INCREASING HEATING RATE AND DECREASING DISINFESTATION TEMPERATURE FOR MORE AFFORDABLE HEAT DISINFESTATION OF GRAIN.

S. J. Beckett and E. J. Wright*.

Stored Grain Research Laboratory, CSIRO Entomology, G.P.O. Box 1700, Canberra, A.C.T 2601, Australia.

Serious problems have been identified for the future of chemical methods of grain disinfestation. Methyl bromide, which has been a very valuable fumigant for rapid disinfestation is becoming increasingly costly and is being phased out under the Montreal Protocol. Phosphine fumigation is slow, progressively being subjected to regulatory restrictions and suffering from growing amounts of insect resistance. Moreover, pesticide residues in grain are becoming increasingly unacceptable to markets in general and resistance to important protectants is widespread.

Compared to the use of chemical methods, heat disinfestation has the potential for high market acceptance by being residue free. It is also, potentially, at least as rapid as methyl bromide fumigation. Due to its versatility of scale, it could be used to disinfest farm-stored grain before delivery or meet the most urgent shipping schedule by being used in-line to treat large tonnages at export terminals.

In the past, the use of heat disinfestation has been seriously constrained by its high capital and running costs in the face of competing cheap chemical alternatives. Therefore, adoption of heat disinfestation depends to a large part on a significant reduction in the cost of heating by noticeably reducing the energy requirements needed to kill insects. This has been explored in two ways. First, by significantly lowering the treatment temperature and holding the grain at that temperature, without further energy input, for a time sufficient for disinfestation. Second, by initially heating the grain, and thus the target insects, very rapidly to achieve a heat-shock effect and thereby bring about faster mortality.

To achieve the required treatment conditions, insect infested grain was heated in a spouted bed similar to that described by Claflin et al. (1986). Four kg of grain were dropped into an air flow sufficient to create a fluidising effect on the particles and thus uniform heating. Different rates of heating were obtained by using a range of air temperatures from ambient to 200°C. The range of grain temperatures targeted was between 49 and 61°C, where 49°C was obtained in just under 2 minutes using 70°C air and under 15 seconds using 200°C air, and 61°C was obtained in approximately 5 minutes using 70°C air and just under 30 seconds using 200°C air. The times required to obtain a given grain temperature for a given heating rate could then be modelled (Fig. 1).

After a specified treatment time, the air flow was turned off so that the grain would come to rest at the bottom of the spouted bed. The bed was constructed in such a way that the temperature of the grain was kept constant for the duration of the experiment. Samples of grain were removed from the 4 kg batch over time and rapidly cooled by fluidising with ambient air before being incubated at 30°C / 50% r.h. for 35 days so any surviving immature insects would complete development. The species used was *Rhyzopertha dominica* as it develops internally in the grain and is considered one of the most heat tolerant pests (Dermott and Evans, 1978). By using a mixed age population and monitoring adult emergence weekly, any variation in immature susceptibility could be observed (Beckett et al. 1998).

Mortality rates for immature stages of *R. dominica* were calculated using probit analysis over a range of grain temperatures from 49°C to 61°C. It appeared that when the rate of heating was initially increased, there was a significant reduction in the time required to achieve a given level of mortality at a given grain temperature. As the rate of heating was increased further, there was, at best, only a marginal further reduction in treatment time (Fig.2). It was likely that the shorter heating times were more liable to result in an uneven distribution of temperature throughout the grain bulk and the further increase in air temperature did not significantly increase the rate of heat penetration.

A comparison of the theoretical cost of heating for each of the potential treatments showed that significant savings to running costs could be made (Fig. 3). While increased energy efficiency was achieved with increased rate of heating and decreased treatment temperatures, this benefit must be associated with increased holding times needed for disinfestation. For example, a theoretical treatment at 50°C, where that temperature was obtained in under 15 seconds, would require over 19 hours to achieve 99.9% mortality. However, at only 5°C higher, if obtained in under 20 seconds, the treatment would be completed in 15 minutes. By 60°C, 99.9% mortality would be achieved before the temperature was reached in under 25 seconds.

The spouted bed is arguably a more efficient means of heating grain using air, compared to a fluid-bed or pneumatic conveyor (Sutherland et al., 1986). However, alternative systems, such as those that make use of concurrent air and grain flow, may be even more cost effective. To scale up to a commercial spouted bed operation that takes advantage of the efficiencies described here requires increasing the air inlet temperature and, depending on tonnage, having several beds in series (Sutherland et al., 1986). A holding stage for heat soakage may also be necessary before cooling is carried out. This imposes engineering challenges and consideration of added capital costs. This research on the effect of heating rates and temperature/time conditions on insect mortality will allow the running costs of any spouted bed system to be calculated for a given treatment and throughput so that the most cost effective system can be designed. Similarly, the running costs of other systems can also be calculated once the energy needed to obtain the required conditions is determined.

REFERENCES

Beckett S. J., Morton R. and Darby J. A. (1998) The mortality of *Rhyzopertha dominica* (F.) (Coleoptera: Bostrychidae) and *Sitophilus oryzae* (L.) (Coleoptera:

Curculionidae) at moderate temperatures. Journal of Stored Products Research. 34, 363-376.
Claflin J. K., Evans D. E., Fane A. G. and Hill R. J. (1986) The thermal disinfestation of wheat in a spouted bed. Journal of Stored Products Research. 22, 153-161.
Dermott T. and Evans D. E. (1978) An evaluation of fluidised-bed heating as a means of disinfesting wheat. Journal of Stored Products Research. 14, 1-12.
Sutherland J. W., Evans D. E., Fane A. G. and Thorpe G. R. (1986) Disinfestation of grain with heated air. In: 4th International Working Conference on Stored-Product Protection, Tel Aviv, Israel, September, 1986.

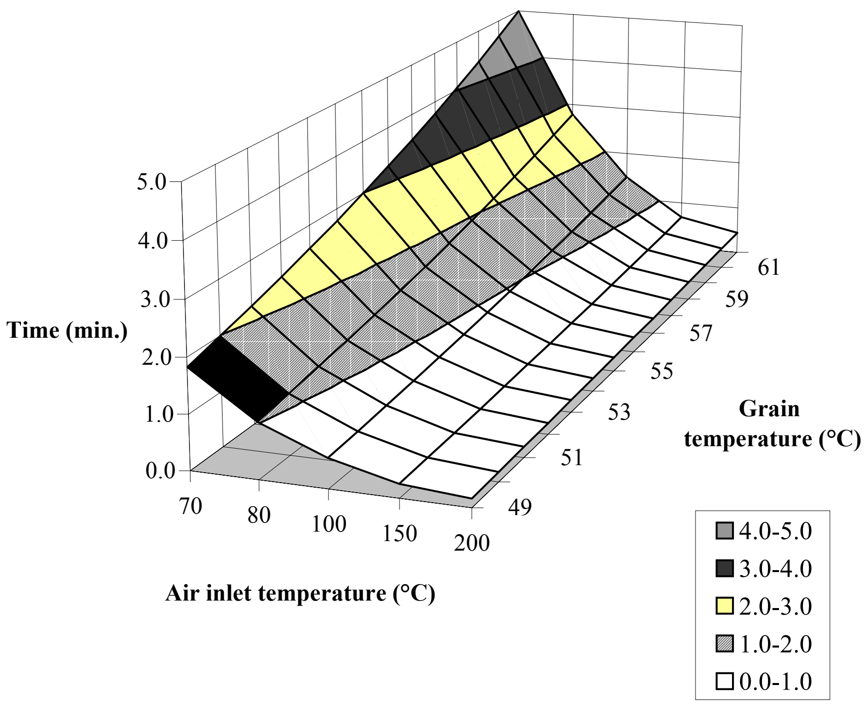

Fig. 1. The time required to heat grain to a range of temperatures using five different inlet temperatures. Response surface is shaded to show sets of heating times.

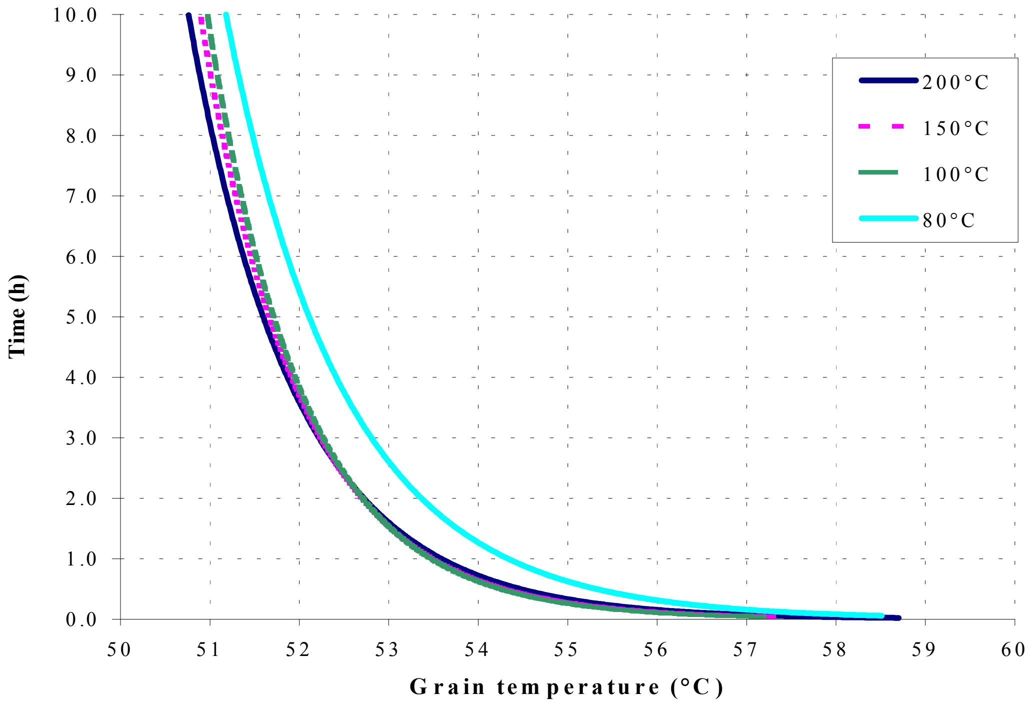

Fig. 2. The times required to achieve 99.9% mortality of *Rhyzopertha dominica* at a range of grain temperatures obtained from four inlet temperatures.

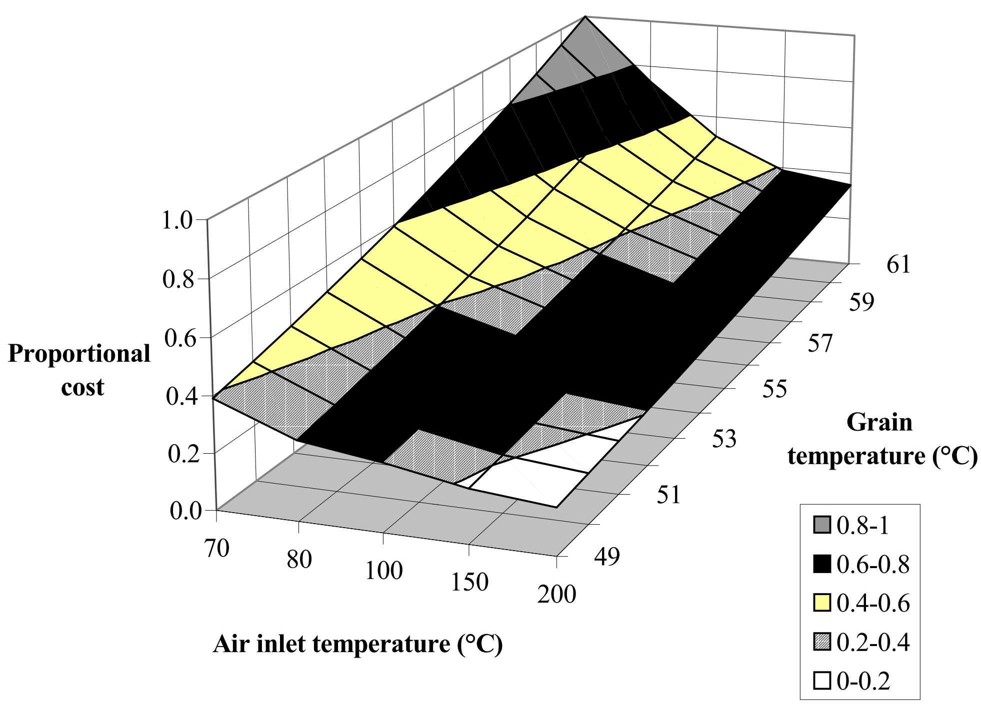

Fig. 3. The proportional cost of heating grain to a range of temperatures using five different inlet temperatures. Response surface is shaded to show sets of proportional cost.