harvesting.
2. Maintaining an airtight seal until feeding commences.

Chopped (forage-harvested) silage

- Ensure harvested forage is at correct DM content for length of chop used.
- Spread harvested forage evenly (to a depth of about 15-30 cm) before rolling.
- Continually roll the forage during harvesting, and ensure forage is well compacted to expel as much air as possible.
- Long, narrow, deep stacks are more effective than short, wide, shallow stacks.
- Until harvest is complete, cover the stack at night, weighting the plastic along the perimeter.
- When harvesting is completed seal the stack as soon as possible after adequate compaction.
- Bury the edges of the plastic in the ground to ensure an airtight seal. This is more effective than simply covering the plastic with soil.
- Regularly inspect the stack for holes during storage. Repair holes as soon as noticed using tape specifically made for silage plastic.

Baled silage

- Bale at the correct DM content.
- Bales should be well compacted (of high density) to minimise air pockets.
- Ensure the storage site is clear, control weeds, rodents and remove objects that may pierce the plastic. Do not store under trees or too close to fence lines.
- Seal the bales with plastic as soon as possible after baling.
- If possible, seal the bales at the storage site rather than in the paddock where they are baled.
- If wrapped bales must be moved, use handling equipment that will not damage the plastic.
- Regularly inspect bales for holes during storage. Repair holes with tapes specifically made for stretchwrap plastic as soon as they are noticed.

Section 9.0

Introduction

Although many high-quality crops are harvested efficiently, there can be significant losses of DM and quality if the silage storage system is inadequate. These losses are due to excessive respiration (overheating), effluent loss and aerobic spoilage in the stack or bales (see Chapter 2, Section 2.5). They can be minimised by good management during filling and storage.

There is a range of storage systems used for preserving silage. These include under- and above-ground systems, with the capacity for handling both chopped and baled forage.

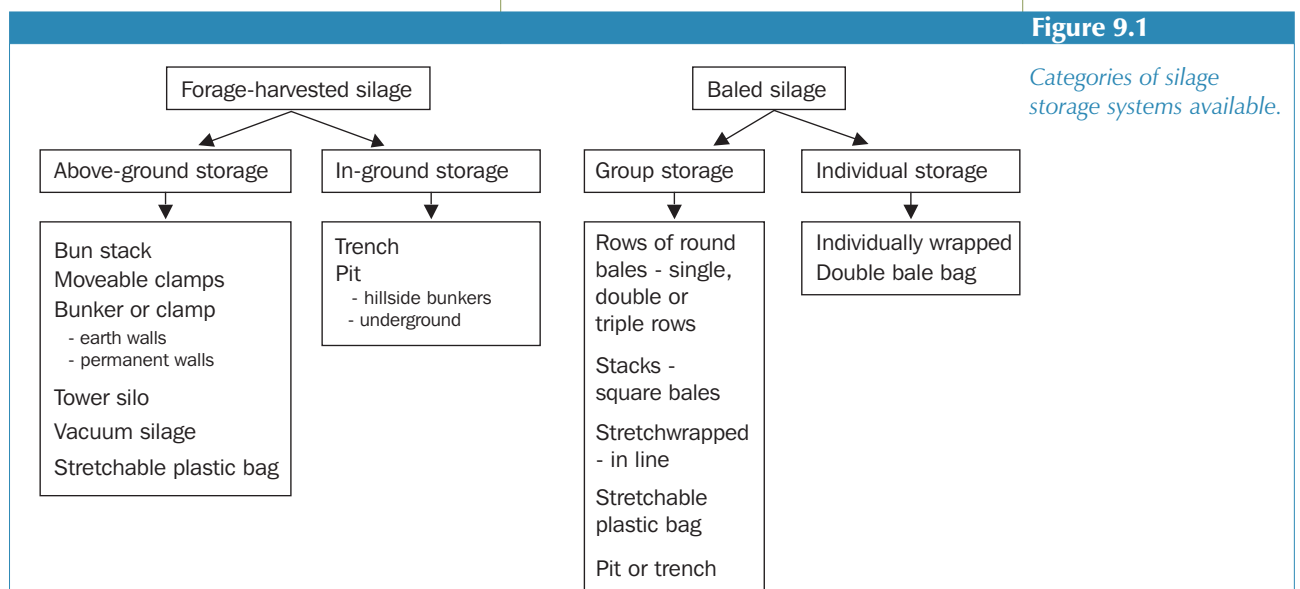
All systems are capable of producing high-quality silage. However, above-ground storage that relies on a plastic cover for protection is usually only suitable for short-term storage. Storage time may be increased by providing a second protective cover over the silage plastic, to reduce breakdown by sunlight (ultra-violet radiation). As long as there is no physical damage to the plastic, this may extend the storage time by 3-5 years.

The system chosen for a particular enterprise will depend on the purpose for which the silage is being used, available equipment, expertise and personal preference.

Safety first

- Whether storing silage in pits, bunkers or bales, take all necessary precautions to avoid injury when using heavy machinery. Safety issues should not be ignored. Ensure all operators read and fully understand any information provided by the manufacturer on the machinery's safe operation.
- When preparing pits or bunkers, excavation is a safety issue. Check the guidelines that apply in your State. In NSW, for example, the NSW Code of Practice: Excavation 2000 provides legal guidelines and responsibilities for persons engaged in excavation work. It is available from the Workcover Authority of NSW or from its website <www.workcover.nsw.gov.au>
- Guidance notes on Hay and Silage Bales and Trenching Codes of Practice are available from <www.workcover.vic.gov.au> and Codes of Practice for Transport of Silage and Hay from the Australian Fodder Industry Association (AFIA) website <www.afia.org.com.au>
- Seek help from Workcover, or the relevant State authority, to ensure all equipment and practices are safe and satisfy recommended guidelines and regulations.

Figure 9.1 categorises the storage options. When choosing a storage system it is also necessary to consider how the silage is to be fed out. Poor planning of the feedout phase through inappropriate design or location of the storage facility, or an inadequate feedout system, can result in an expensive silage system. The feedout aspect is covered more fully in Chapter 10.



Section 9.1

Storage systems for forage-harvested (chopped) silage

Buns are silage units formed above the ground, with no structural support. Sometimes referred to as stacks or bun stacks.

Bunkers refer to above ground storages with structured walls.

Pits refer to storages in the ground or built into the sides of hills.

Chopped or forage-harvested silage is handled and stored in bulk. It can be harvested using forage wagons, flail, single and double chop, and precision (metered) chop forage harvesters. For more details on the various types of forage harvester, see Chapter 8, Section 8.2.1.

The silage is chopped to various lengths, depending on the machine setting.

9.1.1

Silage buns or stacks

Silage buns, also called stacks, are usually a short-term method of storing chopped silage. They are often sited in or near the paddock being harvested, but can be near an intended feedout point.

Buns should be sited:

- ▶ on a reasonably level area of ground, ideally with a slight slope to allow rain water to drain away freely, particularly during feedout;
- ▶ away from depressions where water may pond or areas where water may run during heavy rain; and
- ▶ away from trees (tearing of the plastic sheeting by falling limbs and bird damage is more significant if buns are sited near trees).

Silage buns are very simple to construct. The harvested forage is dumped on top of the ground, then compacted by rolling with a tractor. During rolling, the shape of the bun is formed by pushing the uncompacted forage with a blade or bucket.

The forage should be covered with a plastic sheet as soon as harvesting and rolling are completed. An airtight seal is achieved by burying the edges of the plastic sheet. If compacted and sealed effectively, the silage is preserved with little visible waste.

Buns are produced either by filling from one end (Dorset wedge technique, see Section 9.3) or by topping up over the length of the stack. The latter method is primarily used for buns formed using forage wagons, where the harvested material is offloaded as the wagon is driven across the bun.

As there are no walls, the height to which the bun can be safely constructed is limited. The amount of surface area to

Plate 9.1a

A small-scale silage bun system used to store small amounts of silage. The area around the storage site is clear – minimising potential vermin habitats. A large number of tyres have been used to weigh down the plastic, maintaining contact between the plastic and the silage. Photograph: K. Kerr



Plate 9.1b

Large-scale bun system. In this case the number of tyres is inadequate. At least twice the number are needed to ensure a good seal. Photograph: M. Martin



Silage buns or stacks

Advantages

- No construction cost.
- Can be located with less regard to terrain than trenches or pit silos (rocky soil, subsurface water).
- Are easily adaptable to self-feeding using electric fencing.
- Easily sealed using a blade or bucket.

Disadvantages

- Because of the high surface area to volume ratio, the amount and total cost of plastic used per tonne of ensiled forage is high, and any surface wastage represents a large proportion of the ensiled forage.
- Can be dangerous for tractor operators during rolling.
- Not suitable for long-term storage (>2-3 years) unless the plastic is protected from sunlight.

volume (the surface area to volume ratio) is high and, as a result, the risk of in-silo spoilage is also high. The effect of surface area to volume ratio on storage losses is discussed in Chapter 11, Section 11.2.4.

Circular buns are popular in some areas. They are round stacks of forage, which may be as high as 2-3 m at the centre. Being round, their surface area to volume ratio – and therefore plastic costs – are higher than that of long, narrow buns.

Because there are no walls to provide physical support, silage buns can be unstable, and tractors may tip or bog during rolling. Care must be taken when rolling or delivering and dumping on the stack. Drivers should be experienced or closely supervised by someone who is.

Vacuum silage

Vacuum silage is no longer common, although it has been used in Queensland and found to be economically and practically feasible for short-term storage. Forage is sealed in an airtight plastic cover, which is then evacuated (air removed) with a pump. However, a well-preserved silage can be produced without the added expense of evacuating if the stack is well compacted and sealed quickly.

Vacuum silage requires some compaction by rolling to provide a firm base for machinery to pass over the stack. Additional compaction also occurs when spreading the chopped forage around the stack. However, most of the compaction is achieved in the evacuation process. The system only works well with young, leafy material that is easily compacted. Forage with woody stems may puncture the plastic cover during evacuation of the air. This risk increases as chop length increases.

9.1.2

Portable clamps or walls

Portable clamps or walls can be removed (or left in place) after the stack is completed. They suit stacks where the tractor and cart can travel over the stack's length when delivering the harvested forage.

They can be very dangerous if the walls are not strong and stable enough for the size and weight of machinery used to fill and compact the stack.

They are usually built from metal pipe or tube and sheets of tin or strong plywood. The walls – usually 1.5-2.0 m high – must have sturdy guide rails to prevent the wheels of the rolling tractor slipping over the edge.

Anyone intending to build or use portable walls should seek expert advice to ensure adequate strength, stability and safety.

Although some producers have used large round or square bales of hay as 'side walls', they are not recommended as it is difficult to create an airtight seal:

- ▶ the edges are usually poorly compacted;
- ▶ a lot of air can be trapped between the forage and the bales; and
- ▶ bales can easily puncture or tear the plastic during rolling and sealing.

The use of portable clamps or walls is not recommended because of the risks involved in filling and compacting the stack.

Portable clamps

Advantages

- Inexpensive to construct and may be used for several batches per season.
- Allow a greater depth of silage, reducing plastic costs per tonne and proportion of the ensiled forage lost due to surface waste.
- Adaptable to self-feeding.
- Easily sealed using a blade or bucket, if the walls are removed.

Disadvantages

- Can be extremely dangerous to the tractor operator.
- Need to be assembled and later disassembled for each silage stack.
- Difficult to obtain a good seal around the edges if the walls are not removed.
- Not suitable for long-term storage unless the plastic is protected from sunlight.

Bunkers

Advantages

- Can be built in areas where the soil is rocky or the water table is high.
- Can be built reasonably inexpensively.
- Can be adapted for self-feeding.
- Can be long lasting.
- Reduced plastic costs per tonne of ensiled forage.
- More effective compaction possible, reducing losses.
- Concrete bunkers allow all-weather access.
- Depending on design, can be expanded at relatively low cost by using a common wall.

Disadvantages

- Need to be well sealed where the plastic overlaps or losses can be high.
- Do not always shed rainwater effectively. Pools of water can lie on the plastic surface, seep through and cause losses.
- Not suitable for long-term storage unless the plastic is protected from sunlight.
- Concrete bunkers can be expensive to construct, but can be justified if used regularly.

Plate 9.2a

Low-cost, above-ground bunker – earthen floor, mesh and plastic in walls. Second-hand conveyor belting may be used as walls.



Photograph: A. Kaiser

Plate 9.2b

Low-cost system with earthen floor and corrugated iron walls. Corrosion of metal will be a problem if the bunker is not lined.



Photograph: F. Mickan

Plate 9.2c

Higher-cost, but more durable concrete bunker system.



Photograph: F. Mickan

9.1.3

Above-ground bunkers or clamps

Bunker or clamp silos are permanent structures constructed above ground (see Plate 9.2a, b & c) commonly used in operations where a lot of silage is made and fed.

They are an option in areas where a high water table makes underground storages an impossibility.

Bunkers are rectangular in shape and can be open at either one or both ends. The walls can be made of various materials including concrete, earth, timber (such as railway sleepers) or steel. Floors are earthen or concrete. The durability of the structure will vary with the building materials used. Silage acids will corrode materials over time.

It is essential that producers seek engineering advice on construction to ensure the stability of these structures.

Factors to consider when constructing bunkers or in-ground pits:

- The cost of building bunkers or in-ground pits is a fixed cost. The potential life of the storage is important when considering location.
- If the storages are used regularly, as part of the annual forage conservation program, the construction costs per tonne of silage can be low.
- The storages can be re-used many times if the pit or bunker is well constructed and the surrounding soil is stable.
- Professional advice should be obtained when constructing these storages.

9.1.4

In-ground pits

In-ground storages are suitable for both long- and short-term storage of silage. Silage being used in the short-term need only be sealed with plastic as for the bunker system. For long-term storage, the plastic has to be covered with a layer of soil (see below).

Regular monitoring is recommended to ensure burrowing animals have not disturbed the soil layer, allowing air and water into the silage.

A layer of plastic on top of the silage will prevent soil contaminating the silage, and provide a barrier against air and water penetration. At least 30 cm of soil should cover the plastic. A cheaper, lower-quality plastic, such as builder’s black plastic, although not recommended for above-ground silos or bunkers, may be used if the covering soil is not a porous sand or a cracking clay.

Although it is never recommended that soil be placed directly onto the silage, if plastic is not used then at least 50 cm of soil on top of the forage is required for long-term storage. The soil must not be porous or a cracking clay.

The level of maintenance required depends on how often the pits are used and refilled. Some ‘clean-up’ prior to refilling may be required to remove any soil that has fallen in or to re-level the base of the pit.

Safety must be considered at all times. The risks of walls collapsing and cave-ins will increase with the depth of the pit.

Construction of very deep-sided pits may raise occupational health and safety issues and may involve regulations concerning

In-ground pits

Advantages	Disadvantages
<ul style="list-style-type: none"> • Inexpensive to construct. • Ideal for long-term drought storage. 	<ul style="list-style-type: none"> • Not recommended for short-term storage. • Not suitable for areas with a high water table. • Cannot be used during wet weather. • Unstable walls can be a safety issue.

depth of excavations, fencing off dangerous areas, specifying and erecting formwork, retaining walls and other potentially dangerous situations. Refer to the websites mentioned in Section 9.0 or contact local State authorities for detailed information.

There are numerous variations on types of in-ground storage, but they can be categorised as underground pits, hillside pits or bunkers, or the less-common trenches.

In-ground pits

Underground pits are dug into flat ground with the silage stored completely below ground level or mounded. The soil removed from the hole should be mounded over the top of the pit to shed water. If the stack shrinks below ground level then more soil should be added.

They are usually used for long-term or drought storage and are only recommended for drier areas. Feeding out from the pits should take place during dry weather. If the pits are open during wet weather they will fill with water, making it impossible to remove the silage and causing large losses.

Underground pits should not be constructed in areas where a high water table allows water to seep into the pit, resulting in losses of DM and quality.

Plate 9.3

Hillside pits or bunkers can be effective, low-cost storage systems.



Photograph: M. Martin

Hillside pits

Advantages	Disadvantages
<ul style="list-style-type: none"> • Suitable for long and short-term storage. • Reduced plastic costs per tonne of ensiled forage. • Can be used for self-feeding if the base of the pit is solid and dry, and can be scraped clean. • Good compaction, reducing losses. • Much lower risk of water entry compared to in-ground pits. 	<ul style="list-style-type: none"> • Usually low cost, but can be expensive to construct if rocks or loose soil are encountered. • Need constant attention if walls become unstable, can be a safety issue. • Earthen floors can become untrafficable in wet weather. • Risk of water infiltration if location is not well planned.

Hillside pits or bunkers

Hillside pits are constructed into the sides or tops of hills, or high embankments (see Plate 9.3), the surrounding earth providing the walls of the structure. In some cases the wall height or pit length can be extended using soil excavated from the pit.

Trench silos

Advantages	Disadvantages
<ul style="list-style-type: none"> • Can be constructed quickly and inexpensively, with little preparation. • Plastic costs are lower than for buns. • Can be used for long-term storage if covered with soil. • Shed rainwater well because they are higher than surrounding ground level. 	<ul style="list-style-type: none"> • Losses can be high. • The above ground wall portion is often unstable and may cave in. • The earthen floor is often not trafficable during wet weather. • Not suitable for long-term storage unless the plastic is protected from sunlight.

Trench silos

Trenches are usually a compromise construction between pits and above-ground walled bunkers, where the silage is stored partly above and partly below ground.

The trench silo is a popular method of storage, particularly for producers making silage for the first time. A low-cost, unlined silo can be made with a tractor and blade. It can be built as a temporary silo and lined at a later date. They are quick to construct and repairs are limited to smoothing the walls and base.

Trench silos can be formed with dirt carted from elsewhere and may require only one wall to be constructed, usually from soil.

If trenches are excavated to form relatively low banks (1-1.5 m), rolling a stack above this height must be done carefully. The soil moved from the trench is usually placed and rolled along the trench sides to form the walls.

Banks constructed from loose soil should be battered (sloped) to reduce the risk of collapse. A slope of 1:8 to 1:10 is desirable (i.e. 1 horizontal to 8-10 vertical). If the soil is very loose and it is not possible to build walls any steeper than 1:3, there are likely to be better storage options. Table 9.1 shows guidelines of preferred slopes for various silo constructions. Professional advice should be obtained for individual circumstances.

Table 9.1

Gradients of floors and walls in various silo constructions.

Structure	
Floor type:	Suggested slope (horizontal to vertical):
Earthen floor – mechanical feedout	50:1 to 60:1
Earthen floor – self-feeding feedout	Up to 30:1
Cement floor – mechanical feedout	80:1 to 100:1
Wall type:	Wall slope:
Earthen walls – dry clay	1:6 to 1:8
Earthen walls – loose soils	1:3 (consider a concrete wall)
Cement walls	1:8 to vertical

9.1.5

Stretchable bag system

The stretchable bag system (e.g. German Eberhardt® silopress, American Ag Bag®) is a temporary storage system (1-3 years) suitable for chopped, wilted forage (30-50% DM), maize silage (33-38% DM) or high-moisture grain (68-72% DM). Although mostly used for chopped forage, bags can be used for round bales if an alternative filling mechanism is adopted (see Plate 9.4 a & b and Section 9.5.1).

The heavyweight plastic bags are 2.44-3.64 m in diameter and 50-150 m long, with a range of storage capacities. The chopped forage is compacted as it is forced into the bag, which is then tied off. The level of storage loss with this system depends largely on the density and moisture level of the ensiled material and the amount of compaction developed by the machine. Rodents, particularly rats, can be a problem, chewing holes in the plastic near the ground and inhabiting the bags. Producers should implement some control measures if rodents are expected to be a problem.

Plate 9.4a



Stretchable bag system.

Photograph: K. Kerr

Plate 9.4b



The stretchable bag system is a convenient storage system for chopped or baled silage and requires no capital investment in storage facilities.

Photograph: K. Kerr

Stretchable Bag System

Advantages	Disadvantages
<ul style="list-style-type: none"> • Flexibility with storage siting. • Stronger plastic. • Relatively small exposed face at feeding • Ability to store different batches separately. • Can be used for chopped or baled fodder. 	<ul style="list-style-type: none"> • Specialised packing machine required; contractor probably needed. • Bags more expensive than other plastics. • Not suitable for long-term storage (>3 years).

Tower silos

Advantages

- Losses during storage are very low, particularly with sealed systems.
- Capable of storing a large quantity of material in a limited area.

Disadvantages

- Increased field and harvesting losses due to extended wilting; with direct cut crops, later harvest to achieve high DM may reduce forage quality.
- Expensive to construct and maintain.

Plate 9.5

Tower silo (Harvestore® System).



Photograph: M. Martin

9.1.6

Tower silos

Tower silos are permanent, above-ground structures constructed from metal (e.g. the Harvestore®, see Plate 9.5) or concrete (either concrete staves or poured on site). Although popular in the United States, very few have been built in Australia.

There are two main types of tower silos – those hermetically sealed by closing a filling hatch at the top and unsealed silos in which the surface of the silage is sealed with an impervious sheet.

Sealed silos have two-way relief valves in the roof to prevent a build-up or reduction in pressure that can occur with changes in ambient temperature. In some makes, the valve connects the atmosphere to a large bag in the roof so that any airflow to and from the silo is isolated from the silage.

Tower silos are built on concrete foundations. A drain should be provided on the inside, near the base of the wall, to prevent hydraulic (fluid) pressures developing. The drain outlet should be resealable to stop air entering the silo.

With the Harvestore® system, the forage must have a DM content of 45-55% DM, and is referred to as ‘Haylage’. Ensiling material below the recommended DM content increases the risk of fluid pressure developing and of structural damage to the tower.

Lower DM forages will produce more acid during fermentation. This can corrode the silo and feed out equipment. However, the likelihood of wastage in towers is less than in other types of silos, although well-compacted and sealed stacks can be nearly as efficient.

Section 9.2

Designing bunkers and pits

The design of bunkers and pits must ensure:

- ▶ sufficient slope to allow water and effluent to flow out of, off and away from the storage area;
- ▶ location of the structure to avoid water tables or seepage;
- ▶ location of the structure to avoid accessibility problems;
- ▶ structural soundness; and
- ▶ dimensions to match your feedout system.

Although these points are particularly relevant for ensiling chopped forage, many of the issues covered are pertinent for baled silage. Many also have relevance for portable clamp structures.

The following sections cover the basic principles that must be considered when designing bunkers and pits. Poor design has the potential to be expensive in the long-term (short life and high maintenance costs), difficult to use and dangerous. Potential problems can be avoided by seeking engineering advice before construction begins.

9.2.1

Location

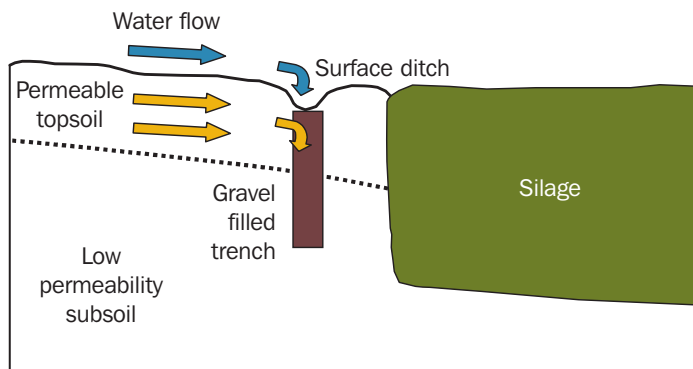
The site of the silage storage facility is important. Unlike a number of other silage systems, these structures are permanent and cannot be moved from season to season. The following factors need be considered when deciding on location:

- ▶ Distance and time to travel to and from the site during feedout will usually be greater than at harvest. The bunkers should be located close to where the silage will be fed out. Alternatively, if the silage will be fed at various places around the farm, the bunkers should either be at a convenient central location or at a number of sites. The latter is the only option if using a forage wagon to harvest.
- ▶ If silage odour is likely to become a problem to neighbours – particularly if sites are near towns and/or easily viewed by the public – consider siting the storage to minimise ‘smell drift’ disputes.
- ▶ Avoid low-lying areas, which may become flooded or difficult to reach in wet weather.
- ▶ Access must be easy for machinery and vehicles at harvest and feeding out. Fences around the storage area should be constructed to allow this.
- ▶ Locate away from streams and waterways to avoid any risk of silage effluent or runoff contamination (see Chapter 2, Section 2.1.1).
- ▶ Avoid overhead power and telephone lines and any below-ground obstacles such as water lines, gas pipes and fibre-optic cables. Also be aware of hazards such as steep slopes to/from the stack.
- ▶ Locate clear of trees.

- Avoid sites where soil water seepage will enter hillside pits or pits. If this is unavoidable, Figure 9.2 shows some options to limit water entry. Water can be intercepted and redirected away from the stack, often by a slotted corrugated plastic pipe. If water entry via the soil profile is not a problem, then a small earthen bank uphill from the stack will divert the surface water.

Figure 9.2

Side view of silage hillside bunker or pit, showing techniques to avoid water entry into the pit.



9.2.2

Dimensions and storage capacity

The dimensions of the bunkers and pits will affect feedout rate, the cost per tonne of silage and accessibility for machinery during storage and feedout.

- Aerobic spoilage will increase if the area of the bunker face is too large, resulting in an insufficient feedout rate (see Chapter 2, Section 2.5.3). The factors affecting feedout rate and calculations for determining pit dimensions for optimum rates are in Chapter 10, Section 10.2.1.
- Unnecessary costs result if the silage face is too small, the pit is too narrow or the walls are not high enough because of:
 - increased construction costs – longer walls;
 - increased sealing costs – plastic, labour to weight down the plastic;
 - increased wear and tear on equipment, pit floor, strain on the operator, and time taken to feedout because of the longer distance between the silage face and the feedout equipment;
- For chopped silage, the bunker must be at least 1.8 times the width of the tractor used to roll the silage to ensure the stack centre is compacted.
- A higher-walled bunker will ensure greater compaction of chopped silage, particularly at the base of the stack. It also reduces the cost of plastic and storage area required, and the amount of surface waste for each tonne of forage ensiled. However, if animals are to self-feed at the bunker, the silage should not be more than 1.5 times the height of the animals (see Chapter 10, Section 10.3.1).

Characteristic	Haycrop* silages (87 silos)		Maize silages (81 silos)	
	Average	Range	Average	Range
DM content (%)	42	24-67	34	25-46
Wet density (kg/m ³)	590	210-980	690	370-960
DM density(kg/m ³)	237	106-434	232	125-378
Average particle size (mm)	11.7	6.9-31.2	10.9	7.1-17.3

* Most hay crops were lucerne crops.

Table 9.2

Dry matter contents and densities of maize and haycrop silages in Wisconsin, United States.

Source: Muck and Holmes (1999)

Estimating storage capacity

Calculation of the silage storage capacity is sometimes necessary to:

- ▶ estimate available stored silage reserves; and
- ▶ determine the dimensions needed to store the required amount of silage.

In a well-compacted pit or bunker, silage density should exceed 225 kg DM/cubic metre, but can be extremely variable (see Table 9.2).

The DM content and chop length of the silage and the effectiveness of rolling (compaction) must be taken into account when estimating the density of silage in storage, after settling. Silage depth is also a consideration. Density will be greatest at the bottom of the silo.

The calculation is sometimes based on the amount of silage stored on a fresh weight basis. This is then calculated back to quantity of stored DM. Table 9.3 gives the storage capacity for bunkers or pits with different dimensions, where the silage has a density of 650 kg fresh silage per cubic metre. An equation that can be used to calculate the density of fresh silage is in Chapter 8, Section 8.3.1.

Average silo width (m)	Silo depth (m)		
	2	2.5	3
3	3.9	4.9	5.9
4	5.2	6.5	7.8
5	6.5	8.1	9.8
6	7.8	9.8	11.7
7	9.1	11.4	13.7
8	10.4	13.0	15.6
9	11.7	14.6	17.6
10	13.0	16.3	19.5

Table 9.3

Silo capacity (tonnes/linear m) at 650 kg fresh silage/m³.

9.2.3

Construction

There are a number of points to consider when constructing walled silage bunkers or pits:

- ▶ The floor should slope towards the open end (or ends) to allow rainfall or effluent to drain away. The recommended slope for various floor types is given in Table 9.1.
- ▶ Concreting the floor will provide all-weather access, and reduce contamination of the silage with mud. The concrete should be strong enough to cope with the weight of machinery and silage. A cement apron at the end of the storage area, upon which chopped forage can be dumped prior to spreading, will reduce contamination with soil and mud.
- ▶ Sloping the walls so that the width at the base of the pit or bunker is narrower than at the top will:
 - allow easier consolidation of the forage at the edges;
 - ensures that as the silage settles, contact with the walls is maintained;
 - increases compaction of the silage at the base of the pit.

Table 9.1 gives recommended wall slopes.

- ▶ It is advisable to have safety rails along the tops of portable clamps and bunkers to avoid tractor wheels dropping off the stack edge.

There are a number of materials and construction methods used for building above ground bunkers. Walls can be constructed of various materials – they can be earthen, or made from concrete, steel mesh, thick plywood or sleepers on their edge. The wall can be reinforced or supported by posts made of metal or timber. Some materials, such as mesh, are porous and need to be lined with plastic sheet to obtain an airtight seal. Others may need sealing to protect them from corrosion by silage acids. Construction details will not be discussed in this publication.

It is recommended that anyone intending to build such structures seek engineering advice. It is important that the correct materials be used – strength and resistance to silage acids must be considered. The design of the structure must ensure that the base and walls are able to withstand the pressure of the compacted silage and the machinery operating during silage making and feedout.

Construction of several smaller pits rather than one large and/or long pit can increase the flexibility of silage storage substantially:

- ▶ different forages can be separated, e.g. maize and lucerne silage;
- ▶ forages of different quality can be stored separately, e.g. early versus late cut pasture;
- ▶ avoids the need to reseal large pits or bunkers if only feeding for a short time;
- ▶ can feed animals with different feed requirements from different silages.

Plate 9.6

Guard rails are strongly recommended on the walls of above-ground bunkers and portable clamps to reduce the risk of tractors slipping over the edge of the wall when rolling silage.

Photograph: R. Morris



Section 9.3

Filling and compacting silage in bunkers, pits and buns

Filling and compaction should be continuous throughout the silage-making period (not more than three days for each storage unit).

At the end of each day's harvesting, cover the stack with a lightly weighted plastic seal to limit respiration losses.

- ▶ Begin filling against the back wall of a pit or one-ended bunker. In the case of open-ended bunkers and buns, filling can be from one end or spread along the area if using a forage wagon which unloads as it travels. Figures 9.3, 9.4 and 9.5 show three alternative methods of filling – two variations on the progressive or Dorset wedge and the top-up method.
- ▶ If the forage is too dry and difficult to compact, alternate with loads of freshly cut or partially wilted forage.
- ▶ Evenly spread each load to <30 cm thick – tractor wheels will have minimal compression effect below this depth.
- ▶ Compaction will be less effective if the chopped forage is delivered to the bunker at a high rate. Under these circumstances, the forage should be spread more thinly (15 cm) to improve compaction. Rolling with a heavy-wheeled tractor (preferably 4WD) achieves better compaction than tracked vehicles, although they are satisfactory if very heavy. Roll slowly to allow the tractor weight to compress the forage. Continue rolling after the last load is delivered until there is little impression left by the tractor wheels.

The version of the progressive or Dorset wedge shown Figure 9.3 is the preferred technique, having shown slightly lower losses than the other two systems (see Figures 9.4 and 9.5).

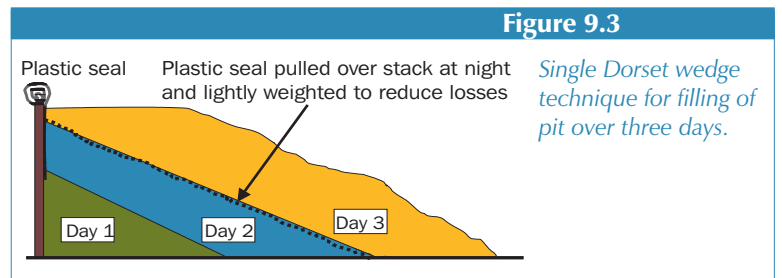


Figure 9.3

Single Dorset wedge technique for filling of pit over three days.

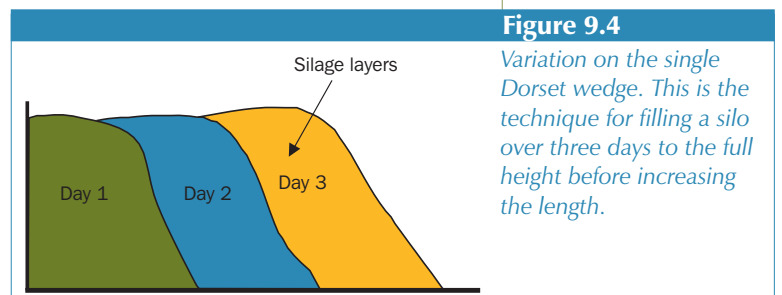


Figure 9.4

Variation on the single Dorset wedge. This is the technique for filling a silo over three days to the full height before increasing the length.

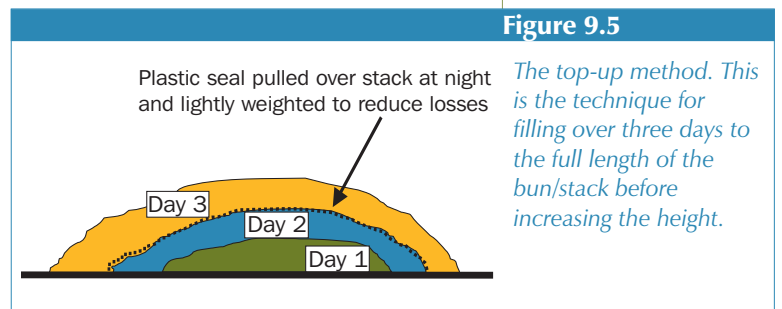


Figure 9.5

The top-up method. This is the technique for filling over three days to the full length of the bun/stack before increasing the height.

With walled bunkers and pits, when reversing the tractor, run the front wheel along the wall to compact the edges. Be careful not to scrape the wall, which may damage the wheel and plastic sheeting (see Figure 9.6).

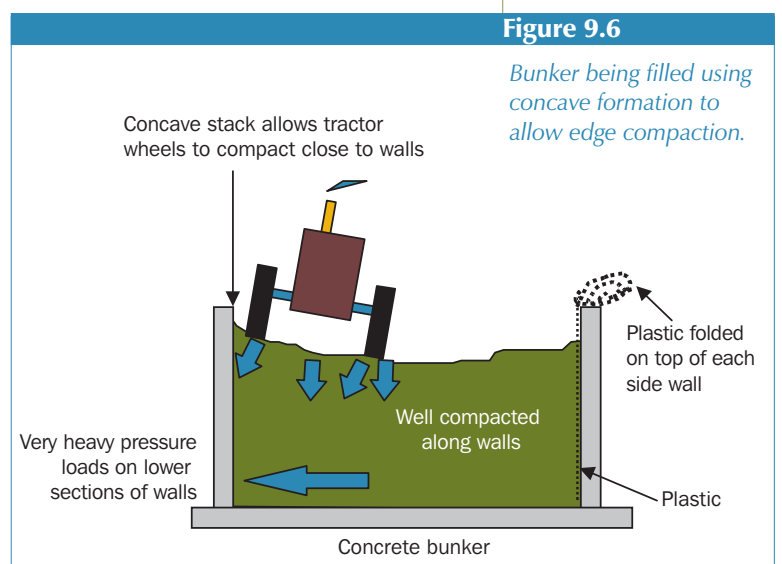


Figure 9.6

Bunker being filled using concave formation to allow edge compaction.

Section 9.4

Sealing bunkers, pits and buns

Effective sealing is critical to ensure the silage is successfully preserved and to minimise storage losses.

The following management procedures will ensure an airtight seal:

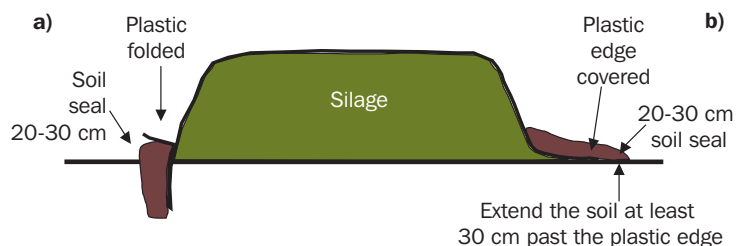
- ▶ Seal as soon as filling and compaction is completed, using plastic specifically manufactured for silage making (see Section 9.7). Overlap any joins by 50 cm and seal them with plastic adhesive tape specifically designed for silage sheeting. The plastic must be clean, dry, not hot, and allowed shrink after cutting for the tape to work effectively. Alternatively, overlap by 1 m and lay tyres or sandbags along the joins.
- If sealing is not possible on the day the

stack is filled, cover with plastic and tyres overnight. Seal the next morning, but do not remove the plastic to re-roll the stack. Delayed sealing increases losses (see Chapter 2, Section 2.2.1).

- ▶ When filling, ensure the surface of the silage has enough slope to allow water to flow off the surface. Avoid forming hollows on the surface, particularly against the walls.
- ▶ Because silage settles during storage, it sinks below its original height, often leaving a depression. If the stack is not well-sealed, moisture may seep through into the silage. Avoid filling walled bunkers above the wall height – this is dangerous and should not be attempted. If pits are covered with soil, this can be mounded up to increase height above ground level, and shaped to assist water run-off.
- ▶ Burying the edges of the plastic in the ground is the most effective way to seal silage buns and pits. Covering the ends with 20-30 cm of soil can create a satisfactory seal (see Figure 9.7). Do not use sand as it is porous and will allow air to enter the silage. For long-term storage, cover the stack with at least 30 cm of soil if the forage is covered with plastic or 50 cm if there is

Figure 9.7

Cross-section of buns showing airtight sealing techniques. Covering the plastic with soil (b) can be unreliable. The seal will not be effective if insufficient soil depth or a porous soil is used.

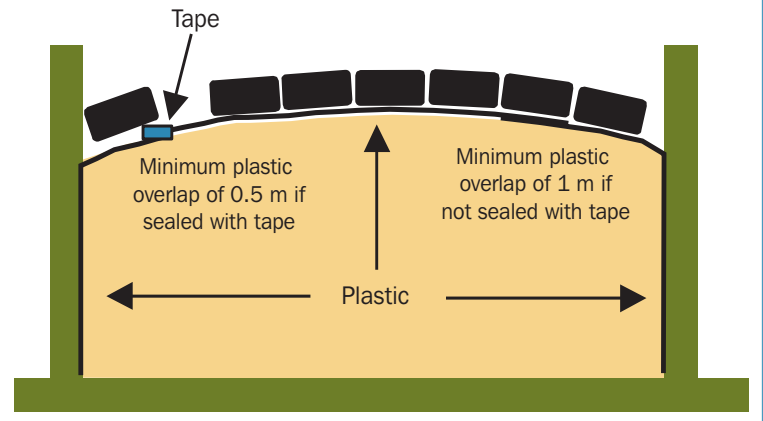


no plastic covering. Increase the depth of coverage for sandy soils or cracking clays. Note that a plastic cover is the recommended option (see Section 9.1.4).

- ▶ With walled bunkers, it is necessary to lay a shoulder sheet of plastic along the wall. This should extend down towards the floor of the silo to improve sealing. This plastic is then folded back onto the bunker and covered with a second sheet weighed down with, for example, tyres or sandbags (see Figure 9.8).
- ▶ There are various ways to seal a bunker with plastic. The final way the plastic is laid out will depend on the width of the silo and the width of the plastic sheeting. Figure 9.8 shows one method, with and without tape.
- ▶ The plastic should be weighed down well, usually with tyres and/or soil.
- ▶ In the past, several alternatives to plastic have been used to seal silage. These include mashed potato, citrus pulp and other by-products, freshly cut wet pasture or weeds, and products such as lime or cement. None of these is recommended because the integrity of the seal cannot be guaranteed, and some may have animal health implications. Plastic seals are recommended and are economical (see Section 9.7).

Figure 9.8

Examples of methods that can be used to seal a bunker. Joining plastic sheets with tape is the preferred option.



Maintenance

Fence off stacks to exclude stock. Single wire electric fencing is often not reliable.

Regularly check for holes in the plastic seal, and repair as soon as they are noticed, using tape specifically manufactured for silage sheets (see Section 9.7).

Where a layer of soil is used, regularly check that burrowing animals have not disturbed the soil seal.

Section 9.5

Storage systems for baled silage

Various systems have been developed to store forage in round and large square bales as silage (see Figure 9.1). Bales can be stored in groups under sheets of plastic, in stretchable bags or wrapped in sausage rows using stretchwrap plastic, or individually in stretchwrap plastic, or in double bale plastic bags.

9.5.1

Bulk storage above-ground

Round bales in stacks

Round baled silage can be stored on their curved sides, under sheets of polythene plastic, in single (see Figure 9.9) or double (see Figure 9.10) rows/sausages, or as triple rows, sometimes referred to as pyramid stacks (see Figure 9.11).

Because it is difficult to effectively reseal bale stacks, careful planning is essential to minimise feedout losses.

- ▶ Minimise aerobic spoilage losses at feedout by storing only enough bales in each stack, or compartment, for 7-10 days' feeding.
- ▶ Use soil or bury plastic to form airtight seals. Don't use sand or cracking clays.

Figure 9.9

Single row or sausage storage system.

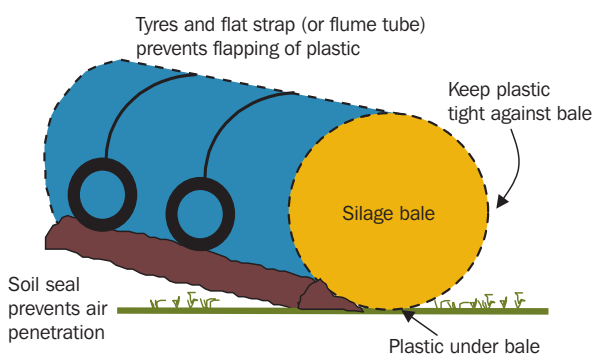


Figure 9.11

Triple row or sausage storage system.

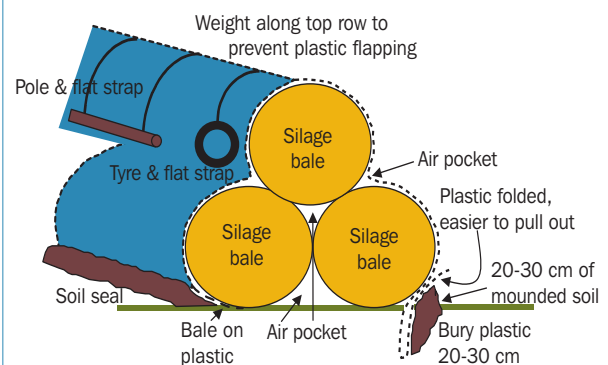


Figure 9.10

Double row or sausage storage system.

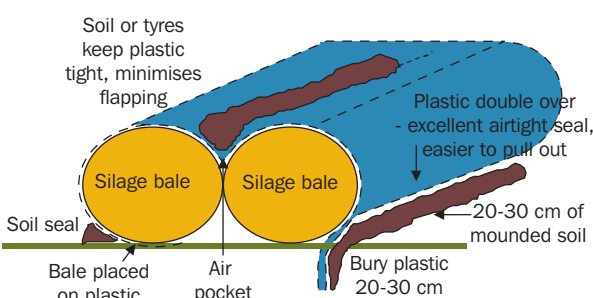
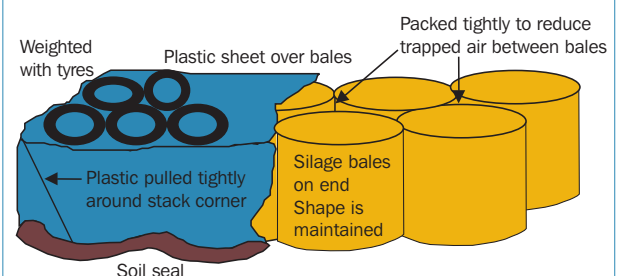


Figure 9.12

Stacks of round bales on their ends.



- For double rows, place soil or tyres between the rows before sealing to maintain plastic contact with bales.
- For triple rows, connect tyres on either side of the stack with wide straps to prevent plastic flapping and tearing.
- Immediately patch any holes with the correct tape. If possible, extract air from stack before patching to reduce amount of aerobic deterioration.

Round bales stored on their ends retain their shape and are easier to feed out (see Figure 9.12). They can be stacked 1-2 rows high depending on the DM content at baling:

- <30% DM (baled too wet), 1 row only
- >35% DM, 2 rows high.

Square bales in stacks

The shape of square bales makes them ideal for storing in stacks covered with plastic.

- Aerobic spoilage losses at feedout can be minimised by storing only enough bales in each stack, or compartment, for 2-3 weeks feeding (see Plate 9.7 a & b).
- Square bales can be stored two or three rows high (see Plate 9.7 a & b). The width of the stack (number of bales wide) is limited by the width of the plastic, as well as the anticipated rate of feedout (see Chapter 10, Section 10.2.1).
- Stack the bales starting at one corner, keeping the line of bales straight on one side. Because bales vary slightly in their width, it is difficult to not to leave gaps between the bales and the plastic. Keeping the stack straight, so there is a flat surface on one side, reduces the amount of air trapped at sealing, and the movement of air down the stack when it is opened.

Plate 9.7a

Individual stacks of big bale silage.

Photograph: M. Martin



Plate 9.7b

Dividing a large stack into several small compartments is an alternative to making several smaller stacks. The internal sealing reduces feedout losses, there is less area covered and less perimeter to maintain.

Photograph: D. Stanley



Bulk storage of bales

Advantages

- Less expensive than individually wrapped or bagged bales.
- Does not require additional operator or equipment for wrapping.
- Plastic sheeting used is more durable than plastic wrap, providing a storage life of up to 2-3 years.

Disadvantages

- Losses can be high with round bales because of trapped air between and around the bales.
- The whole stack will begin to deteriorate after opening.
- Any small tear in the plastic will cause the whole stack to deteriorate.
- Not suitable for long-term storage (>2-3 years) unless the plastic is protected from sunlight.

Stretchable bag system

Round and large square bales can be stored in plastic tubes (see Plate 9.8) as for chopped silage (see Section 9.1.5).

- ▶ Bales must be similar in size to minimise pockets of trapped air.
- ▶ Bags should last 2-3 years, if handled carefully and not damaged.
- ▶ Storage losses are low (see Section 9.8).
- ▶ Length varies from 30-45 m and diameters range from 1.2-1.5 m. They hold between 23 and 35 bales. These can be stretched approximately 15% oversize and then allowed to shrink back onto the bale.

Stretchwrapped bales – in a line

Round and square bales may be wrapped in line as an alternative to individual wrapping. This saves about 40% in plastic compared to individual wrapping.

- ▶ Bales are laid end to end. End bales act as a ‘plug’ to stop air entry and must be well sealed.
- ▶ Bales should have consistent diameters to avoid air being trapped between large and small diameter bales. Overstretching the plastic can be a problem when bales are of different diameters.
- ▶ Square bales are usually stacked two high before wrapping.
- ▶ Plastic is wrapped with 75% overlap at 55% stretch.
- ▶ Bales must be covered with at least 4 layers of plastic.
- ▶ Storage life is limited to about 12 months after which time the plastic begins to deteriorate. Covering the line of wrapped bales with an extra sheet of plastic will increase storage life.
- ▶ The line of bales can be divided into segments by placing an individually wrapped bale or sheet of plastic along the row. This will act as a secondary seal if feeding out stops before stack is completely used.

Plate 9.8

Bales can be stored in stretchable (multi-bale) bags or socks.

Photograph: M. Martin



9.5.2

Individual above-ground bale storage

Single bales

Round and square bales can be individually stored in stretchwrap plastic. This is an expensive form of conservation because of high plastic and wrapping cost. However, many producers find the individual bales convenient to handle, although a storage life of only 12 months can be expected.

Individually wrapped bales are susceptible to air penetration, resulting in losses of DM and quality. This is because the surface area to volume is large – about half the silage volume is within 12 cm of the plastic film. All silage is within about 60 cm from the covering plastic.

- ▶ Forage stored in bales should be in the 35-50% DM range. Bales that are too wet are at risk of poor fermentation and greater DM losses, highlighted by the Australian data in Table 9.4.
- ▶ Wrap the bales as soon as possible after baling. The guidelines in Table 9.5 show the maximum number of hours recommended between wrapping and baling at various temperatures. The higher the temperature, the greater the respiration losses from the baled forage.
- ▶ Bales must be tight and of even shape. Plastic application follows the bale contour more effectively on convex

Temperature (°C)	Period after baling (hrs)
30	0-1
20	2
15	3

Maximum delay (hours) recommended between baling and wrapping for a range of temperatures.

shaped bales. Air is more easily trapped in concave shaped bales. Loose bales, conical shaped bales and uneven bales are very difficult to wrap, and will not have four layers of plastic all over without extra revolutions of the wrapper.

- ▶ Ensure the plastic wrap contains sufficient UV stabiliser (see Section 9.7). Be wary of cheap plastic that may not contain sufficient UV stabilisers for use under Australian conditions.
- ▶ It is preferable to wrap the bales at the storage site to reduce risk of damage to the plastic and movement of the plastic layers during transport. If wrapped in the paddock, bales should be moved immediately after wrapping, taking care to minimise damage to the plastic. Check bales carefully at the storage site and repair any holes with appropriate silage tape.
- ▶ Wrap bales using the 2+2 system, with 50% overlap (see Figure 9.13), ensuring there is a minimum covering of four layers of plastic over the entire bale. A 2+2 system with less than 50% overlap results in areas of the bales with only two to three layers, allowing air to enter

	Bagged bales		Wrapped bales	
	Low DM (28.6% DM)	High DM (49.2% DM)	Low DM (31.7% DM)	High DM (44.6% DM)
Fresh weight at baling	686	514	686	540
DM weight at baling	193	249	210	240
DM weight after 4 mths	149	197	185	238
Total DM loss (kg DM)*	44	52	25	2
Total DM loss (%)	23	21	12	1

Weights and losses from bagged and wrapped round bales of low and high DM.

Source: Adapted from Hadero-Ertiro (1987)

Individual above-ground bale storage

Advantages	Disadvantages
<ul style="list-style-type: none"> • Flexible system suitable for small batches of silage. • No construction costs for storage. • Flexibility in locating storage site. • Existing hay equipment may be used. • Easy to monitor silage stocks/supply. • Convenient to handle and feed out. • A saleable commodity. 	<ul style="list-style-type: none"> • Not suitable for all crop types. • High cost/t DM (wrapping and plastic). • More susceptible to damage if handled after wrapping. • More susceptible to bird and vermin damage. • Short-term storage only (12 months). • Feedout costs are high if handling large quantities. • Plastic disposal is an issue.

Example

If 7 turns are needed to cover a 1.2 m x 1.2 m bale with one layer of a 750 mm wide film, then $(7 + 1) \times 2 = 16$ rotations is required to apply 4 layers.

the bale and resulting in aerobic spoilage, DM and nutrient loss (see Figure 9.14 and Section 9.8.2). Use six layers if the silage is being stored for more than 12 months or it is made from crops that are stalky.

- ▶ To ensure four layers on all parts of the bale, record the number of rotations of

the turntable to cover all visible forage. At this stage, all except the last section of the bale will have two layers of cover. Add one more rotation to give a complete two layer cover. Double this number to apply four layers, and triple it for six layers, see example at left.

See Table 9.6 for recommended rotations required to apply four layers to 1.2 m x 1.2 m bales of consistent diameter and the likely numbers of bales covered per roll of film for a range of film sizes.

- ▶ Check that the pre-stretcher is working correctly, mark a fixed length, e.g. a match box, on the plastic roll before it passes through the pre-stretcher. Once the plastic film is applied to the bale the length should now be about 1.5 matchbox lengths, about 55% stretch.

Figure 9.13

Bale correctly wrapped.

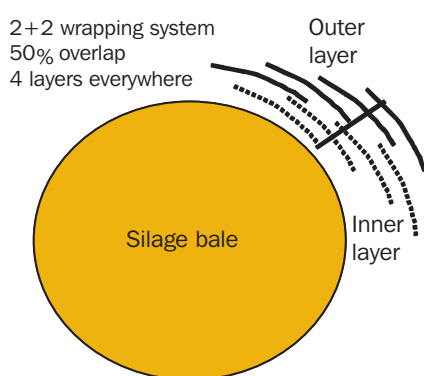


Figure 9.14

Bale incorrectly wrapped.

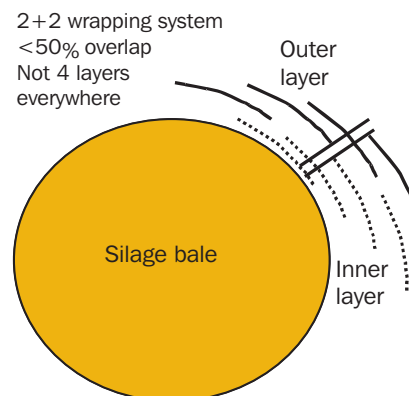


Table 9.6

Number of rotations to apply 4 layers and number of bales (1.2 m x 1.2 m) wrapped from a range of plastic sizes at 55% stretch.

Stretchwrap plastic roll size – width (mm) x length (m)	Approx. number of rotations to apply 4 layers	Approx. number of bales wrapped/roll
480 mm x 3,100 m*	24	Up to 34
500 mm x 1,500 m	24	17-18
500 mm x 1,800 m	24	21-23
600 mm x 1,500 m	20	20-22
600 mm x 1,800 m	20	25-27
730 mm x 3,100 m*	16	Up to 54
750 mm x 1,500 m	16	27-30
750 mm x 1,800 m	16	32-35

* Pre-stretched plastic film – gearing of the wrapper will need to be altered.

- ▶ Spikes should not be used to transport wrapped bales. It is very difficult to repair damage and prevent air penetration.
- ▶ Store round bales on the flat surface. This increases the number of layers of wrap exposed to the direct sun, and any sharp grass or twigs on the ground.

Double bagged bales

Single bale, heavy gauge (150 micron thick) black plastic bags were originally used for bale storage. These were then replaced by double bale-sized bags to reduce storage costs.

- ▶ The first bale is usually spiked in the centre then placed at the back of the bag at the storage site. The second bale is positioned in front of the first bale.
- ▶ The bales must be of uniform size and fit snugly into the bag.
- ▶ The neck of the bale is twisted as tightly as possible and tied off. The neck is then doubled over and retied to ensure that air cannot enter the bag. Gases during early fermentation will expand the bag, but will dissipate over time. Do not puncture the bag and check for burst gussets in the corners. A small hole or poorly tied neck can result in large losses.

Bagged bale systems have been superseded by wrapping because the former system is slow, labour intensive and expensive, and losses are greater.

9.5.3

Bales stored in pits

Unwrapped round and square bales may be stored in pits or hillside bunkers. Round bales are usually of lower density and create much larger air pockets than large square bales when stored in pits. This means there is much greater risk of aerobic spoilage if the plastic seal is damaged during storage and on opening for feeding. The risk of losses can be reduced by storing the bales in compartments of 7-10 days feed supply, with plastic sheets separating each group.

Round bales will lose their shape and the feedout machinery may have difficulty handling them.

Large square bales are well suited to storage in pits, although compartments, containing enough feed for 2-3 weeks, are also recommended (see Plate 9.7b). The larger compartment size, compared to that recommended for round bales, is possible because the square bales trap considerably less air, so reducing the risk of spoilage.

After the bales are covered with plastic, placing soil over the top and particularly down the sides of the pit, will improve the seal. Figures 9.15 and 9.16 show cross-sections of bales stored in an earthen pit.

Figure 9.15

End section of round bales in a pit.

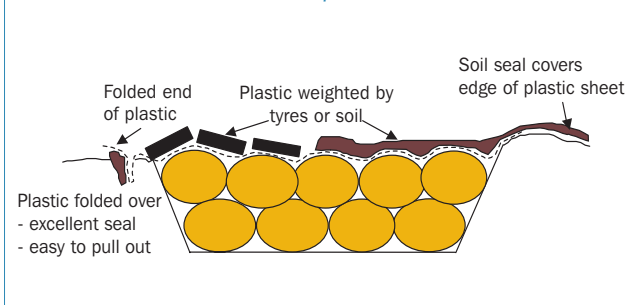
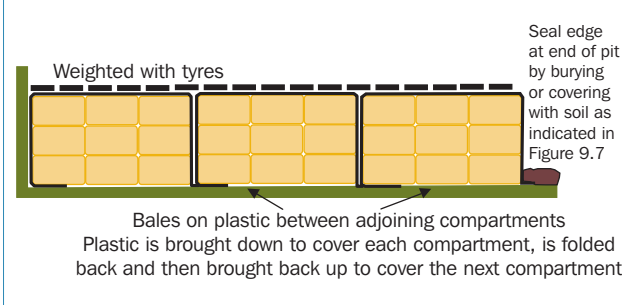


Figure 9.16

Side section of round/square bales in a pit.



Section 9.6

Location and maintenance of stored bales

A number of the issues raised in Section 9.2.1 regarding the location of pits, bunkers and buns, particularly issues of accessibility, are relevant to baled silage. Additional measures and precautions need to be taken because bales are more prone to damage from birds, rodents, foxes and livestock. Bales wrapped with thin stretchwrap plastic are even more at risk than bale stacks.

Some techniques to minimise these problems are:

- ▶ Because freshly harvested paddocks attract birds, move bales as soon as possible.

- ▶ Do not store bales under or near tree lines as they are likely to suffer damage from falling branches and birds sheltering in the trees.
- ▶ Stack bales well clear of fencing, including the permanent fence line.
- ▶ Construct solid fences in preference to single-wire electric fences, which are often unreliable. If electric fences are used, check them regularly.
- ▶ Place rodent bait in area surrounding bales, preferably not between bales as the baits are an attractant. A plastic, claimed to contain a pest repellent, was introduced onto the Australian market in 2001.
- ▶ Maintain a vegetation-free area around the site to remove cover for rodents.
- ▶ Irish research has shown that bales painted with an eye design (about 10 cm wide) suffered 70-80% less damage from birds compared to light netting stretched over tyres on top of bales, or monofilament lines at 1 m spacings and 1 m above the bales.
- ▶ Monofilament lines spaced about 0.5 m above bales and at 0.5 m spacings also greatly reduced bird damage. This spacing tends to make landing and ‘taking off’ very difficult for the birds.
- ▶ ‘Humming wires’ (plastic tape), used in orchards, set up in a diamond pattern across tops of bales catch wind from any direction (see Plate 9.9a).
- ▶ Tying silver foil or light plastic bags to single strings/wires above the row of bales.
- ▶ Tyres on bales can ‘scare’ some birds, who fear predators may be hidden in them.
- ▶ Similarly an artificial cat placed on bales can act as a deterrent to birds.
- ▶ Cover the bales with some form of netting.

Plate 9.9a

Humming wire deters birds from bales.

Photograph: F. Mickan



Plate 9.9b

Store bales well clear of fence lines to avoid damage from livestock. These bales are too close to the trees in the background, which may increase the risk of bird damage.

Photograph: F. Mickan



Section 9.7

Plastics used for silage

Plastics used for silage come in thick sheet form, stretchwrap (cling wrap, shrink wrap) form, in short or long bags, or as an open-ended plastic tube. The latter is also stretchable, to a small degree, and shrinks back onto the bales.

Plastic tape specifically developed for patching holes and punctures in sheet and stretchwrap plastic is also considered briefly here.

9.7.1

Plastic sheeting

Plastic sheeting used for sealing silage is made from Low Density Polyethylene (LDPE), should contain UV stabiliser and be strong enough to prevent most puncturing and last several years. The plastics currently used are designed specifically for silage and are 150-200 microns thick.

Silage plastic should be made from ‘virgin’ polyethylene. Recycled plastics can have very small holes, due to impurities, that allow more air to penetrate.

Although plastic sheets were traditionally black most are now laminated (two sheets joined together) – white on one side and black on the other. Laminated plastic is much stronger than traditional black plastics of the same thickness. The white side faces the sun to reflect heat, reducing heat load and heat damage to silage at the surface.

Bird damage to the laminated plastics is claimed to be reduced because they do not like landing on the bright surface. Black plastic is more susceptible to bird damage because it ‘softens’ on hot days and, when a bird lands on it, is more easily punctured.

Although plastic sheets can be used for several years, it rarely lasts that long. The plastic is usually torn or punctured by machinery, animals or vermin before it deteriorates. Some farmers use old plastic to cover the new plastic, to extend the life of the new sheet to 5-7 years.

Builder’s plastic should not be used on silage unless it is covered with at least 30 cm of soil. It is made from lower-quality plastic (often recycled) and will allow some transfer of air through to the silage. It will break down quickly when exposed to sunlight.

9.7.2

Stretchwrap plastic film

Stretchwrap plastic films are made from either a Low Density Polyethylene (LDPE) or a Linear Low Density Polyethylene (LLDPE) polymer or a mix of the two. Most films contain UV light inhibitor or stabiliser, colour and some form of 'tackifier.' The tackifier ensures that the layers of film 'stick' together after being applied to the bale, producing a relatively impermeable barrier to air when four layers are applied.

Most manufacturers guarantee the stretchwrap film for 12 months of silage storage. If the following points are observed, it is reasonable to expect a 12-month storage life for individually wrapped bales under Australian conditions.

High temperatures will affect the plastic's stretchability and thickness, becoming thinner as the temperature rises. The thinner the plastic, the greater the air penetration. Plastic rolls should be kept in cool locations during hot weather to avoid this problem.

- ▶ Store stretchwrap plastic rolls in shade until required.
- ▶ Avoid damaging film by allowing it to roll around in vehicles and on gravel. Avoid damage to the edges of the roll.
- ▶ Do not allow the cardboard centre roll to become wet as it may collapse.
- ▶ Light-coloured plastics tend to reflect more heat than black plastics.
- ▶ Repair holes immediately, with tape specified for silage plastic.
- ▶ Films usually have a batch number, which should be recorded in case there are quality problems.

Although stretchwrap film is 25 micron thick, it undergoes a 55% 'stretch' after it passes through a geared pre-stretcher, resulting in less than a total of 100 micron thickness for four layers. Earlier machines were set at 70% stretch. This is suitable for European conditions but is too much for Australian conditions.

After passing through the pre-stretcher mechanism the plastic will reduce in width ('neck down'), before being applied to the bale. If the film has been correctly stretched, the width of a 500 mm wide film should measure about 400 mm when measured on the flat end of the bale. A 750 mm wide film should measure about 600 mm. However, film quality, temperature and pre-stretcher unit type can all affect the final amount of 'stretch' or 'necking down'.

Stretchwrap film comes in a range of colours from white, black, grey, beige, brown and various shades of green. Some companies, using multi-layers (laminated), have produced films with a black interior but lighter colour exterior. Preferences vary widely between farmers and contractors and between regions. Film colour also has an impact on the heat generated within the wrapped bale (see Section 9.8.2).

It is important to recognise that film colour, apart from temperature effects of the darker films, is a much less important issue than the film quality. Films produced in Australia, which did not contain enough UV inhibitor, broke down within months in the field. Also some films are 'dumped' or offloaded in Australia from European countries at the end of their silage season. Some of these originate from countries requiring little or no UV inhibitor. Producers should ensure that the plastics they buy are guaranteed for use under Australian conditions.

9.7.3***Silage tapes***

To minimise losses due to air penetrating the stack or bale:

- ▶ Use tape to seal joins of plastic sheeting when sealing bunkers and stacks.
- ▶ Seal any holes in the plastic as soon as they are noticed.
- ▶ Use only tape specifically manufactured for plastic sheeting or stretchwrap film. Before applying the patch ensure that the plastic is clean, dry, not hot and allow the patch to shrink after cutting to size.
- ▶ Inferior quality tapes (e.g. duct tape) may seal well initially, but cannot be guaranteed to withstand exposure to weather and sunlight. After a period of time, most will either fall off or disintegrate.

Section 9.8

Storage losses

During storage, loss of silage DM and quality can result from:

- Effluent production (avoidable).
- Respiration (unavoidable, but manageable). Prolonged respiration results in excessive heating and will reduce silage quality.
- Fermentation (unavoidable, but affected by management e.g. wilting).
- Aerobic spoilage (avoidable with good management) can account for significant losses if compaction is inadequate or if the airtight seal is damaged and air is allowed to penetrate the silo.

The extent of losses will vary with management, forage type and DM content. Some indicative levels of storage losses are given in Chapter 2, Section 2.5.2.

9.8.1

Effluent

The principles and magnitude of effluent losses are covered in Chapter 2 (Sections 2.1.1 and 2.5.2), and wilting strategies to avoid effluent production are discussed in Chapter 6.

Chopped silages tend to produce more effluent than baled silages at any given DM content because:

- fine chopping causes more damage to the plant cell, increasing the release of fluids; and
- low DM, chopped silages are more densely compacted than most bales.

In the case of wrapped or bagged bales the effluent is trapped and pools towards the base of the bale. The result is often a dark, slimy layer which may have undergone a clostridial fermentation (see Chapter 2, Section 2.2.2).

9.8.2

Respiration and aerobic spoilage

Some respiration occurs in all silages during filling or immediately after baling, and continues after sealing, while oxygen and WSCs are available (see Chapter 2, Section 2.2.1). DM and quality is lost during the respiration process (see Table 9.11). Respiration should be kept to a minimum by:

- ▶ rapid filling and efficient compaction of pits and bunkers;
- ▶ sealing of pits and bunkers immediately filling is completed; and
- ▶ wrapping bales soon after baling, with sufficient, good quality plastic.

Poor quality fermentation can occur if a significant proportion of the WSCs are lost during respiration. Forages with a low WSC content are most susceptible to poor fermentation and this problem is exacerbated by delayed sealing (see Table 9.11 and Section 9.8.3).

A prolonged aerobic respiration phase at the start of the ensiling process, due to poor compaction or sealing, allows the growth of aerobic micro-organisms including moulds, which results in visible spoilage and waste. Although moulds are more often found on the surface of the bunker or bale, they can occur in pockets throughout poorly compacted silage. These mould patches may be toxic, and are unpalatable and of almost no nutritional value (see Chapter 2, Section 2.3.4). Establishing an airtight seal quickly, and

maintaining it during storage, is essential if aerobic spoilage losses are to be minimised.

The Appendices to this Chapter show likely patterns of storage losses, the possible problems and their solutions.

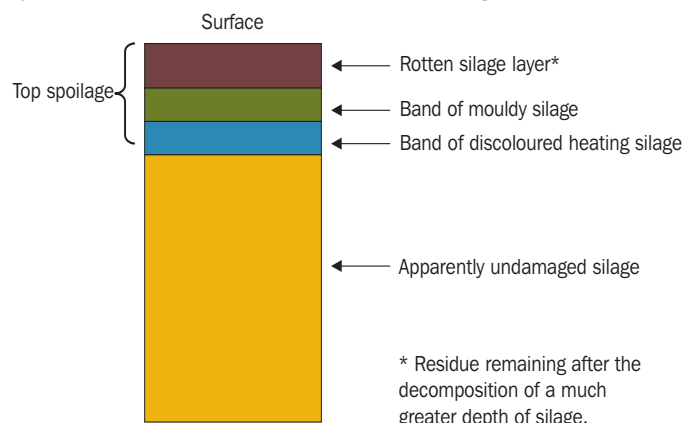
Appendix 9.A1 contains patterns relevant to pit or bunker storages and Appendix 9.A2 contains those for baled silages.

Losses in pit and bunker silage

Storage losses are minimal with good management – rapid filling, and effective compaction and sealing. However, some producers do not seal pits and bunkers of chopped silage, in the belief that the stack will seal itself, that losses are minimal, and that the cost and inconvenience of using plastic is not justified. The levels of waste may appear small because the bands of discoloured and mouldy silage are often not very thick (see Figure 9.17). However, these bands are all that remains of what was a much greater thickness of forage that is gradually decaying (see Table 9.7

Figure 9.17

Layers observed near the surface of unsealed silage.



Source: Kaiser (1997)

Table 9.7

Depth from original surface (cm)	Lucerne DM losses (%)		Maize DM losses (%)	
	Covered	Uncovered	Covered	Uncovered
25	7	78	23	80
50	2	23	9	29
75	6	15	12	19

Effect of sealing treatment and depth from original surface on DM losses for farm-scale lucerne and maize silage.

Source: Adapted from Bolsen et al. (1993)

Table 9.8

Cattle production from wilted lucerne silages stored with and without covering.

	Covered	Uncovered
Wilted to 34% DM¹		
Liveweight gain (kg/day)	0.30	0.12
Feed efficiency (kg liveweight gain /t silage DM)	60	25
OMD% in sheep	60.3	58.2
Wilted to 43% DM¹		
Liveweight gain (kg/day)	0.39	0.29
Feed efficiency (kg liveweight gain /t silage DM)	69	61
OMD% in sheep	60.1	57.4
Wilted to 44% DM²		
Liveweight gain (kg/day)	0.64	0.57
Feed efficiency (kg liveweight gain /t silage DM)	91	84

Sources:
¹ McGuffey and Owens (1979);
² Oelberg et al. (1983)

When quality decline and loss of physical DM in poorly stored silages are considered, they not only represent a significant loss of potential animal production, but also an increase in the cost per tonne of silage fed.

and Figure 9.18). The silage in the discoloured layer has also lost significant quality, even though there is no visible sign of mould.

In a study on 15 dairy farms in Gippsland, Victoria, the losses in DM for unsealed and sealed pits were measured at 15-30 cm and 1 m below the surface of the stack. Losses were greater at both depths for the unsealed silage (see Figure 9.18). Although not determined in this study, other studies have shown that associated with an increased loss of DM is an increased loss in digestibility of the silage deeper in the stack, and therefore animal production (see Table 9.8). Losses, as a proportion of ensiled forage, decline with increasing depth of the silage.

Where cattle production was compared on

covered and uncovered silage, growth rates were low for the covered silage and lower on the uncovered silage. A similar study using high-quality silages, capable of supporting gains of 0.8-1.0 kg/day, would probably have shown a greater loss of potential animal production.

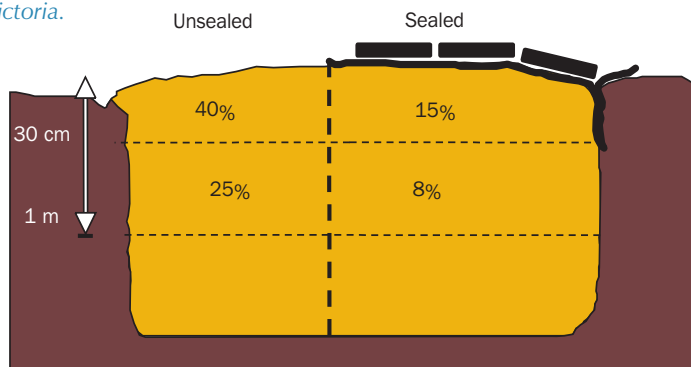
If the plastic seal on pits or bunkers is damaged aerobic spoilage may be confined to a localised area. The rate at which air can move through a pit will depend on the density of the silage (how well it is compacted) and the pressure applied to maintain contact between the plastic and the silage (number and closeness of tyres). Rain entering the silage through holes will increase losses.

Losses in wrapped bale silage

Insufficient or poor wrapping is one of the major causes of prolonged respiration, aerobic spoilage and the resulting higher DM and quality losses in wrapped bale silage (see Table 9.9). An inadequate number of wraps or poor wrapping technique can allow air to penetrate the bale.

If the plastic seal protecting the silage is damaged at any time between sealing and feedout air will penetrate the silage and aerobic spoilage will begin. In the case of baled silages, there is little to restrict air movement around the bales, whether they are individually wrapped or stored above

Figure 9.18
Losses of DM in pit silage stored either unsealed or sealed in Gippsland, Victoria.



Source: Hadero-Ertiro (1987)

		Low density			High density		
		2	4	6	2	4	6
Number of layers of plastic		2	4	6	2	4	6
Mould patch (%)*	Bale end	20.4	1.3	4.7	18.5	5.5	2.6
	Bale side	32.1	1.1	2.1	32.3	3.1	2.5
Mould depth (cm)	Bale end	10.0	2.2	3.2	9.4	3.1	2.4
	Bale side	10.0	2.4	3.4	8.9	3.4	4.6
Aerobically rotted bale surface (%)*	Bale end	68	0	1	82	3	0
	Bale side	64	0	0	90	11	0
Aerobically rotted depth on bale (cm)		45	0	2	54	1	0
DM content (%)		36.8	39.6	37.7	36.8	39.0	40.7
pH		5.8	4.7	4.7	5.7	5.0	4.5
DM Digestibility (%)		68.3	70.5	72.9	71.2	73.5	71.8
Ammonia-N(% of total N)		13.6	9.6	9.9	13.4	10.9	8.9

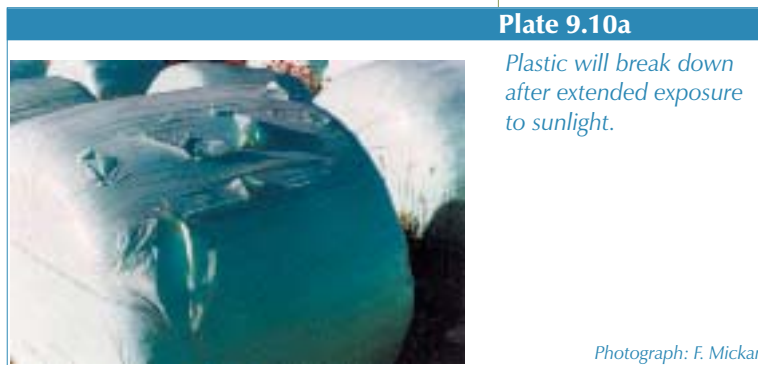
* % of visible surface area.

Source: Adapted from O'Kiely et al. (2000)

ground in modules. As a result, the DM losses can be very high and, in some cases, the whole bale or stack of bales will deteriorate.

Plastic colour may also have an impact on silage losses. Bales wrapped in dark plastic become hotter near the surface than bales wrapped in light-coloured plastic. Because heat can reduce forage digestibility, it has been speculated that wrap colour may affect silage digestibility. However, results from an Irish study showed that there was no effect of bale colour on digestibility, amount of visible mould or quality of the fermentation (see Table 9.10).

The results may have been different under Australian conditions where the intensity of sunlight and heat load is greater. Producer experience and research from warmer climates has measured significantly higher temperatures under



Colour	DM content (%)	DMD* (%)	pH	Crude protein (% DM)	Lactic acid (% DM)	Ammonia-N (% of total N)	Visible mould (% area)
Black	30.4	76.8	4.7	13.9	2.7	8.5	7.7
Clear	31.3	76.3	4.7	13.6	2.7	9.6	8.7
Green	31.0	76.2	4.9	13.8	2.6	9.2	9.3
Light green	31.0	77.3	4.8	13.8	2.8	8.6	5.2
White	30.8	77.2	4.7	13.9	2.8	9.0	9.0

* DM digestibility.

Source: Forristal et al. (1999)

black films than the lighter coloured films. There have been reports of temperatures inside bales sealed with black plastic being 10 to 30°C higher to depths of about 0.10 m. Heat-damaged silage can caramelise, resulting in some bonding of the sugars and protein components, reducing their availability to the animals (see Chapter 12, Section 12.4.4).

Plastic deterioration

Plastic deterioration can be in two forms: UV light degradation and heat breakdown. Plastic affected by UV light degradation will usually break down in 3-4 layers at the same time. Heat degradation breaks down one layer at a time, starting from the outside layer.

Although not confirmed by controlled experiments, there is anecdotal evidence that chemicals released from some silages may break down plastics. Anecdotal evidence indicates that sulphur compounds in canola silage may affect stretchwrap plastics.

9.8.3

Fermentation

Losses during fermentation are usually small – between 2 and 4% (see Chapter 2, Sections 2.2.2 and 2.5.2). With a rapid and efficient fermentation, where WSCs are fermented primarily to lactic acid, the losses of DM are small, and the loss of energy is even less. Where WSC content is low or insufficient, the fermentation will be slower and less efficient, and fermentation losses of DM and energy will be higher (see Table 9.11). The losses will be greater when there is a delay in sealing.

Fermentation losses are affected by a number of factors and will:

- ▶ decline with increasing DM content because bacterial activity is restricted;
- ▶ lessen when homofermentative LAB dominate the fermentation;
- ▶ increase when the fermentation is slow due to low WSC content or high buffering capacity;
- ▶ increase if enterobacteria, yeasts or clostridia contribute to the fermentation.

Fermentation losses can sometimes be reduced through the use of additives (see Chapter 7).

Reducing storage losses

- ▶ Wilt to ensure DM is >30% to avoid effluent losses.
- ▶ Wilt quickly to the recommended target DM content (see Chapters 4, 5 and 6) to avoid a poor fermentation.
- ▶ Consider using an additive (see Chapter 7) for 'at risk' or problem forages (low WSC content, or unable to wilt successfully).
- ▶ Compact chopped forage well or bale at high density to minimise the amount of trapped air.
- ▶ Seal effectively, as quickly as possible after filling or baling.
- ▶ Protect buns, pits and bales from vermin and livestock damage.
- ▶ Regularly inspect storage and immediately patch any holes.

Table 9.11

Effect of initial WSC content and delay until sealing on the fermentation quality of forage harvested ryegrass.*

	Experiment 1 (27.3% WSC content)		Experiment 2 (10.8% WSC content)	
	0	3	0	3
Time to sealing (days)	0	3	0	3
pH				
near the surface	4.36	4.41	4.45	5.74
middle of the silage	4.25	4.24	4.42	5.01
Loss of DM (%)	9	22	15	20

Source: Henderson and McDonald (1975)

* DM basis.

Section 9.9

Drought (or long-term) storage

Silage has an important role as a drought reserve and has been successfully stored in underground pits for 20-40 years. Because drought reserves may need to be stored for long periods (>20 years), some additional factors need to be considered to ensure the silage remains well preserved. Take note of the guidelines for sealing in Section 9.4 and consider the following points to ensure the silage will remain preserved for long periods.

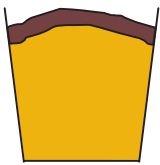
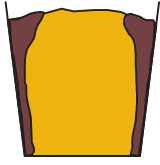
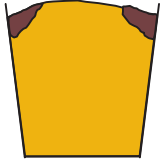
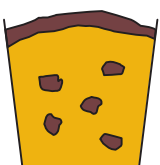
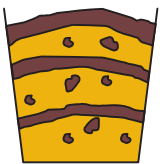
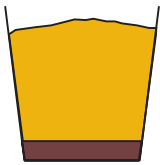
- ▶ Good site selection will minimise the risk of water entry.
- ▶ Where silage is part of the regular farming practice, the 'drought' supply can be part of the normal rotation. Aim to accumulate two years' supply of silage when excess high-quality forage is available. Such a program ensures that the silage is never more than a couple of years old, and it is less likely to suffer losses due to the storage seal breaking down.
- ▶ Conserve a high-quality forage. The conservation costs per tonne of forage ensiled are about the same, regardless of quality. High-quality forage is capable of maintaining animals for longer, and allows flexibility – it may be used for production as well as maintenance (see Chapter 14, Table 14.26). Costs of pit construction per tonne of ensiled energy (ME) are reduced.
- ▶ If storage is used infrequently, the overhead costs of pit construction are spread over a lower tonnage and a longer time compared to when the pit is used often and emptied regularly.
- ▶ Drought reserves are best stored in hillside or underground pits, sealed with plastic and covered with soil. The soil acts as a protective layer for the plastic – at least 30 cm of soil is required.
- ▶ Regularly inspect the storage area for signs of damage, such as burrowing by vermin. The silage will begin to deteriorate as soon as the airtight seal is broken or water seeps into the pit.
- ▶ Keep records of when and where silage is stored to avoid 'losing' underground pits.

Section 9.10

Appendices

9.A1

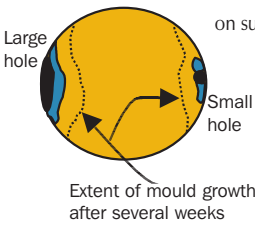
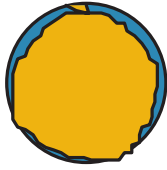
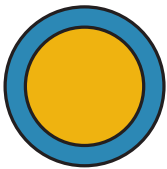
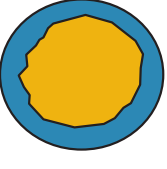
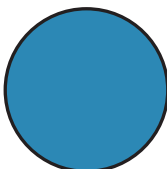
Spoilage losses with forage-harvested silages – likely causes and solutions


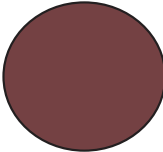


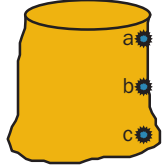
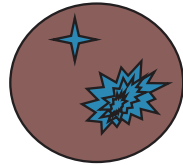
	PROBLEM	LIKELY CAUSE	SOLUTION
1. 	Top waste or crust. Actual losses are much greater than they appear.	Inadequate sealing. Final rolling insufficient and/or final load DM too high.	Adequate rolling/compaction Ensure plastic sheeting is adequately weighted, use plastic sheeting on walls of stack. Ensure seal between wall and plastic.
2. 	Side waste.	Porous walls. Inadequate seal between plastic and wall. Inadequate compaction along edges.	Apply a sealer to concrete walls or use plastic sheeting on walls of stack. Ensure edge compaction is adequate.
3. 	Shoulder waste.	Lack of consolidation, or ineffective sealing of shoulders.	Improve compaction and sealing technique. Plastic sheeting folded over from the side walls will assist. Ensure edge compaction is adequate.
4. 	Top waste and mouldy pockets throughout stack.	Inadequate consolidation of over-wilted or mature material resulting in trapped air.	Improve consolidation, seal immediately and weigh down sheet. Avoid over-wilting. Top stack with loads of moist or direct cut material. To improve compaction – spread loads evenly over area; spread loads to <30 cm depth
5. 	(a) Layers of poor-quality dark brown unpalatable silage. (b) Rotten pockets.	Frequent stops, lack of rolling and covering during extended stops. Forage too wet. Contamination by soil.	Wilt longer. If major delay occurs seal off stack as a separate batch. Avoid soil contamination.
6. 	Butyric and foul-smelling bottom layer.	(a) Crop too wet (b) Poor drainage from stack.	(a) Wilt, avoid excessive rain. (b) Improve drainage from stack.

Source: NSW Agriculture (1997)

9.A2

Spoilage losses with baled silage – likely causes and solutions

	PROBLEM	LIKELY CAUSE	SOLUTION
	<p>Mould growth patches on surface of bale.</p>	<p>Air entering at site of hole. Air entering hole over extended period. Much greater surface area affected. Holes not noticed or patched; if patched, incorrect tape used or incorrectly applied.</p>	<p>Patch holes as soon as detected, using proper silage tape. Inspect bales more frequently and carefully for signs of damage.</p>
	<p>Mould around bale & ~1-5cm depth.</p>	<p>Baler left outside of bale 'fluffy'. Plastic starting to break down or seal damage. Tackifier not fully effective. Layers not sticking together tightly. Wrapper underlapping regularly or conical shaped bales cause underlapping.</p>	<p>Reduce excessive turning of the bale in chamber before ejecting. Use net wrap instead of twine. Check plastic: is it cracking/splitting off? Possibly faulty stretchwrapping – discuss problem with the supplier. Correct overlap on wrapper (50% overlap, 55% stretch). Tight, even-shaped bales, with very slight barrel shape.</p>
	<p>Mould around outside of bale and ~5-20+cm depth, often rotten layer on outside.</p>	<p>Plastic seal damaged. Plastic severely breaking down (UV light) or damaged in a number of places. Plastic over-stretched when applied. Not enough plastic applied.</p>	<p>Check regularly and repair holes. Ensure plastic has UV stabiliser incorporated. Check pre-stretcher – 55% stretch only. Essential to apply 4 layers all over.</p>
	<p>Unpleasant odour, moisture under plastic and in outer 5-20+cm, often slimy, but warm/hot. Common in cereal bales & rank, dry pastures.</p>	<p>Air penetrating bale rapidly. Bale density too low.</p>	<p>Bale less mature forage or at lower DM. Bale more tightly.</p>
	<p>Mould throughout most of bale. Musty odour.</p>	<p>Air entering the bale for extended period. Not properly sealed or seal broken early in storage period. Bale stored too long, e.g. >12 months. Plastic starting to break down.</p>	<p>Avoid baling over-dry or stemmy crops. Ensure adequate bale density. Seal correctly, check regularly for holes. Use within 12 months, or use more layers/ or thicker wrap for longer storage period.</p>

PROBLEM	LIKELY CAUSE	SOLUTION
 <p>Mould in centre of bale or rotten pockets inside bale</p>	<p>Air in centre of bale.</p> <p>Soil or manure picked up at baling.</p> <p>Dead plant material picked up at baling.</p>	<p>Loosely baled with early model fixed-chamber baler. Bale spiked in middle when transported.</p> <p>Avoid contamination.</p> <p>Graze or slash well ahead of harvest period.</p>
 <p>Dark brown coloured silage, possibly with black charring – no mould, pleasant odour.</p>	<p>Too much air in bale at wrapping</p>	<p>Avoid delayed sealing or wrapping, or wrapping too dry.</p>
 <p>Bale slumped, mould throughout</p>	<p>Baled too loosely.</p> <p>Bale density low.</p>	<p>Bale more tightly, regularly adjust bale chamber.</p>
 <p>Bale severely slumped, very unpleasant odour, wet, often water in bottom, no holes</p>	<p>Baled too wet.</p>	<p>Bale at 35-50% DM. Use tedder, etc, to increase drying rate.</p>
	<p>a) Driest part, more pleasant & palatable.</p> <p>b) Very damp/wet, unpleasant odour, will be eaten.</p> <p>c) Possibly rotten, slimy, very strong unpleasant odour, often not eaten.</p>	
 <p>Plastic breaking down 1 layer at a time, from outside.</p> <p>Plastic breaking down 3-4 layers at a time</p>	<p>Heat degradation due to faulty manufacture.</p> <p>UV breakdown due to lack of UV light inhibitor.</p>	<p>Rewrap or protect bales from heat with a cover (be aware of rodents under covered area). Feed out before silage deterioration begins.</p> <p>Manufacturing problem. Low UV inhibitor in some imported films.</p>