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On-farm storage of organic grain

Robyn Neeson

Organic Farming Liaison Officer, Yanco

HJ Banks

Formerly, CSIRO Stored Grain Research Laboratory, Canberra

Introduction

Many producers of organic grain make use of on-farm facilities for the storage of grain. Proper storage allows growers to:

- store seed for sowing future crops;
- store stock feed for drought proofing or future on-farm use;
- dry or store grain to suit market demands or to achieve higher market prices;
- add further value or processing;
- manage cash flow/tax planning.

Successful storage requires protecting grain from insect or animal pests, preventing contamination by moulds or physical contaminants, and maintaining the viability of the grain and its nutritional and manufacturing properties. This Primefact describes how to achieve these objectives in ways that comply with the National Standard for Organic and Biodynamic Produce.

Organic farming

Organic farming can be defined as a system of sustainable farming that produces agricultural products without the need for artificial pesticides or fertilisers. Biodynamic farming is a similar system utilising lunar and planetary rhythms in the farming calendar, as well as a number of microbial preparations to improve soil health. Both follow a set of well defined, published standards that constitute an organic quality assurance (QA) system.

In recent years there has been a dramatic increase in the demand for organic and biodynamic grain and grain products, arising largely from food safety and environmental concerns in food production systems. Markets into Asia have been identified for Australian organic wheat flour and noodles, rice and rice flour, soybean products, and barley, while organic and biodynamic wheat has been exported to Europe.

Organic certification and grain storage

If a farm and produce are to be certified ‘organic’, the farmer’s methods of production and storage must comply with standards for organic farming. The farm is inspected by an organic certification organisation on a yearly and random basis to

Figure 1. Riverina Organic Farmers Organisation members inspect a grain silo with CO2 disinfestation capability. Photo R. Neeson

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ensure that standards are being met. The certifier's standards cover all the requirements of the National Standard for Organic and Biodynamic Produce. Since January 1993, exports of organic produce have been required to meet this standard. Some Certifier's Standards give details on grain storage.

Organic certification aims to guarantee the integrity of the product 'from paddock to plate'. Production, storage, transport, handling and packing facilities must conform to organic standards in order to maintain the organic integrity of the product.

The National Standard for Organic and Biodynamic Produce prescribes that all products grown to organic standards must also be handled or stored in a manner that prevents contamination or substitution with substances or products not compatible with the Standard. The use of pesticides is generally not permitted, thus excluding many widely used postharvest pest and disease control measures.

Potential problems in storing grain

Some storage problems result from conditions before or at harvest. Some are caused by conditions during storage. Grain quality loss prior to storage can result from weather damage in head, incorrect or delayed drying or incorrect harvester settings. Grain with high dockage content or damaged grain is more difficult to store well than sound, clean grain. Grain quality losses after harvest can include moulding and mould toxin contamination, loss of viability and processing quality (e.g. baking quality, malting grade, excessive free fatty acid content, reduction in oil yield) and gross loss of product.

In general, grain in long-term storage should be held cool and dry. Grain quality loss after harvest results primarily from high storage temperature and moisture content. These may be present at the time of binning or may result from the action of pests (insects, mites, moulds), respiration of the grain itself, or physical causes such as moisture migration, solar heating or water leakage into the bin. Effective grain storage requires management of the grain temperature and moisture and control of grain pests.

Organic grain storage strategies

Retaining grain quality during storage involves satisfactorily managing the physical storage environment to prevent infestations developing and to maintain seed viability. This includes monitoring the condition of the grain, maintaining good hygiene levels, knowing when and what pest control methods to use, and controlling temperature and moisture levels in the grain.

Under Australian storage conditions, moulds are readily controlled by storing only dry grain and keeping it dry. Moulds develop typically at higher humidities than that found in wheat of about 13.5% moisture content. Moulds must be controlled to avoid tainting the grain and to eliminate the risk of mycotoxin formation in store. Mycotoxins are chemicals produced by moulds and are toxic to humans or livestock.

The principal pests of dry grain are insects, the main ones being beetles, moths and booklice (psocids). These may be controlled by reducing the temperature of grain in storage, but they are not eliminated. Typically, storage of grain at 20ºC or less reduces problems from grain insect pests, but a disinfestation stage is typically required to meet trading standards.

A number of organic-compatible practices are useful in maintaining the quality of stored grain. These include harvesting strategies, storage design and layout, grain storage management practices, monitoring pest incidence, controlled atmosphere storage, heating and cooling treatments, and inert atmosphere vacuum packaging.

Harvesting strategies

Harvesting at the correct time can avoid yield losses and minimise postharvest storage problems. Testing grain before harvest allows quality control of the product grade, leading to a better understanding of the on-farm storage requirements. Weathering of seed often occurs before low moisture levels are attained, reducing quality and storability. Colour of the seed coat can also be influenced by storage conditions and/or delays in harvesting.

Where there are facilities for handling and drying grain that is too moist (greater than 13.5% moisture content for cereal grain), the grain can be harvested as soon as possible after maturity is reached. Grain harvested at higher moisture content will cake and mould quickly when in store unless dried or cooled quickly. It is also above normal market and receival limits.

If drying and conditioning facilities are not available, grain should be harvested at or below normal receival limits for moisture. These are usually set at 12.5% for wheat, 12% for barley, oats and triticale, 8% for canola and 9% for sunflower. Cereal grain stored below these limits should be stable over long periods and easily storable if protected from pests and weather. Oilseeds should be aerated using well controlled aeration if they are to be stored for more than a month.

Grain storage management

Good hygiene within grain handling and storage premises is a primary goal so that the quality of the products handled is not compromised through contamination. In a premises registered under the *Export Control Act 1982*, contamination refers to insects, rodents or any other noxious or objectionable matter as described in the 'Grains, Plants and Plant Products' Orders. These Orders are complementary to the National Standard for Organic and Biodynamic Produce.

Infestation in cereal grains can be expected to become obvious in 2–3 months under most Australian storage conditions unless precautions are taken, and can originate from a variety of sources.

Good hygiene in grain storage facilities can be achieved by ensuring that storages facilitate:

- easy cleaning and inspection
- regular equipment maintenance and removal of grain residues in sheds, around silos, in headers, augers, field bins, trucks, animal troughs and in silos after emptying.

Good storage design should be complemented by:

- proper training of staff in safety and hygiene related Issues
- the establishment of a system for recording and checking hygiene procedures
- the development of action strategies should contamination occur.

Adopting a HACCP based management system can greatly assist this process.

Grain moisture and *grain temperature* are key factors affecting the number and species of insects infesting grain. Growers can manage insect populations by controlling the temperature and moisture content of their grain in storage. (See 'Grain management by cooling', below.)

Other important management practices are *rotation of stocks* to ensure they do not become sources of infestation and *destruction of old stocks* that are likely to be heavily infested.

Monitoring pest incidence

The use of insect traps in storages and surrounds can significantly reduce the amount of time needed to search for insects, detecting pests while growers sleep.

For most storage pest species, traps can detect the presence of insects at lower population levels than is usually possible by visual inspection. Insects detected by trapping are an early warning that control measures need to be taken.

Various types of insect traps are available:

- pitfall traps catch insects as they fall into a container from which they cannot escape;
- crevice traps provide a physical environment into which insects crawl and remain;
- bait traps contain food or some other form of bait attractive to the insect.

Simple and effective insect traps can be made from items found in most homes. Traps designed for specific applications and pests are available commercially.

Reducing the initial infestation

Every effort should be made to reduce the opportunity for initial infestation of insect pests and mice. Remove all grain and plant material from equipment used for harvesting, storage, transport and processing so that there is little opportunity for insect pests and mice to survive.

High pressure air is often the most suitable method for cleaning equipment, but high pressure water can be used where it will not damage equipment, and vacuum cleaning is suitable where there is reasonable access. Plan the cleaning sequence so that cleaned areas cannot be re-contaminated and use suitable personal protection when using high pressure air. In areas where machines cannot be thoroughly cleaned, the use of Dryacide® may be beneficial but this should not be used as an alternative to cleaning.

Reducing harbours around storage areas, such as rubbish and long grass, will minimise mice problems. A clear area exposes mice to their natural predators.

The potential for insect infestation can be greatly reduced by keeping the grain temperature as low as possible at and after harvest and by storing dry grain as soon as possible in a sealed, white-painted silo. Disinfest within a month of storing grain.

Figure 2. Experimental use of CO2 in a maize bunker, Peoria, USA. Photo HJ Banks (© CSIRO)

Never add freshly harvested grain to silos retaining the previous year's grain unless it has been effectively treated by a controlled atmosphere disinfestation. Thoroughly clean out silos and preferably leave them empty for a time before storing the new season's grain.

Storage design

Poor storage design and on-farm layout of storages may affect the quality of stored grain. A well planned layout of storages will allow for segregation and short-term holding of grain for blending of product to meet quality and grade specifications.

Organic grain producers should consider the use of sealed storages. There is no organic compatible disinfestation process currently available that operates in unsealed bins. Sealed storages allow controlled atmosphere (CA) such as carbon dioxide or nitrogen to be applied for insect elimination. Currently, CA is the only process compatible with organic standards that can eliminate an established infestation of grain pests.

An effective method for the mid to long-term storage of grain is the use of underground storages and bunkers. These can be sealed, in the case of bunkers with tarpaulins, and filled with carbon dioxide to kill insects.

Very well sealed bunkers can eliminate infestation merely by the hermetic storage process. In this process, grain (which might be infested) is put in a very well sealed flexible or underground system. Natural respiration uses up the oxygen in the system, leaving an insecticidal and preservative atmosphere. In some situations, a 'sacrificial layer' of grain or straw is needed on the grain surface to absorb moisture that accumulates there.

Modern plastic 'sausages' and bags work on this principle (see Figure 4).

In a sealed silo, grain can be treated effectively, providing long lasting insect control without the need for pesticides and without the problem of pesticide residues. A sealed silo prevents re-entry of insects, provided it stays sealed. Seals should be checked regularly and replaced every two years. Silos can be checked for leaks by using a farm compressor. The silo superstructure as well as pressure relief valves should be checked regularly. Silos can be retrosealed – a list of suppliers is included at the end of this publication.

Grain quality can be affected by high temperatures. As a guide, every 4ºC rise in temperature, at constant moisture content, cuts seed life by half. The simplest solution is to paint your silos white to reflect sunlight and much of the heat. In hot and humid grain growing regions or with larger storages (greater than 100 tonne capacity), grain cooling can be facilitated by aeration (see 'Grain management by cooling and aeration', below).

In sealed silos with long-term storage there may be some moisture migration, producing an increased moisture content on the grain surface. If this process is allowed to continue, moulding, sprouting and quality damage can occur, though this is restricted to the grain surface. This moisture migration can be stopped with aeration (see 'Grain management by cooling and aeration', below).

Grain handling and conveyor systems should be designed to minimise damage to grain, particularly in the seed, legume, oilseed and specialist grain areas. All grain handling and storage facilities should be designed for easy and thorough cleaning. Time spent sealing gaps on new equipment will be more than repaid by faster and more effective cleaning over the life of the equipment.

Mineral dusts

Mineral dusts based on diatomaceous earth products are acceptable as grain treatments under organic standards. Diatomaceous earth comprises the remnants of tiny fossilised diatoms, which now occur as mine deposits in various parts of the world. Diatomaceous earth is registered as a food additive in many countries.

Two products which are non-toxic to mammals, Dryacide® and Absorba-Cide Sorptive Dust Insecticide®, are currently registered for application to grain at rates of 1g/kg (0.1%). Absorba-Cide® differs in that it does not contain a silica gel component and cannot be applied as a slurry in water. These products work by adhering to and absorbing the waxy coatings on insects causing death by dehydration, rather than by chemical action. Insects will be controlled when the grain is dry but may survive if the moisture content is higher than the normal standard of 12.5% moisture content in wheat. Grain is also at risk if the silo has a tendency to become damp at the base. Either product can be applied by a pickle applicator to whole grain to give protection from insect attack.

Treated grain should retain protection for 1–2 years provided the grain remains dry. If grain has already become infested some control may also be possible at higher rates listed on the label. No withholding period is required so treated grain can be given immediately to stock.

Grain treated with Dryacide or Absorba-Cide® is not accepted by bulk handlers and grain traders because it slows grain movement through augers and affects some grain qualities.

Dryacide and Absorba-Cide® can be effectively used to disinfest empty storages. Dryacide can be applied to surfaces as a slurry using a centrifugal

pump. Either can be applied as a dust using a hand bellow or power duster. The slurry is more useful in sheds where the deposit dries to a light coating that is sufficient to be seen without being obviously caked. The application rate is 6 g/m^2. In smaller silos the dust is applied from the top hatch at the rate of 2 g/m^2. When applying the dust to large areas, a power duster is used. Operators should wear disposable dust masks.

Other mineral dusts such as magnesite (magnesium carbonate) and agricultural lime have also been found to be of some help in protecting grain, but they are not as effective as diatomaceous earth products, and are not registered for the purpose. They are used for on farm purposes only and will not be accepted in trade. Magnesite is a relatively cheap natural product mined in the Young area of southern NSW. Magnesite has potential for long-term protection of drought reserve oats if the grain is genuinely dry, but it rapidly loses effectiveness at higher moisture levels. Researchers with Industry & Investment NSW found that magnesite would protect oats at moisture levels below 10% for up to two years in farm silo trials. An application rate of 0.5% was a compromise between effectiveness and difficulty of handling. Intending users should seek advice on their specific situation from Industry & Investment NSW.

Controlled atmosphere disinfestation

Carbon dioxide has been used by some organic growers for many years to store bulk grain, i.e. for larger 50 tonne silo lots as commonly found in small farm bins. A well-sealed bin, preferably painted white externally, is required, and the bin should be checked for gas-tightness to ensure the pressure halving time exceeds three minutes.

The concentration of carbon dioxide must remain above 35% for 14 days at all points in the grain bulk to ensure all stages of the insect life cycle are killed. The amount of carbon dioxide needed to achieve this is about 1 kg per tonne of grain if the bin is full. More gas is needed if the bin is partially filled with grain. Currently the only practical method is to introduce carbon dioxide to the base of the silo from gas cylinders.

DANGER: Silos are ‘confined spaces’. Avoid entering them unless absolutely necessary and ensure that the bin atmosphere has been thoroughly ventilated, such as by running the aeration fan before entry. The atmosphere within the bin or store must be tested for oxygen before anyone enters it. Under CO^2 treatment, dangerous levels of CO^2 can easily be present in unventilated bins. Employers and their staff should comply with Australian Standard AS 2865 ‘Safe Working in a Confined Space’.

Grain management by cooling and aeration

A range of techniques have been developed to facilitate the chemical-free drying, cooling and maintenance of grain in storage. Grain temperature in-store should be kept as uniform and as low as possible. Low temperatures slow down or prevent insect development. They also reduce microbial growth, which can spoil grain, cause off-odours and increase grain temperature.

Grain aeration (aeration cooling). Aeration is the practice of moving air through stored grain to reduce the rate of grain deterioration and prevent storage losses.

Aeration is usually by means of ducts in the floor, through which cool air is fan-forced at low speeds and vented at the top, though it can be forced from top to bottom with extractor fans in the floor ducts. Aeration is generally done at night when the outside air is coolest.

Supplementary refrigeration is sometimes used to reduce the relative humidity of the input air if the air is too humid.

Traditionally, aeration is used to protect ‘dry’ grain from quality loss due to insect attack or unfavourable temperature and moisture combinations. With well-designed equipment, aeration can also be used to manipulate moisture

Figure 3. Bins at Newcastle (NSW) export terminal under nitrogen disinfestation treatment before export. The nitrogen storage is at the base of the bins. Photo Julie Cassells (© CSIRO).

content in over-dried grain or where variable moisture levels exist in stored grain.

It may be possible to meet market specifications using ‘smart’ aeration coupled with a grain surface treatment. In smart aeration, grain is placed in store immediately after harvest when pest infestation is very low. Aeration is started immediately after inloading to prevent pest build-up and to take advantage of any cool weather during early summer (for summer harvested grain). In warmer, wetter areas in NSW, typically north of Dubbo, grain should be cooled to about 23ºC and then disinfested using a controlled atmosphere gas. This requires efficient aeration design and control, as well as a sealable bin. After disinfestation, the grain should be aerated further to a target of 15ºC. Higher target temperatures are possible if grain moisture is lower than the limits stated earlier. South of Dubbo, in the eastern states and in SA and WA, the precautionary disinfestation treatment may not be necessary, provided grain temperatures can be rapidly reduced and maintained below the limit throughout storage.

Ambient and/or refrigerated aeration combined with a surface application of Dryacide has been used successfully for the storage of grain for Organic Vita Brits by the Uncle Tobys company at Wahgunyah, near Rutherglen. Aeration-cooling systems are increasingly being used to maintain the quality of conventional canola in storage. Safe storage of canola for long periods requires storage at a moisture content of less than 8% and a grain temperature of less than 20ºC.

In-store drying

In the Australian climate, in-store drying can often be achieved without necessitating artificial drying. The advantages offered for artificial drying systems include the potential for earlier harvest and less harvest time lost due to weather stress. However, it is easy to overheat grain in an artificial dryer. Temperature varies considerably and this can have a detrimental effect on dough properties of wheat.

Factors to consider when deciding if in-store drying systems meet your requirements include: system cost; available power supply (the ideal power supply is three-phase electricity); sufficient air flow to avoid condensation on top of the grain mass; fan size; and acceptable drying times.

The major advantage of ambient in-store drying is the cost compared with purpose-built dryers. Both capital costs and running cost are reduced. A typical cost for an ambient air drying system is around $5,000. This will increase if power alterations or supplementary heating are required. For typical farm storages the running cost of a drying system is around $1–2 per tonne for the removal of up to 5% moisture content. However, this will vary depending on the size of the storage, the aeration rate, the quantity of moisture to be removed, weather at the time of drying and if supplementary heating is required.

Disadvantages of aeration drying include: it may take days or weeks to achieve an outcome that may take only a day or two in a conventional drier; and the need to provide supplementary heating (additional cost) in cold, wet climates with certain crops or when grain with excess moisture is being dried during wet weather.

Heat disinfestation

Heat disinfestation offers a rapid chemical-free process for the disinfestation of grain. While other techniques represent cheaper alternatives, heat disinfestation may become a useful strategy as technological advances are made. It is not yet available commercially.

Heat disinfestation aims to create high grain temperatures (around 63ºC or higher) for brief periods (around a minute or so) and thus achieve a complete kill of insect pests. With rapid cooling, immediately following the required heat dosage, damage to grain is minimised. For long-term storage, heat disinfestation needs to be integrated with other methods, such as cooling or sealed storage, to avoid reinfestation.

A technique known as ‘bake-out’, where structures are heated to around 50ºC for about one day, may hold potential as a structural treatment in grain storage sheds. Dryacide can assist bake-out effectiveness when applied to hard-to-heat surfaces such as external walls and cavities.

Research being undertaken by the CSIRO Stored Grain Research Laboratory, Canberra, aims to

Figure 4. Modern hermetic storage. Wise Joseph sacks preserve seed maize and rice by hermetic storage. (Dumaguette, Philippines). Photo HJ Banks (© CSIRO)

provide new options using heat, that will be suitable for large- and small-scale in-line disinfestation as well as small-scale on-site disinfestation.

In-transit disinfestation

Grain can be disinfested using CO^2 in freight containers. This can be done on-farm before shipping, or in transit. Instructions for the process can be found in Banks (1988), the last reference under 'Further reading'.

Vacuum packaging

Raw and processed grains are becoming increasingly popular in the health food market. Some organic farmers process and package grain for direct sale, thus adding value to the raw product. This market requires grain to be stored in retail outlets, often for a significant time, and still retain freshness and quality. The product will need to be packaged in a manner that is attractive, but that also ensures the exclusion of pests and adequate shelf life.

Inert atmosphere or vacuum packaging offers an alternative packaging for small retail quantities of grain. With this method of packaging, the product must be dry. Ground coffee is often packaged using this system. The packaging process involves filling a laminate/polythene package with a carbon dioxide and nitrogen mixture to kill insect pests, then the packaging is sealed. The packaging must have very low oxygen permeability ('barrier' film) to retain the insecticidal atmosphere. The pack must be well sealed, as insects are very good at laying eggs through the smallest of breaks.

Another approach is to pack the product in barrier film and include a sachet of Ageless®. Ageless removes the oxygen from the air in the pack to give a nitrogen atmosphere.

Contacts

Robyn Neeson
Organic Farming Liaison Officer
Industry & Investment
PMB Yanco Agricultural Institute
Yanco NSW 2703.
Phone: (02) 6951 2735; fax: (02) 6951 2620
E-mail: robyn.neeson@industry.nsw.gov.au

CSIRO Entomology
Mrs Julie Carter
Communication Manager, Entomology
Phone: (02) 6246 4040
Fax: (02) 6246 4177
Email: Julie.Carter@csiro.au

Silo sealing suppliers

You could contact a silo sealing contractor to obtain a quote on the costs associated with sealing if you have an unsealed bin. This entry is for the convenience of users and no endorsement is given or should be implied. Others may exist with products equal to or better than this company but their identity was not known at the time of compilation:

Fred Swithenbank & Co.
Lot 382, Walton St
Corrigin WA 6375
Phone: (08) 9063 2275

Aeration equipment suppliers

The following list of aeration manufacturers/ suppliers was known at the time of compiling these pages. This list is compiled for the convenience of users and no endorsement of any supplier listed is given or should be inferred. Other suppliers may exist with products equal to or better than those listed but their identity was not known at the time of compilation.

Agridry Rimik Pty Ltd
14 Molloy Street
Toowoomba QLD 4350
Phone: (07) 4631 4300
Fax: (07) 4631 4301

Customvac Australia Pty Ltd
PO Box 2426
Toowoomba QLD 4350
Phone: (07) 4634 7344

Downfields Engineering Pty Ltd
PO Box 6095
Toowoomba QLD 4350
Phone: (07) 4634 4622

Kotzur Silo
Modern Engineering & Construction
56/60 Commercial Street
Walla Walla NSW 2659
Phone: (02) 6029 4700

Smallaire Pty Ltd
King Drive
Horsham VIC 3400
Phone: (03) 5382 5688

Further reading

Stored Grain in Australia. Proceedings of the Australian Postharvest Technical Conference, Canberra 26-29 May 1998. H.J. Banks, E.J. Wright and K.A. Damcevski.(eds.) Available from CSIRO Entomology Canberra.

National Standard for Organic and Biodynamic Produce. Edition 3.4, 2009. Available from

Australian Quarantine Inspection Service. GPO Box 858, Canberra ACT 2601.
Phone: (02) 6272 3933; Freecall: 1800 020 504 or at

www.daff.gov.au/agriculture-food/food/organic-biodynamic

Australian Standard AS 2865. Available from Standards Australia, PO Box 1055, Strathfield, NSW. Phone: 1300 654 646; fax: 1300 654 949; Website: www.standards.com.au

Stalk to Store: the on-farm grain handling and storage manual. 1990. Kondinin Group, Mt Lawley, WA.

Storage, Handling & Drying Grain: a management guide for farms. A. Andrews. Queensland Department of Primary Industries. Information series Q196081.

Insects of Stored Grain. D. Rees. CSIRO Division of Entomology, GPO Box 1700, Canberra. 'Home-made Traps Keep Pests Under Wraps'. D Rees. *Farming Ahead* No. 91, July 1999.

Insect Pests in Stored Grain: a management guide for farmers. Eds. E. Sinclair and G. White. Queensland Department of Primary Industries. Information series Q190021.

Agricultural Commodity Standards Manual for Many Australian Crops is published and updated periodically by National Agricultural Commodities Marketing Association (NACMA) 530 Wilberforce Rd Wilberforce, NSW. 2756.

'Disinfestation of Durable Foodstuffs in ISO Containers using Carbon Dioxide'. H.J. Banks in *Transport of Fresh Fruit and Vegetables*, ACIAR Proceedings No. 23 pp 45-54. 1988.

Information brokers and libraries

FarmLine

This branch of the Kondinin group will put together information packages for farmers about specific grain storage questions.

Kondinin Group: www.kondinin.com.au/

Phone: 1800 677 761

CSIRO Publishing

CSIRO Publishing has a large collection of reference material on grain storage matters.
Web: www.publish.csiro.au/

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