Grains Research UPDATE ADVICE

GRDC Grains Research & Development Corporation

How aeration works

Aeration cooling

Changing grain storage temperature is a relatively quick process compared to changing grain moisture. Cool grain is far less prone to quality loss than grain at higher temperatures.

To maintain grain quality and help avoid the build-up of hot spots of mould or insects, regular air movement and changing of the air is needed, once grain temperature has been stabilised. Low flow rate aeration cooling fans should regularly be turned on at appropriate times to move fresh, cool air into and around the grain storage. Exhaust vents must be open when aerating.

In many areas the best cooling conditions usually occur late at night and early in the morning. However there can be situations where air quality for cooling is better at other times, eg. when a low relative humidity results in a high level of evaporative cooling.

To cool grain, relatively low flow rates of air at around 2 litres per second per tonne (L/s/t) are pushed through the grain stack. The air takes heat from (or hot air can add heat to) the grain and is then vented to the atmosphere. A cooling front will move upwards through the grain.

Aeration drying

Ambient air can also be used to dry grain. Here, high flow rates of air of at a temperature and humidity that will remove water from the grain (see grain equilibrium moistures) is pumped through the grain bulk. Providing the air is of a quality that will dry and not re-wet the grain, the grain will dry from the bottom of the silo, with a drying front moving upwards through the grain stack.

Aeration drying is a much slower process than aeration cooling or hot-air drying. The time it takes and the moisture content of grain after a drying front has reached the top of the grain stack is highly dependent on the quality of the air available and used for drying. Several drying fronts may be needed to dry grain to receival standards. If aeration is to be used for drying, check with your aeration supplier that the fan and ducting have sufficient flow rate and pressure to force a moisture change front through the grain in your silo quickly enough to prevent mould development. It is also critical to ensure that flow fields are even and grain depth is not too deep.

Air with greatest capacity to dry, occurs most during the day when temperatures are high and relative humidity low, but this is not always the case. Very hot dry air can overdry and crack grain. The average quality of the inlet air (note fan heat effects) determines the final grain moisture content.

Flow fields

A flow field describes the way air moves in a grain stack. Air, like water or electricity follows the path of least resistance. Different depths of grain provide different back-pressures or levels of resistance. Air takes the easiest route to the surface and if the grain depth varies, or if poor duct design leads to uneven air distribution, pockets of grain can remain warm or fail to dry and hot spots for mould and insects can develop. For this reason grain spreaders are often used in the top of flat-bottomed drying bins. All systems require design input to ensure an even flow of air through the system.

In a deep grain bulk and especially with dense packing small grain like canola, more fan pressure is needed to maintain flow rate and the drying front will take longer to reach the top. Both significantly reduce the efficiency of the drying process.

Methods of selecting air

Air quality changes between region, throughout the year and throughout the day. It is important to understand how air quality varies in your region at different times of the day and year.

Long term data for air temperature and humidity by time of day and time of year is available for around 50 locations around Australia. This is very useful information to have when determining what is likely to be possible and what type of system is likely to work for you.

Temperature and relative humidity are generally at their best for drying from late morning to late afternoon when it's usually hottest and the air often has its lowest relative humidity.

Air for grain cooling

Air temperature, humidity and grain moisture content determine the grain temperature resulting from aeration (Table 1). Part of the change in temperature is similar to evaporative cooling as occurs in a canvas waterbag, while a large part is no more complex than using cold air to cool the grain. For this reason, most aeration cooling with low flow rate fans is usually done during the colder night-time hours.

Due to evaporative cooling, aeration of high moisture grain results in greater cooling than in low moisture grain. Aeration of 14% moisture grain results in temperatures >4°C cooler than aeration of 10% grain with the same air. Similarly aeration with dry air results in greater cooling than with humid air. For example, aeration of the same grain with 30% humidity air results in temperatures >3°C cooler than aeration with 60% humidity air.

Some growers elect to manually switch on their cooling fans or use timers, while others prefer to automate the process by installing an automated controller. The main type of controller used for cooling is the time proportioning controller.

Time proportioning controllers are fitted with sensors to measure air temperature. Some also measure humidity. When protecting grain quality during long term storage, time proportioning controllers are programmed to try to select the best 1/7th of hours per month (approx. 24 hours per week) in which to aerate and cool grain. Fans are switched on and off automatically. They do this by selecting air with the greatest capacity to cool when it is available. Controllers with relative humidity sensors also enable rules based on wet bulb temperature to be used. This feature can also prevent fans turning on when relative humidity is too high such as in a fog.

Air for grain drying

Grain left in air of a certain temperature and humidity for long enough will eventually reach a moisture content in equilibrium with the air. This is called the Equilibrium Grain Moisture Content. Table 2 shows this for wheat at different air temperatures and relative humidities.

To reach equilibrium, moisture must diffuse (usually from the grain to the air) from within the grain. This is a much slower process than heat transfer associated with cooling. Drying a single layer of grain with ambient air takes hundreds of minutes, while drying grain in a stack will take weeks. By comparison the cooling process is measured in hours and days.

Table 2: Approximate moisture content of wheat resulting from aeration with air at various temperatures and humidities (equilibrium grain moisture content).

Temperature °C	Relative humidity %				
	30%	40%	50%	60%	70%
15°	9.8	11.0	12.1	13.4	15.0
25°	9.0	10.3	11.4	12.8	14.0
35°	8.5	9.7	10.7	12.0	13.5

For the same relative humidity, more drying will be achieved with warmer air. A good supply of air of moderate to low relative humidity is needed to dry grain to Australian receival standards. As a rough guide, air around an average humidity of 50-60% will get close to receival standards.

Table 1: Approximate grain temperatures that would result from aeration with air at various temperatures and relative humidity (RH) passing through wheat at various moistures.

Inlet air		Approximate resulting temperatures in wheat at moisture content %			
Temperature °C	Relative humidity %	10%	12%	14%	16%
10°	30%	10.2	8.5	7.7	5.6
	45%	12.0	10.0	8.3	7.3
	60%	14.0	11.6	10.0	8.7
	75%	15.3	13.0	11.0	9.0
20°	30%	18.7	16.1	14.2	13.0
	45%	21.8	18.8	16.8	15.6
	60%	24.1	21.0	18.8	17.5
	75%	26.4	23.2	21.0	19.5
30°	30%	27.4	24.3	22.0	20.0
	45%	30.8	27.5	25.0	23.5
	60%	34.0	30.4	27.9	26.5
	75%	36.7	33.2	30.5	29.0

Table 3: The effect on air quality and Equilibrium Grain Moisture (%) (ASW wheat) of using supplemental heating to raise air temperature 4, 6, 8 and 10 degrees.

	Starting conditions	Increase in inlet air temperature from supplemental heating			
		+4°	+6°	+8°	+10°
Air temperature (dry bulb t°C)	25°	29°	31°	33°	35°
Relative humidity (%)	70%	56%	49%	44%	39%
Approx. Equilibrium Grain Moisture (%) with starting RH of 70%	14.0%	11.8%	11.0%	10.2%	9.6%
Relative humidity (%)	90%	71%	64%	57%	51%
Approx. Equilibrium Grain Moisture (%) with starting RH of 90%	>16%	14.1%	12.7%	11.7%	10.8%

In coastal environments or areas where the air supply can be humid for extended periods, it is more difficult to dry grain than in drier inland areas. In difficult drying environments, air can still often be found to dry grain from very high moisture contents down to around 15-16%. The difficulty is usually in drying from 15 or 16% down to receival standards of 12-13%.

In these difficult environments, automatic controllers would assist selection of air of a quality that will dry grain. Also, supplementary heating can be fitted to artificially increase the drying potential of the air by heating it 4 -10 degrees. Heating the air also reduces relative humidity. The combined effect of lower RH% and higher temperature provides air with greatly increased drying capability (Table 3). Increasing the temperature too much can result in over drying and damaging grain.

Management strategies

For cooling

(Assumes a flow rate of 2-4 L/s/t. Use caution if controlling systems with airflow outside this range or in partly filled bins)

Fans can be started as soon as grain covers the ducts.

For grain that is unlikely to go mouldy in the short term, ie dry or of moderate moisture:

- Run fans continuously for the first 24-48 hours to remove harvest heat. (Manual mode for automatic controllers)
- After removal of harvest heat, run the aeration fans for 9-12 hours at the coolest time each 24 hour period (usually at night) to even out temperature, moisture and to cool. Manage in this way for up to 7 days. (Rapid mode for automatic controllers)
- Once grain is stabilised, reduce the fan hours to the coolest 24 hours total for the week (usually at night and often between 2am and 5-6am) to cool as much as possible. (Select run times to suit local conditions) Running hours on cooler days can be extended to overcome warmer conditions. (Maintenance mode for automatic controllers)
- Do not run fans if conditions are of very high humidity, raining or foggy.

BE CAREFUL! NEVER RUN FANS WHEN WEATHER IS FOGGY! AERATING DURING A FOG WILL RE-WET GRAIN AND MAY CAUSE STRUCTURAL DAMAGE TO THE SILO

A controller that automatically selects the most suitable air for cooling is the best way to manage cooling. Controllers are available from aeration suppliers.

Where fan capacity exceeds the needs of cooling / maintenance and when grain is cool and at the low moisture levels needed for safe long term storage, reduce fan run hours or disconnect unneeded fans. This minimises the risk of potentially re-wetting the grain, which could happen if large volumes of over moist air were pumped in.

While the best air for cooling is often at night or early morning, this is not always the case. Be aware of your local conditions to pick the best times for cooling.

For drying

If air conditions are such that grain will dry, fans should be turned on and left on. When conditions are such that grain is no longer drying, turn the fans off and turn them back on when air conditions will again dry grain. The moisture content that grain will dry to is determined by the average condition of the air used. If the average condition of air used is too dry, grain below the drying front will be over dried.

To calculate if air of a certain quality will or will not dry grain, training in calculating Equilibrium Grain Moisture Contents is needed. The data presented in Table 2 provides a rough guide. It should be noted that different types of grain have slightly different equilibrium grain moistures. Automated drying controllers simplify the process of selecting suitable air for drying.

If air conditions are such that drying will not occur, supplemental heating can be used to raise the air inlet temperature a few degrees. This greatly increases the potential of that air for drying. Care should be taken not to over dry. If supplementary heating is unavailable and the available air will not dry the grain, a short term holding measure may be to change strategy and cool the grain, with the intent of maintaining its quality, until such time as better quality air for drying is available. Such situations place the grain at risk of mould development if moisture content is high and air conditions do not improve in the short term. This risk is far greater if air of suitable quality to cool grain is also unavailable.

The best air for drying is often from midday to dusk but this does vary from region to region. There are 50 locations around Australia where the drying potential of air has been monitored and recorded over many years. This data can provide information on the frequency of air suitable to dry grain from varying moisture contents and will assist in determining if supplemental heating is likely to be needed or not. It also gives insight as to the time of the day when the best air quality for cooling or drying is likely to occur.

Is it working?

Aeration is not a set and forget exercise. Aeration bins need and must have regular inspection, particularly if high moisture grain is involved.

The smell of the air leaving the bin is one of the most reliable indicators if the system is working or not.

Other items for inspection include:

- Are the fans working?
  (Feel for suction in or air flow out)
- Are the ducts and vents open and is air coming out?
- Check and record controller logs and fan run times.

If possible check the smell of air leaving the silo every day during the first two to three weeks, then at least once a week thereafter. A sweet fresh smell is good, while off, musty/mouldy smells are a sure sign of a problem.

Quality management tools including temperature and moisture probes will improve the security of storage further, but are not as accurate as your most sensitive instrument – your nose!

As the moisture change / drying front moves up through the grain stack, probing the top of the bin for moisture will tell you when the front has reached the top. The moisture content through the bin will be determined by the average air quality that has been pumped through the stack over time. If there are side inspection ports for sampling up the bin, these could provide measurement of where the drying front has reached.

Temperature sensors located throughout the grain stack at varying depths in the silo can provide a guide as to the location of the drying front, but the data provided can be misinterpreted.

It is important to ensure that drying fronts do not become stalled or stuck for any length of time. This zone is both warm and wet and must be kept moving or damage to grain quality is likely.

Other parts of the system

Hygiene

When selecting a storage system, keep in mind the need to keep it clean of all grain residues that can harbour insects. Temperatures in Australian storages are far hotter than in many areas of the Northern Hemisphere. As a result insects are one of our biggest storage issues. Systems that work well in cold conditions in Europe or the USA may have big problems with insects in the warmer, more insect prone Australian storage conditions. Avoid systems with areas that are difficult to thoroughly clean.

Ducts

A range of duct types are available. Some types are only suited for use with certain grains and will block up if other grains are stored (i.e. canola). Check with your supplier. Ensure that duct design enables thorough cleaning.

Vents

All aeration silos need adequate venting – the more the better. This doesn't mean that aerated silos cannot also be sealed. Several manufacturers produce aeration drying and cooling silos that can be sealed to enable effective fumigation when needed.

Further Information

QDPI website: http://www.dpi.qld.gov.au/home/
many articles if search for 'grain storage'
SGRL website: http://sgrl.csiro.au
Kotzur Silos: http://www.kotzur.com.au
Customvac: http://www.customvac.com.au
AgriDry Rimik website: http://www.agridry.com.au/
Agriculture WA website: http://www.agric.wa.gov.au
USA websites: http://bru.gmprc.ksu.edu/sci/flinn/
http://pasture.ecn.purdue.edu/~grainlab/

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