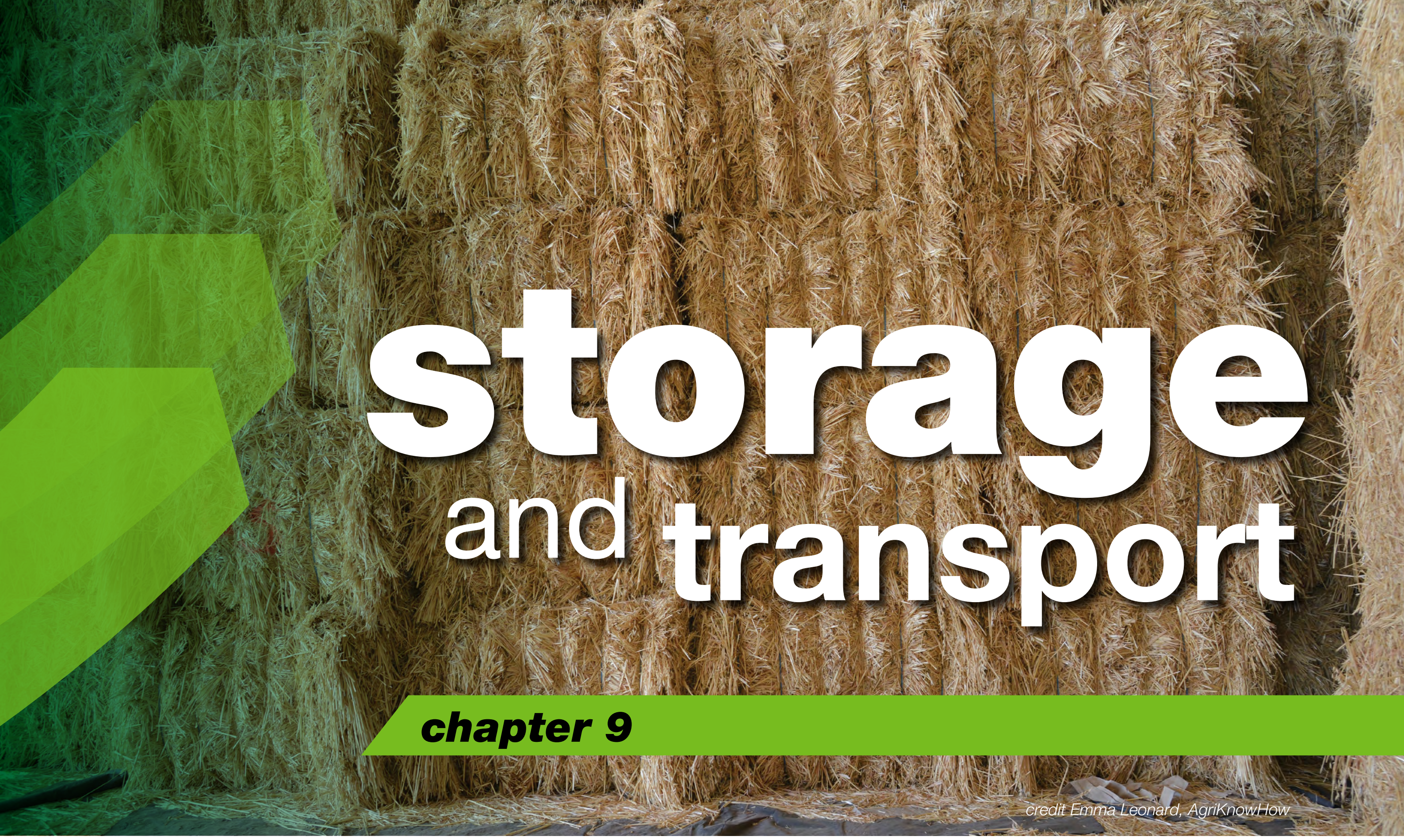


credit Emma Leonard, AgriKnowHow

storage and transport

chapter 9

Hay can be stored for long periods of time with little reduction in quality, providing the hay is in dense, well formed bales and remains dry and free from damage by vermin.

Left outside and unprotected, hay will degrade and a substantial proportion of the bale can be wasted due to the formation of moulds. For example, 33% of the total volume of a 2m round bale is in the outside 15cm and nearly 60% is in the outside 30cm.

Storage requirements

For short periods of time, especially if rain is anticipated, large square bales for export can be stored on their narrow end in the paddock, in order to minimise weather damage. Otherwise, export hay must be stored so that it is protected from sunlight, rain and wind, ideally in a fully clad shed. Export hay buyers generally pay a premium for hay stored in a shed.

Any shed openings should be away from the prevailing weather and the roof and walls must be secure and leak free. The floor should either be concrete, bitumen or covered with heavy duty black plastic sheeting to prevent moisture rising into the bales. Rubble floors should be avoided as they allow moisture to penetrate bales and stones and dirt can become lodged in the bales.

The shed's gutters and downpipes must divert water away from the shed and water must be prevented from flowing back to the base of the stored bales.

Bales from the perimeter of the paddock should be stored together as these may be tested separately by the export hay buyer.

The criteria for storing export hay will also maintain the best hay quality for the domestic market. However, hay for the domestic market may be baled at higher moisture content making it more susceptible to spoilage and combustion (Table 9.1).

Table 9.1 Recommended moisture content for safe storage of various types of hay bales *– source DEDJTR.*

Bale type	Moisture content range (%)
Small rectangular bales	16-18
Round bales - soft centre	14-16
Round bales – hard centre	13-15
Large square bales	12-14
Export bales	Less than 12

Storage options

There are multiple storage options and selecting the most suitable option will depend on a variety of factors (Table 9.2), including costs (Figure 9.1).

These factors include:

- timeframe of storage;
- available capital;
- frequency of loading in and out;
- distance to existing storage; and
- customer requirements.

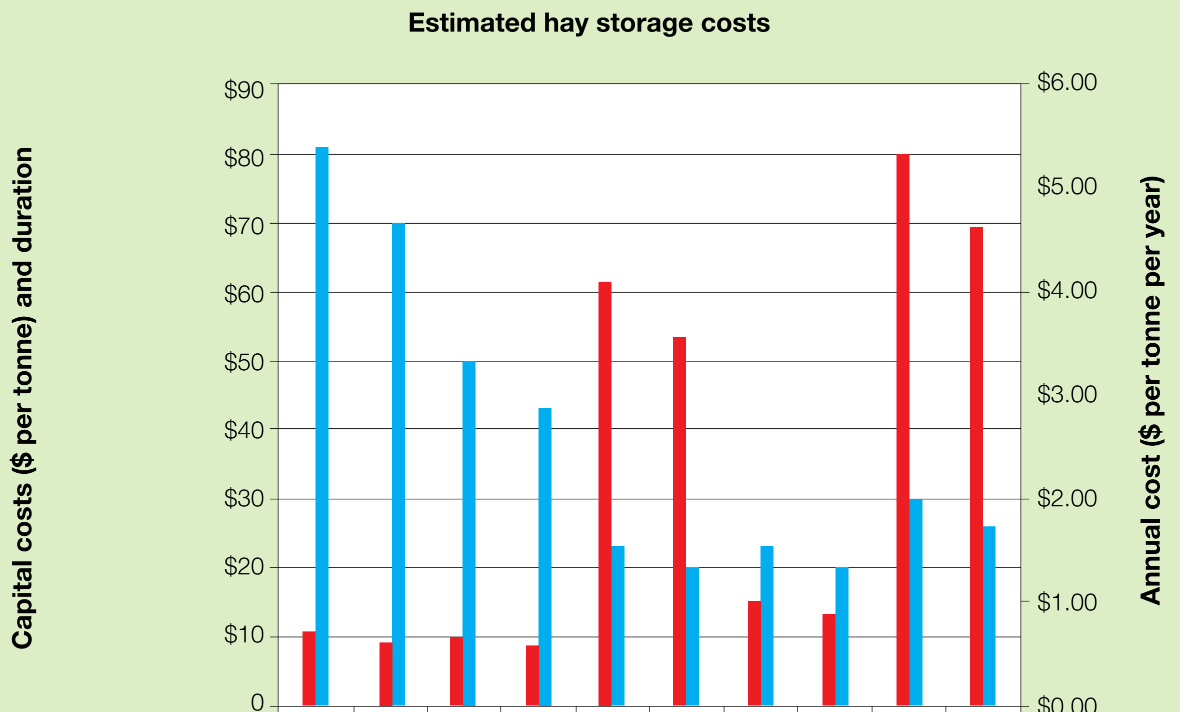
Table 9.2 Hay storage options pros and cons – three stars is the best outcome, one star the poorest – *source AFIA.* This Table excludes emerging technologies such as breathable materials for individually wrapping bales to provide about 18 months of protection from rain and ground moisture.

Storage factor	Top hay tarp	Full hay tarp	Steel shed 3 sides	Steel shed open sided	Hay caps
Capital cost per tonne	***	**	*	*	**
Durability	*	*	***	***	**
Annualised cost per year	**	**	**	***	***
Top layer waterproof	*	**	***	***	**
Seepage from beneath	*	***	***	***	*
Side bleaching	*	***	***	**	*
Labour required at stacking	**	*	***	***	**
OH&S during stacking	*	*	***	***	***
Freight savings from paddock	***	***	*	*	***

Causes of heating in hay

For a hay stack to combust, it must undergo a process of self heating that even now is not fully understood. However, it is known that several sources of heat can contribute to the process.

Spontaneous fires in stacked hay generally require five to 10 weeks for sufficient heat to be generated. Under ideal conditions of moisture and high ambient temperatures, ignition has been observed in six or seven days after stacking. Stacks should be continuously monitored.



	Top Tarp	Top Tarp HD	Full hay tarp	Full hay tarp HD	Steel shed open sided	Steel shed open sided HD	Hay caps	Hay caps HD	Steel shed 3 sided	Steel shed 3 sided HD
Capital cost per tonne	$10.77	$9.33	$9.96	$8.63	$61.54	$53.33	$15.38	$13.33	$80.00	$69.33
Duration years	2	2	3	3	40	40	10	10	10	10
Annual costs /t/yr	$5.38	$4.67	$3.32	$2.88	$1.54	$1.33	$1.54	$1.33	$2.00	$1.73

Figure 9.1 Estimated hay storage costs for large square bales compared to high density (HD) bales which are the same size but approximately 10% heavier – *source AFIA 2016.* The storage costs exclude the cost of labour and logistical inputs required for each option. Year on year the cost of sheds appears to have decreased.

credit Emma Leonard, AgriKnowHow

Primary heating

Respiration and biological

Respiration of freshly cut plants and subsequent bacterial action cause bale temperature to increase to a maximum of between 48 to 70°C (Figure 9.2).

Partially cured hay (moisture content between 12 to 21%) is the most prone to fire due to biological heating. This will heat the hay to the thermal death point of the organisms involved; that is in the vicinity of 70°C.

In dry years, water soluble carbohydrate (WSC) levels of cereal hay tend to be higher (>20%) and even hay baled at about 15% moisture has self-combusted.

If the hay is well cured, it will not allow this destructive fermentation to occur. Conversely if too wet, not enough oxygen can diffuse into the mass and no fire will occur.

When the heating hay is located on the outside of the stack, where the heat can dissipate, the process may very well stop here. However, if the heating is located at the bottom or inside of the stack then the heat may continue to build.

Regardless of how well the heated hay is insulated, temperatures of 70°C fall far short of the ignition point of hay, which is in the vicinity of 280°C with minimal air (Figure 9.2).

Secondary heating

Exothermic

Once hay reaches the limit of the primary heating (70°C), the exothermic process can be initiated to raise the temperature much higher.

Theories about this process include the production of pyrophoric carbon, pyrophoric iron, heat from enzyme action and even the auto-oxidation of the oils contained in seeds. This process is generally accompanied by the production of much acid in the early stages and is accompanied by a marked browning of the hay.

If insulated, this process can progressively raise the temperature inside the stack to 240 to 280°C at which point the slightest introduction of oxygen will result in the ignition of the stack.

Some research has shown that hay does not need to reach such high temperatures to ignite spontaneously. If hay is subjected to long periods of heating at temperatures as low as 88°C and remains in the presence of volatile gases produced by oxidation, it may ignite when air is introduced. In other words, a relatively low temperature for long periods may have the same effect on hay as high temperatures for short periods.

Combustion occurs in two different ways, in a hot pocket of carbonised hay or in a larger volume surrounding the hot pocket.

Monitoring - a simple test

The temperature of a stack may be checked with a ‘temperature probe’, a crowbar or other piece of steel. The bar should be left in place and checked regularly (Figure 9.3). Pipe or tubing should NOT be used as this may entrain air into the stack and cause ignition to occur.

Infra-red thermal images only show temperature differences on the surface of the stack.

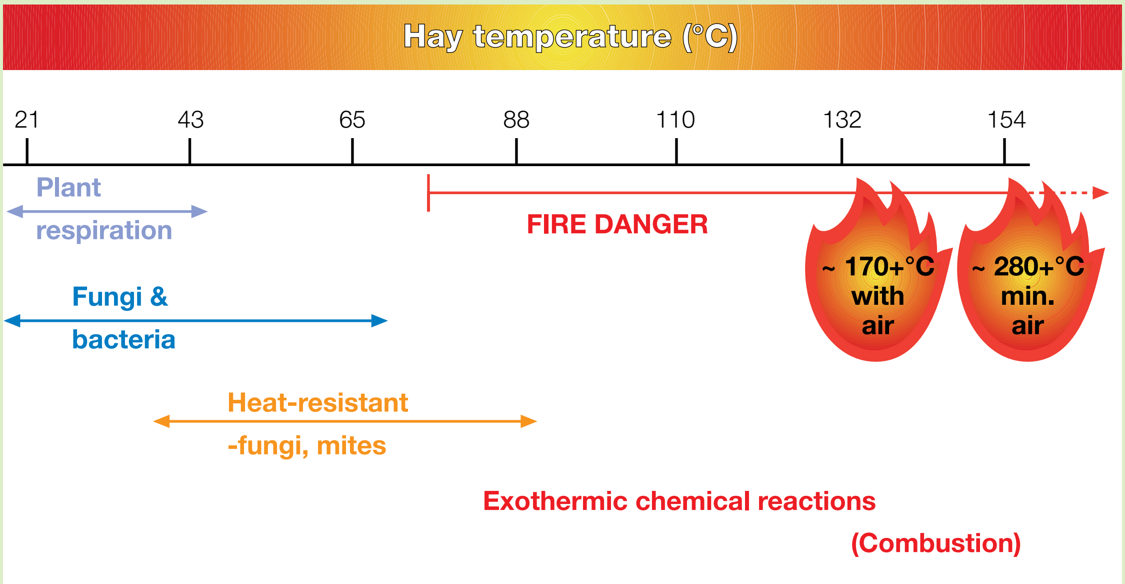


Figure 9.2 Causes of heating in hay – *source C Sheaffer & N Martin.*

Any stack that is known to be heating should be checked even more regularly to determine if temperature is rising or falling. If the stack continues to heat the only solution is to pull it apart. Bales that have reached a high enough temperature may spontaneously combust as they are introduced to a more available oxygen supply. Water and fire fighting equipment should always be on hand to extinguish a possible fire.

Hay transport

It is the responsibility of the vehicle owner, manufacturer or operator to ensure the safe performance, fitness for purpose and regulatory compliance of any vehicle in relation to the state or territory in which it is operated.

Push the crowbar into the stack and leave for ~ 2 hours

After 2 hours remove	Temperature (°C)	Action
Can handle bar without discomfort	<50	Check temperature daily.
Can only handle bar for short time	50 - 60	Check temperature twice daily. Remove machinery from shed.
Can touch bar only briefly	60 - 70	Check temperature every 2-4 hours. Carefully move hay to improve air flow. Have fire unit on hand.
Bar is too hot to hold. Potential for fire.	>70	Call Fire Brigade immediately. Avoid walking on top of haystack.

Figure 9.3 Testing the temperature within a hay stack – *source Victorian Department of Primary Industries.*

The majority of these documents can be found on the website of the National Heavy Vehicle Regulator (www.nhvr.gov.au) on the Transitional notices or state HVNL notices pages.

In 2016, each state and territory has its own regulations regarding the transport of hay. The Australian Fodder Industry Association (AFIA) is working to develop a set of national standards for the transport of hay.

A summary of the regulations can be found on the AFIA website transport page (http://www.afia.org.au).

Bale orientation

Round bales are less dense than squares, so properly stacked and restrained loads of round bales tend to be more stable than square bales stacked to the same height.

The load stability of large square bales can be improved if they are stacked with the strings around the sides and the knots to the centre. This is because the bales tend to lean into the centre of the trailer due to a natural thickness bias in bales being thinner near the knots. This method of loading also means bales are loaded in the same orientation as they were stored on-farm, so any compression or settling of the bales over time is not disturbed by loading on their sides.

For export hay, the tags attached to bale strings can be readily inspected on the laden vehicle, when stacked in this manner.

Load restraint

The method of load restraint has been shown to have a measurable effect on vehicle stability. The importance of load restraint is more than simply keeping the load on the vehicle. The shift of a load's centre-of-gravity that results from the movement of poorly restrained loads (either in the fore-aft or lateral directions) impacts on vehicle performance, because it causes a change in the load distribution between all tyres of the vehicle.

Lateral load shift brings about a small amount of load transfer from the tyres on one side of the vehicle to the other. Fore-aft (or longitudinal) load shift brings about a change in load distribution between axle groups, which can affect roll stability and braking performance.

Load restraint guidelines can be found on the National Transport Commissions website (http://ntc.gov.au/) and are summarised in AFIA document - Assessment of Vehicles for the Transport of Hay and Straw on the AFIA website (www.afia.org.au).

A commonly accepted threshold for safe lateral load shift is 100mm. Research conducted by Roaduser Systems Ltd and funded by the Rural Industries Research and Development Corporation (RIRDC), showed that the maximum lateral movement for all of the properly restrained loads tested is less than 100mm. The load shift at the centre-of-gravity is less than 50mm, which represents a movement of about 3% of the axle track width. Longitudinally, this equates to an effective centre-of-gravity shift of about 300mm based on trailer wheelbase.

This research also found that there are small but worthwhile benefits gained by using more effective load restraint methods such as double-strapping or 'double-dogging' of single straps (one load binder on each side of the load for a single strap).

It was found that the use of a diagonal bracing strap provided an enormous improvement on load stability (Figure 9.4). The research recommends that diagonal bracing straps are used for securing all groups of bales on a semi-trailer, two per group of bales, at opposing angles.

Figure 9.4 The use of a diagonal bracing strap improves load stability. Diagonal bracing should be considered for at least the front and rear groups of bales on a trailer, with thebracing pulling towards the centre of the trailer. Diagonally bracing all groups of bales with two straps is also acceptable *– source ARRB Group, 2006.*

credit Emma Leonard, AgriKnowHow