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GRDC GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

FABA BEAN

SECTION 13

STORAGE

HANDLING FABA AND BROAD BEAN | GRAIN CLEANING | GRAIN QUALITY | GRAIN STORAGE PRINCIPLES | INSECT PESTS IN STORAGE | FARM AND GRAIN HYGIENE | FUMIGATION | SILO OR GRAIN BAGS | REFERENCES AND FURTHER READING

Storage

13.1 Handling faba and broad bean

Faba beans are a very large, plump grain and are prone to mechanical damage during handling. This especially applies to:

- over-dry grain (<10% moisture content)
- crops that have been exposed to weather damage prior to harvest

The use of belt conveyors can reduce damage compared with conventional spiral augers.

Grain can be handled up to six times before delivery to receival points, so it is important to:

- minimise the number of handling stages wherever possible; and
- use efficient handling techniques that minimise damage.

If using augers:

- Operate slow and full.
- Use large diameter augers.
- The flight pitch should be greater than the auger diameter.
- Length of the auger should be no longer than is necessary; the shorter the better.
- Keep auger incline as low as practical.
- Check flight casing clearance; optimal clearance is typically 50% of grain size to minimise grain becoming wedged between the auger spiral and the casing and cracking.
- Auger drives should be at the discharge end, and not on the intake.

Approximate weight of grain stored in a cubic metre of silo is shown in Table 1. The actual figures can vary as much as 6–7% in wheat and barley and 15% in oats. In pulses, the variation is likely to be less (3–4%), and will vary with grain size, variety and season.

MORE INFORMATION

Faba bean foray into the north takes hold

Table 1: *Calculating silo capacities.*

Grain	Volume (m^3)	Weight (kg)
Broad beans	1	645
Chickpeas	1	750
Faba beans	1	750
Field peas	1	750
Lentils	1	800
Lupins	1	750
Vetch	1	750
Wheat	1	750
Barley	1	625
Oat	1	500
Example silo of faba beans	67.4	50,550

Source: Grain legume Handbook.

Calculating the volume of a cylinder

Volume = area of base (diameter squared × 0.7854) × height

Calculating the volume of a cone

Volume = 1/3 (area of base × height)

13.2 Grain cleaning

Re-cleaning of samples after harvest is sometimes necessary. Cereals can be cleaned from most pulses (not lentils) with a 3- or 4-mm rotary screen. The 3.75-mm slotted screen is popular and will help screen out split grain. The paddles or agitators in rotary screens should be new or sufficiently worn so that the grain being harvested cannot jam between the outside of the paddle and the rotary screen.

Screens or paddles can be damaged beyond repair if the grain jams. Fitting the screens with a spacer will provide additional clearance and so avoid the problem.

Milk thistle buds can be difficult to separate if they contaminate the sample, because they are similar in size and weight to peas. However, if desiccated or given time to dry, the buds disintegrate when put through an auger and can be easily separated.

Dirt and most small weed seeds can be separated in rotary screens; however, the dirt will increase component wear.

13.3 Grain quality

For information on grain quality see Section 12.10 Grain quality.

13.4 Grain storage principles

Store grain dry and clean. Take multiple samples during harvest, checking the moisture content of grain entering storage with a moisture meter that has been checked for accuracy. Moisture content of grain during harvest changes during the day and evening. Aerate grain while filling storages and during the storage period to maintain low grain temperatures. Monitor grain at regular intervals, checking on quality and pests. Keep a record for each silo, recording pests and any treatment details.

MORE INFORMATION

GRDC Fact Sheet 'Storing pulses': https://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

Cooling grain and aeration cooling

Cooler grain temperatures have several advantages:

- Seed viability (germination and vigour) is maintained longer.
- Moist grain can be safely held for a short time before blending or drying.
- Moisture migration and condensation inside the silo is reduced.
- Insect-breeding life cycles are slowed (or cease in some instances) and hot spots are prevented.
- Mould growth is reduced.
- Darkening of the seed coat is slower.

Aeration cooling is a vital tool when storing pulses in a silo. It allows for longer term storage of low-moisture grain by creating cool, uniform conditions that maintain seed quality, protect seed viability, and reduce mould and insect development. Its use also allows grain to be harvested earlier and at higher moisture levels, capturing grain quality and reducing mechanical seed damage.

Aerated silos are fitted with fans that push air through the grain to cool the grain and equalise the moisture and temperature throughout the silo. An aeration system requires a waterproofed vent on the top of the silo to allow air to escape freely. This vent needs to be sealable if fumigation is required in a gas-tight, sealable silo.

An aeration system should provide the appropriate airflow rates. Aeration cooling can be achieved with airflow rates of 2–4 L/s.t. For example, a small, single-phase aeration fan driven by a 0.37 kW (0.5 horsepower) electric motor for silos ~70–100 t capacity should deliver this airflow rate.

Controlled aeration should reduce grain temperature to ≤23°C. Controlling aeration cooling is a three-stage process: continual, rapid, and maintenance. Cooling achieved during storage depends on the moisture content of the grain and the humidity and temperature of the incoming air. An understanding of the effects of relative humidity and temperature when aerating stored grain is important. Automatic aeration controllers are used to turn fans on and off automatically, selecting the optimum ambient temperature and humidity conditions. This provides the most reliable results.

MORE INFORMATION

GRDC booklet 'Aerating stored grain—cooling or drying for quality control': http://www.grdc.com.au/GRDC-Booklet-AeratingStoredGrain

Grain Storage Fact Sheet 'Performance testing aeration systems': http://www.grdc.com.au/Resources/Factsheets/2012/08/Grain-Storage-Performance-testing-aeration-systems

13.4.1 Preventing moisture migration

For most storage situations, grain is best stored using aeration cooling. Generally, a silo is only left sealed for a short period of 1 or 2 weeks for fumigating an insect pest infestation. If, however, grain is sealed up in a silo, it must be of sufficiently low moisture content to prevent moisture migration.

While a silo is sealed, there is no venting and therefore no escape for warm, moist air in the headspace. Hence, moisture can migrate and condense in upper silo headspace and grain layers. This top area of the grain is at high risk from mould and insect pests if left warm and moist over time.

Moisture sources

Grains. Grain and seed are living and release moisture as they respire. Especially in silos with no aeration, this moisture moves upwards by convection currents created by the temperature difference between the grain in the center of the silo and the walls, which can be either warmer or cooler.

Grain insects. Insects or mites in the grain respire and release moisture and heat into air spaces as they respire. If grain is stored at >14% moisture content, then enough moisture may be carried into upper grain layers to place that grain at risk of mould. There is no moisture migration in an aerated silo as the entire stack is normally cooled to one temperature (≤23°C).

Condensation impact. Moisture carried into the silo headspace can condense on a cold roof and fall back as free water. This can then cause a circle of mould

MORE INFORMATION

GRDC booklet 'Aerating stored grain—cooling or drying for quality control': https://www.grdc.com.au/~/media/75BCB3243E4F490FB4B7CB8D38ADAABF.pdf

Grain Storage Fact Sheet 'Performance testing aeration systems': http://www.grdc.com.au/Resources/Factsheets/2012/08/Grain-Storage-Performance-testing-aeration-systems

GRDC Fact Sheet 'Dealing with high-moisture grain': http://www.grdc.com.au/Resources/Factsheets/2013/06/Grain-Storage-Dealing-with-highmoisture-grain

For general information on handling, drying and cooling see: Agridry Rimik Pty Ltd: http://www.agridry.com.au

or germinated grain against the silo wall. Moist grain can also contain greater numbers of insects.

Leaks. Water entering through structural damage will increase grain moisture content to a level where mould and insect growth can occur.

13.4.2 Drying grain and aeration drying

Continuous-flow or batch dryers provide reliable drying, although they can reduce quality if run at too high a temperature. Do not exceed 45°C when using heat to dry faba beans. Check the specifications or talk to the manufacturer about safe conditions for drying pulses.

High-capacity aeration drying systems can also be used to dry grain, and are ideally suited for drying grain harvested at 15–16% moisture content. Aeration drying has a lower risk of cracking and damaging pulses, which can occur with hot air dryers. Aeration drying requires much higher performance fans to move high volumes of air through the grain at a faster rate than that required for cooling only.

Airflow rates of at least 15–25 L/s.t are required for reliable aeration drying. By comparison, airflow rates as small as 2–4 L/s.t can achieve aeration cooling.

Careful selection of ambient air using an automated controller can remove moisture from the stored grain over a period of 1 or 2 weeks.

13.5 Insect pests in storage

Insects are not considered a major problem in stored faba beans. While bruchids (Bruchinae) are considered primary pests of pulse crops, very few bruchid species in Australia attack faba bean. (Note: there are exotic Bruchids (not present in Australia) that attack faba bean.)

The only exception appears to be in cases where faba beans are loaded into storages containing residues of cereal grain already infested with cereal pest insects such as flour beetles (*Tribolium* spp.) and grain borers (*Rhyzopertha* spp.). These prior infestations can develop and spread in the faba beans.

The key to control is maintaining excellent hygiene in and around storage facilities. Combined with aeration cooling, this should prevent infestations developing.

Most insect development ceases at temperatures <20°C. Freshly harvested grain usually has a temperature of ~30°C, which is an ideal breeding temperature for many storage pests. Aeration fitted to stores will rapidly reduce grain temperatures, reducing insect breeding and aiding grain quality (Table 2).

Table 2: *Effect of grain temperature on storage pest insects and mould.*

Temperature (°C)	Insect and mould development
40–55	Seed damage occurs, reducing viability
30–40	Mould and insects are prolific
25–30	Mould and insects active
20–25	Mould development is limited
18–20	Young insects stop developing
<15	Most insects stop reproducing, mould stops developing

Source: Kondinin Group via GRDC factsheet 'Aeration cooling for pest control'.

If insects in stored faba beans need treatment, the only control options are phosphine fumigation, an alternative fumigant or controlled atmospheres such as carbon dioxide (CO_2) or nitrogen (N_2).

MORE INFORMATION

GRDC Grain Storage Fact Sheet 'Hygiene and structural treatments for grain storages': http://www.grdc.com.au/Resources/Factsheets/2013/06/Grain-Storage-Fact-Sheet-Hygiene-and-structural-treatments-for-grain-storages

GRDC Fact Sheet 'Storing pulses': https://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

To ensure effective fumigation and control of all insect life stages, and to reduce the risk of resistance development, fumigation must be carried out in a sealed, gas-tight silo.

No insecticide sprays are currently registered for use on faba beans. Markets are particularly sensitive to insecticide residues, so detection of any residues on faba beans could result in loss of a market, not just rejection of a contaminated delivery.

Residual sprays should not be used on storages and handling equipment that is to be used for faba beans.

Use of diatomaceous earth (DE, e.g. Dryacide®) as a structural treatment may be possible. Always check with the grain buyer for delivery standards or allowances before using any product that will come into contact with stored grain.

Not all silos can be sealed adequately to enable fumigation. However, all silos can have aeration added to them. So if the silo is not sealable to make it suitable for fumigation, fitting aeration cooling fans will assist with pest control and grain quality. Well-managed aeration cooling, coupled with excellent hygiene, can overcome insect pest infestation problems in 7 out of 10 years. However, aim to have at least two sealable silos available on your farm to enable effective fumigations when required.

13.6 Farm and grain hygiene

Maintaining good farm and grain hygiene plays a crucial role in overcoming many problems associated with storage pests leading to reduced grain quality. Prevention is better than cure.

Basic hygiene practices include:

- Remove all grain residues from empty storage facilities and all grain handling and carriage equipment before new grain is stored and equipment used.
- Clean up spillages around silos and remove or use all residues to prevent re-infestation.
- Always spread grain hygiene residues to a depth of <50 mm at a dump-site to prevent the site from becoming an infested breeding site for storage pests. Most of these insects are strong fliers, moving >1 or 2 km.
- Once storages and equipment have been cleaned, treat them with an inert dust treatment (i.e. DE).
- Ensure that insect pests or weeds are not carried onto your property on farm equipment (i.e. harvesters); equipment should be thoroughly cleaned down after use.

MORE INFORMATION

GRDC Fact Sheet 'Grain storage pressure testing sealable silos': https://grdc.com.au/~/media/ReFocus-media-library/Document/GRDC-Document-Store/Publications-Media-and-Communications/Factsheets/Grain-Storage-FS-Pressure-testing-sealable-silos.pdf

13.7 Fumigation

Phosphine is the only fumigant currently registered for use in pulses. It is illegal and dangerous to put phosphine into unsealed storages.

Successful fumigation requires a gas-tight, sealable silo. For a fumigation to be effective against all life-cycle stages, as well as insects with resistance, the fumigant gas must be held in the silo at a given concentration for a certain period. This is only possible in gas-tight, sealable silos.

Silos purchased as gas-tight should be checked by the silo supplier and grower once they are erected, by using a pressure test. When they are filled with grain, they should be checked again prior to fumigation. Pressure testing should be part of the annual silo maintenance routine when checking and replacing worn or damaged seals and carrying out any repairs when the silo is empty.

Minimum fumigation exposure times for phosphine fumigation are:

- 7 days with grain temperatures >25°C
- 10 days at 15–25°C

Grain stored <15°C should not be fumigated with phosphine, because insects are hard to kill at low temperatures.

For large, sealable storages (e.g. >150 t capacity), a fumigation recirculation system should be fitted to the storage to ensure that gas is evenly distributed throughout the grain bulk in a timely manner during the fumigation exposure period.

Controlling insects in storage

During crop growth, insect control programs aim to control field insects. For insect pests detected in stored grain, fumigation is the primary control measure.

Provided fumigation is carried out correctly, the fumigant will penetrate the grain and destroy all stages of insects: adults, eggs, larvae in the storage. This includes insects that may have developed some level of phosphine resistance.

Effective fumigation with phosphine needs a concentration of 300 ppm (a chemical to air ratio) to be maintained for 7 days (when grain is stored >25°C) or 200 ppm for 10 days (15–25°C). An unsealed silo will not hold these concentrations, even using a high dosage rate. Poor fumigations may appear to have been successful when dead adults are observed, but many of the eggs, larvae and pupae survive and will continue to infest the grain. In addition, insects that survive are more likely to carry phosphine-resistance genes. This has serious consequences for future insect control across the entire industry.

Treating stored pulses

Storages should be cleaned prior to filling with new grain. If, however, there is reason to believe there are stored-grain insect pests in a silo or in freshly harvested grain, fumigation can be carried out as soon possible to ensure that all stages are eliminated before any grain damage or weight loss occurs. If possible, prior to fumigation, aeration of freshly harvested grain to create uniform, cool conditions in the grain bulk is a valuable first step.

Phosphine fumigation

Phosphine is a highly toxic substance (Schedule 7). Always read safety advice on the label and comply with state legislative requirements.

Caution should always be used when dealing with phosphine gas; it is not only toxic but also highly explosive. Observe all post-fumigation ventilation and withholding periods for handling and grain use.

Gas respirators suitable for protection against phosphine must be worn. Always open containers of phosphine preparations in the open air. When opened, use the entire contents or dispose of excess chemical. Do not reseal leftover tablets; once they have been exposed to air, they will begin to evolve into gas and may become explosive.

For safety reasons, it is best not to work alone when applying phosphine tablets or in a structures that have been fumigated.

Warning signs must be clearly displayed when the fumigation is in process (Figure 1). These should have details of when the fumigation started and the end date, as well as ventilation details, with entry to the silo prohibited during both fumigation and ventilation. Signs should be placed at all storage access points during fumigation.

MORE INFORMATION

Grains Industry Guide 'Fumigating with phosphine, other fumigants and controlled atmospheres': http://www.grdc.com.au/uploads/documents/GRDC-Fumigating-with-Phosphine-other-fumigants-and-controlled-atmospheres.pdf?shortcut=1

Figure 1: *Warning sign that must be clearly displayed when fumigation is in process.*

This phosphine warning sign can be downloaded from www.storedgrain.com.au.

Phosphine application and dosage rates

Refer to label instructions. Use only sealable storage.

Phosphine has about the same density as air and spreads rapidly in all directions once applied in a storage.

There are two forms of phosphine available for use on-farm: bag chains and tablets. Bag chains are the safest form, and ensure that no residue is spilt onto the grain. Tablets are the more traditional form and can be purchased in tins of 100. Phosphine blankets are also available; however, these are designed for bulk storages of ≥600 t.

Phosphine application rates are based on the total silo capacity (internal volume of the structure) that is to be fumigated, whether or not the silo is full, partly filled or empty (Table 3). The rates are the same for all crops.

The application rate for fumigating with a standard bag chain is one bag chain per 75 m^3. The application rate for phosphine is 1.5 g/m^3, which is equivalent to three tablets per 2 m^3.

Always read the product label to confirm recommended application rates.

Table 3: *Recommended rates of phosphine—sealed silo.*

Cubic metres	Bushels	Tonnes	Number of tablets
18	500	14	28
37	1000	28	56
56	1500	42	84
74	2000	56	111
92	2500	70	138

Source: Grain Legume Handbook.

Bag chains may be hung in the headspace or rolled out flat in the top of a gas-tight silo so that air can pass freely around them. Tablets should be spread out evenly on trays and then hung in the headspace or placed level on the grain surface. Some silos may also be fitted with purpose-built facilities to apply phosphine

MORE INFORMATION

Grain Legume Handbook 2008: https://grdc.com.au/uploads/documents/Index.pdf

Grain Storage Fact Sheet 'Performance testing aeration systems': http://www.grdc.com.au/Resources/Factsheets/2012/08/Grain-Storage-Performance-testing-aeration-systems

Grain Storage Fact Sheet 'Hygiene and structural treatments for grain storages': http://www.grdc.com.au/Resources/Factsheets/2013/06/Grain-Storage-Fact-Sheet-Hygiene-and-structural-treatments-for-grain-storages

Grain Storage Fact Sheet 'Pressure testing sealable silos': https://grdc.com.au/~/media/ReFocus-media-library/Document/GRDC-Document-Store/Publications-Media-and-Communications/Factsheets/Grain-Storage-FS-Pressure-testing-sealable-silos.pdf

from the bottom. These must have a passive or active air circulation system to carry the phosphine gas out of the confined space as it evolves, otherwise explosion can occur.

Ventilation and withholding period after fumigation

Ensure that correct, safe ventilation of the fumigation is carried out and the withholding period is observed according to label directions.

Sealing silos

The Australian Standard (AS 2628-2010) allows growers to refer to an industry benchmark when purchasing a gas-tight, sealable silo, giving confidence that they are investing in a silo that will perform in the way it is intended when fumigation is required.

Growers may choose to retro-seal existing farm silos rather than buying new gas-tight silos. Note, however, that not all silo designs can be successfully retro-sealed and made gas-tight.

Silos that are not adequately sealed lose gas through very small holes, preventing the fumigant reaching and maintaining gas concentrations necessary for an effective insect kill (Figures 2–4).

Figure 2: *Obviously, this silo is not sealed. It is dangerous as well as ineffective with a fumigant such as phosphine.*

Photo: Grain Legume Handbook

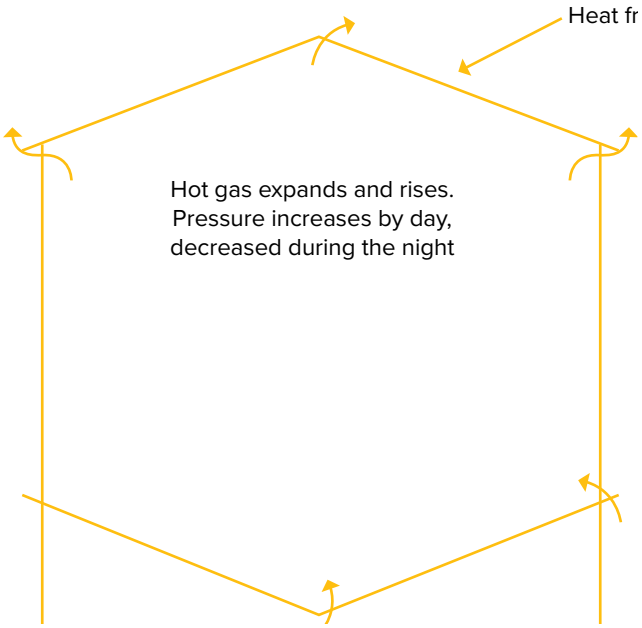

Figure 3: *Gas loss from silo through heat effects.*

Source: Grain Legume Handbook

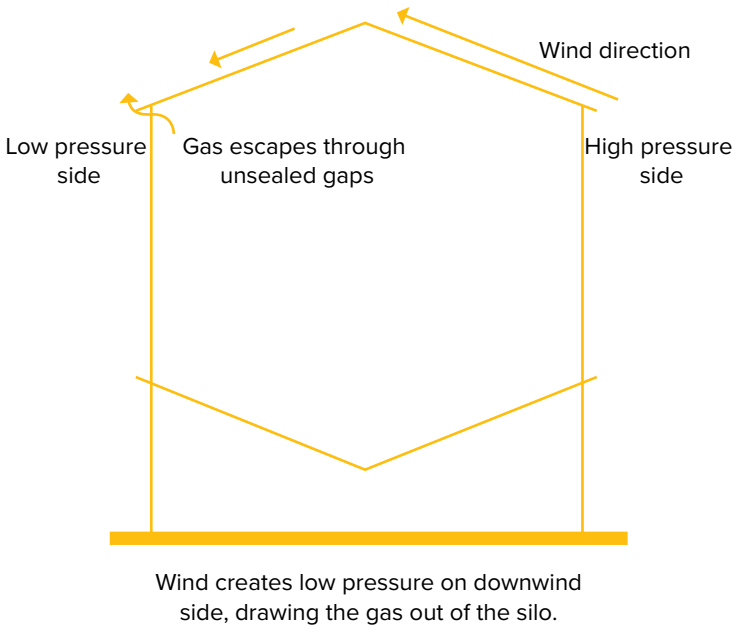

Figure 4: *Gas loss from silo through wind effects.*

Source: Grain Legume Handbook

Figure 5: *A gas lock on sealed silos gives a quick and reliable means of checking the seal of the silo. Some silos marketed as 'sealed' may not prove to be when tested.*

13.7.1 Testing silos for seal

A relief valve fitted to protect the structure of a sealable silos can also be used as a gauge for pressure testing. This allows for easy and regular seal tests. The relief valve should be filled to the second line (Figure 5) with light hydraulic oil. Do not use water, as it will evaporate. Vegetable oil is also unsuitable because it may react with the phosphine.

Test the silo for gas tightness using the pressure relief valve by applying a '5-minute half-life test' when new and a '3-minute half-life test' for all older existing sealable silos.

Key points:

- A silo sold as a 'sealable silo' needs to be pressure tested to be sure it's gas-tight.
- Check new sealable silos for Australian Standard pressure sealing compliance (AS2628).
- Pressure test sealed silos upon erection, annually and before fumigating.
- Maintenance is the key to ensuring a silo purchased as sealable can provide a reliable fumigation result.

MORE INFORMATION

Grain Storage Fact Sheet 'Pressure testing sealable silos': https://grdc.com.au/~/media/ReFocus-media-library/Document/GRDC-Document-Store/Publications-Media-and-Communications/Factsheets/Grain-Storage-FS-Pressure-testing-sealable-silos.pdf

13.8 Silo or grain bags

Grain bags (known also as silo bags, sausage bags or harvest bags) are becoming increasingly popular (Figure 6). It is important to appreciate their role and how they function, particularly when used to store pulse grain.

There are success stories with grain bags when used to store grain temporarily, including pulses. Failures have also occurred when appropriate precautions were not taken.

Pulses are riskier grains than cereals to store in grain bags. Pulse grain has been rejected by markets because of objectionable taints and odours derived during improper storage in a grain bag.

Grain bags are a sealed storage with no aeration. To maintain grain quality in storage, it is essential to bag the grain at the correct moisture content and ensure that the bag remains sealed throughout the entire storage period to prevent moisture ingress.

High-moisture grain, condensation, water aggregation under the film or leaks can cause localised mould and widespread spoilage in pulses.

Even with adequate seals, hermetic conditions (low oxygen (O_2), high CO_2) to protect against insects and mould are difficult to achieve consistently because of either high grain temperatures or low grain moisture content at the time of storage.

Figure 6: *Silo bags (or grain, harvest bags) should be considered as only temporary storage for pulse grains because of quality issues that can arise.*

Photo: W. Hawthorne, Pulse Australia

13.8.1 Pulse quality risks and grain bags

There are risks associated with storing pulses in grain bags:

- Pulse grain may not retain its quality, colour or odour, especially if the seal is breached.
- Contamination and moisture can enter bags from vermin and other pests that create holes in the bag.
- Excessive grain moisture can result in condensation within the bag, causing localised areas of mould and objectionable odours.
- Pockets of mouldy grain can develop in grain bags, along with an offensive, distinctive 'mouldy' odour throughout. There is a nil tolerance of this in receival standards
- Marketers have rejected pulse grain because of objectionable moulds, taints and odours acquired through storage in grain bags.
- Removing taints and odours in affected grain is not necessarily possible, even with further aeration.
- Grain stored in grain bags can develop an overall offensive, distinctive 'plastic' odour that requires considerable periods of aeration to remove. There is nil tolerance of odours in receival standards
- Achieving and keeping hermetic conditions under Australian conditions is difficult and it should not be relied upon as the only source of storage insect control.

MORE INFORMATION

GRDC Fact Sheet 'Successful storage in grain bags': http://storedgrain.com.au/successful-storage-in-grain-bags/

- Grain moisture content is critical. Pulses, particularly the larger seeded ones such as faba bean, have bigger airspaces between grains than do cereals, so moisture can move more freely in them.

13.9 References and further reading

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