## Keeping grain pest-free

In much of the world, wastage of food is a calamity — despite the surpluses of some regions, notably the European Economic Community with its mountains of grain and butter and lakes of milk and wine. Huge quantities of food are lost or damaged while growing on the farm, during storage, and during transport to the consumer.

Grain is one of the most stored commodities. Losses of it during storage are mainly due to pests. The worst culprits are insects, although mites, fungi, rodents, and birds are not far behind in some areas.

In addition, grain can be lost through germination or fermentation during storage.

Figures for losses are difficult to ascertain, very variable, and frequently inaccurate. The FAO estimates world-wide annual losses as 10% of all stored grain — a figure representing hundreds of millions of tonnes. Some areas, of course, fare far worse than others.

Losses in the tropics and subtropics are generally much greater than those in temperate areas. This is a burden for the many developing countries located near the equator.

Coupled with problems of climate are the familiar difficulties of lack of resources, lack of technology, and rapid increase in the population. By contrast, we in Australia now lose almost no grain during storage, and only a little during transport and handling.

Obviously, preventing losses in storage helps to increase the amount of food available to feed the world's ever-expanding population. It also gives countries and individual farmers the potential to make more money, and to raise living standards. Australia, as a major exporter of grain, has developed considerable expertise in the science of grain storage. Major innovations have come from the CSIRO Division of Entomology's Stored Grain Research Laboratory in Canberra, currently led by Dr David Evans.

While its research has primarily concerned preventing losses of stored wheat in Australia, the Laboratory has carried out much work directly applicable to the problems faced by developing countries. Some particularly relevant projects are sponsored by ACIAR (Australian Centre for International Agricultural Research).

For many years control of the insect pests of grain rested on the use of chemical insecticides, termed contact insecticides because the compounds must come into contact with the insects in

In the Philippines, Mr Peter Annis and Mr Jan van Graver conducted an experiment to test disinfestation and long-term storage of grain using carbon dioxide. This picture shows the grain being sampled before the disinfestation and storage period. The others show subsequent steps.





PVC sheeting is placed over the stack of bags, which here contain milled rice.

order to kill them. These chemicals are efficient if properly used, but have their drawbacks.

One is their price — they don't come cheap. Another is that they are toxic when in concentrated form, and so must be handled carefully to avoid constituting a hazard to workers.

However, they have no toxic effects on mammals at the low concentrations in which they occur in grain that has been properly treated. Nevertheless, increasing consumer pressure for totally pesticide-free grain makes the problem of chemical residues another potential drawback. In fact, demand for pesticide-free grain is a major driving force in the development of alternative strategies of disinfestation and storage.

Another important drawback is the problem of resistance to pesticides. Continued use of insecticides sets up an artificial selection process, and resistant strains of insects come to predominate. (The process is familiar to the medical and veterinary professions, which face the problem of bacterial resistance to antibiotics.)

The chemicals used as contact insecticides may come in the form of water-miscible compounds, usually applied as a spray. Important alternatives are phosphine and methyl bromide — two gases commonly used to disinfest grain. Resistance to normal levels of phosphine, it appears, can develop quite rapidly in some insects, and is already a severe problem in Bangladesh.

To avoid the development of resistance, the pesticides must be applied in such a way that all the pests within a volume of grain receive sufficient to kill them. Sub-lethal doses, which result in all the insects being exposed to the compound but a few surviving, will merely encourage the development of resistance. Conversely, too large a dose leaves excessive pesticide residues.

Further difficulties relate to the different susceptibilities of the various pests. An insecticide dose sufficient to give a complete kill for one species may be only sub-lethal for another.

Frequently grain may need to be stored for prolonged periods — possibly up to a year. Pesticides, like many complex compounds, have a slow but continous rate of breakdown or decay, and so towards the end of a prolonged storage pesticide levels may become too low to be effective.

The rate of pesticide breakdown depends chiefly on temperature and humidity. And this is where the work of Dr Jim Desmarchelier, of the Stored Grain Laboratory, comes into the story.

He has developed mathematical models, based

on well-known principles governing the kinetics of chemical decay, to predict the rate of breakdown of a number of different insecticides experiencing differing temperature and humidity regimes. Using his models, scientists anywhere in the world can now calculate the precise insecticide dosage to use for their particular commodity, climatic conditions, and period of storage, and know that this dosage will not be sub-lethal.

In general, the higher the temperature and relative humidity rise, the more rapidly the pesticides decay. In Australia, more often than not, temperatures outside grain silos are high (about 30°C) and relative humidities low (50% or less). Similar conditions apply to much of North Africa, northern India. and Pakistan. By contrast, in parts of China, the temperature may be about 20°C but the relative humidity may be 65% or more.

As well as a reduction in insecticide breakdown with lower temperatures, a reduction in toxicity may occur in some — for example, the organophosphorus compounds. This too must be considered when planning insecticide doses for particular storage conditions and pest types.

However, Dr Desmarchelier found that the increased persistence of these

insecticides at low temperatures more than compensated for the decrease in their toxicity. He also showed that some compounds, such as synthetic pyrethroids, are in fact more toxic at lower temperatures. These important findings mean that the quantity of insecticide necessary for effective disinfestation can be considerably reduced for storages equipped with cooling, thus cutting expenditure on pesticides and decreasing residue levels.

Under ACIAR sponsorship, Dr Desmarchelier's studies on the kinetics of pesticide decay are being extended to cover a wide range of commodities stored under the warm humid conditions of South-East Asia.

In warm countries, by means of efficient insulation and judicious use of mechanical aeration during the coolest hours, it is possible to keep grain storages cool. In theory, farmers in many tropical areas could, with minimum expenditure, prevent the temperature within a store exceeding the temperature that pertains outside during the two coolest daylight hours — on average about 20°C.

Maintaining this temperature would serve to slow both insect population growth and insecticide breakdown.

But in practice, most grain storages in tropical countries

Sealing in a small port for the introduction of the gas. Any small holes can also be sealed in the same way.



are not cooled in this way, partly because of lack of resources, and partly because of fear of increasing grain moisture content by ventilating with humid air.

Relevant to this is a solar-regenerated desiccantbed cooling system designed and patented by CSIRO. It allows use of the cool night air in the tropics without its inherent problems of high humidity, which could cause condensation that can damage grain. The combination of coolness and dryness that it produces in the air is inimical to the insects.

The device is based on a simple concept proposed by Dr Graham Thorpe of CSIRO's former Agricultural Engineering Group, now part of the Stored Grain Research Laboratory. Put simply, it consists of a solar panel containing a bed of the desiccant silica gel. During the day, sunlight heats this and so dries it. At night, it then dehumidifies the cooler air, which a fan blows across it.

The result is relatively cool, dry air with which to ventilate a grain store without increasing the moisture content of the grain. Alcan Australia Pty Ltd made the first commercial prototype of the machine, and Dr Thorpe is hoping that a company will shortly be found to produce and market it.

As well as in water-based sprays, insecticides can be applied with the active compound adsorbed onto dust-sized particles of a 'carrier' material, often clay.

Each method has its good and bad points. Spraying requires an expensive spray-pump, but the active component, made up with water on the site, travels in concentrated form and is thus cheaper to transport than the dust. Dusts have the advantages that they adhere readily to the insects' bodies, and also that less of the pesticide actually enters the grain.

This last point is very important. Research by Dr Desmarchelier and others has shown that, when a pesticide is applied as a spray, most of the active chemical is absorbed by the grains. Consequently, only a low concentration of the compounds remains on the outside of the grains—the site from which most insect pests would pick them up.

Before the carbon dioxide is introduced, the sheeting is tested for any leakage — by creating a partial vacuum within it and measuring how long this remains.





Carbon dioxide from cylinders enters at the bottom of the stack.

With carriers (or dusts), most of the compound is not absorbed by the grain but is carried on its surface. In fact, the concentration of the insecticide can be as much as 90 000 times greater on the outside of the dust particles than on the outside of sprayed grains!

<sup>•</sup> Dusts have a further advantage in that they can be removed by washing before the grain is consumed. This may not be essential, as dusts are applied at the very low concentration of 150–250 g per tonne of grain (about one part in 5000.) However, removal does help to provide a commodity that contains very much lower pesticide residues than those remaining after conventional insecticide spray treatments.

Grain can be safely stored without the use of any chemical insecticides whatsoever; all that is required is to keep the grain in an atmosphere inimical to the pests. Such an atmosphere may contain large amounts of carbon dioxide (35% or more), which, in effect, acts as a fumigant, killing the insects by its toxicity at high concentrations. Alternatively, oxygen levels may be reduced to 1% or less; the lack of oxygen then kills the pests.

Obviously the storage container must be effectively leak-free to maintain these levels. To achieve this can take considerable effort, but the store would have to be air-tight to fumigate anyway, and a controlled atmosphere has the advantage over pesticides of leaving absolutely no residues.

Of course, a gas-tight bulk storage is expensive and difficult to build — and to make an old storage gas-tight can be both costly and laborious. An alternative, therefore, is to create a gas-tight area within a storage.

A solution along these lines for less-developed countries is being studied by the Stored Grain Research Laboratory's Mr Peter Annis. His work takes account of the fact that in many developing countries grain is kept and transported in 50- to 100-kg bags, made of hessian or woven polypropylene. The bags are stored in stacks of 100–500 tonnes.

For long-term storage and disinfestation, using carbon dioxide, Mr Annis recommends a method that involves enveloping the stacks with PVC sheeting, and releasing carbon dioxide (from cylinders) under the sealed sheet. A vent at the top allows the air to escape as it is displaced upwards.

Although the structure is well sealed, over time the carbon dioxide concentration falls because of minute leaks in the sheeting, and slow permeation of the gas through the PVC.

However, the sheeting certainly prevents the entry of insects. Provided the concentration of carbon dioxide remains above 35% for at least 15 days, the grain will be disinfested.

Mr Annis' experiments have shown that, with an initial carbon dioxide concentration of 80%, the atmosphere within the cover will retain a carbon dioxide level greater than 35% for at least 30 days — a more than adequate time span for total disinfestation.

The cost of carbon dioxide for long-term storage compares well with that of phosphine and methyl bromide. Moreover, carbon dioxide is locally produced whereas developing countries must generally import phosphine.

A further advance in the generation of controlled

intriguing device designed by Dr Jonathan Banks, also within the Laboratory. Starting with a basic internal combustion engine, he has developed a machine that runs off liquid petroleum gas and produces an atmosphere comprising 85% nitrogen, 15% carbon dioxide, and, crucially, insignificant levels of oxygen. The concept has proved sound, the machine having run well in extensive field trials.

Dr Banks' engine was designed for remote areas of Australia, which face problems similar to those in the agricultural regions of many developing countries. It

The process is complete, and the storage period commences. During this time some of the carbon dioxide will find its way into the grain, and the billowing appearance of the sheeting will slowly disappear.





Scanning electron micrographs of two relatively common and widespread grain pests: *Tribolium castaneum* (left), the flour beetle, and *Sitophilus granarius* (right), the granary weevil. Both are but a few millimetres long.

obviates the need for

expensive transport of bottled gases from cities. The engine itself can be carried easily from one silo to another on a trailer, and it requires only minimal maintenance. It is cheap and does not rely on sophisticated high technology — and its production, by the Melbournebased company Capco Pty Ltd, should start soon.

Capco expects good overseas sales — with the United States and China as major foreign markets. Within Australia, the large wheat-growing areas of Western Australia and New South Wales should be the major benificiaries of this useful device.

Various other ideas for the control of grain pests, with application both in Australia and overseas, are now being developed through experimentation and field trials. Most research involves improving the cost-effectiveness, efficacy, and safety of concepts that date, in essence, from the 1920s if not before, such as heat treatment, controlled atmospheres, cooling and drying, and toxic compounds.

Newer ideas that the Laboratory is studying at a more experimental level include the use of pheromones to hamper insect reproduction or to act as baits for insect traps.

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Selective treatments. including combinations of pyrethroid and organophosphorus insecticides for control of stored product Coleoptera at two temperatures. J.M.Desmarchelier. Journal of Stored Product Research, 1977, 13, 129-37. Moving towards insecticide-free storage of grain in Australia. D.E. Evans. Proceedings of the Fourth Australian Applied Entomological Research Conference - September 1984. Behaviour of pesticide residues. J.M. Desmarchelier. Proceedings of the Seminar on Pesticides and Humid Tropical Grain Storage Systems, Manila, 1985 (in press). Current methods and potential systems for production of controlled atmospheres for grain storage. H.J. Banks. Proceedings of Practical Aspects of Controlled Atmosphere and Fumigation in Grain Storage, Perth, 11-22 April 1983.