Commodity disinfestation treatments with heat

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Abstract

Heat disinfestation treatment requirements for stored products and perishable commodities are compared. Typically, grain disinfestation treatments are rapid and use relatively high temperatures. By contrast, commodity treatments are slower and use treatments at the low end of the mortality scale for insects. To date, research on these two groups of products has proceeded independently. There is clearly scope to relate the two disinfestation processes in the area of lethal heat response of the insects. It is also possible that heat sensitive seeds could be disinfested without unacceptable damage by use of perishable commodity heat treatment schedules. The possible use of aeration facilities to heat grain during summer months is considered.

Introduction

Food commodities which are susceptible to insect attack typically require disinfestation procedures at one or more stages between harvesting and consumption. Consumer preference is becoming increasingly antagonistic to chemical residues resulting from disinfestation and protection treatments. Physical treatments with heat, cold or irradiation are technically regarded as residue free. In this paper consideration is given to heat disinfestation possibilities at temperatures near the lethal threshold.

Heat Disinfestation Treatments

Historically, heating has been used to disinfest grains and other stored commodities both industrially and domestically. Laboratory media can be sterilised by heating in an oven to 60°C for 10 minutes (Winks 1981). Bulk handled grain can be disinfested by fluidised bed heating to 80, 70 or 60°C for 4, 6 or 12 minutes, respectively (Dermott and Evans 1978). These illustrate the time × temperature relationship of disinfestation with heat. It follows that there is the possibility of using extended times at temperatures just above the upper threshold for insect survival.

Heat treatment has been used since around 1930 for post-harvest disinfestation of perishable commodities (Baker 1939). Vapour-heat treatments in which citrus fruit was disinfested of fruit flies used steam to heat and humidify the storage atmosphere. Treatment involved extended heating times of around 8 hours at a temperature of 44°C. The treatment was superseded by more efficient ethylene dibromide fumigation but was subsequently revived when the chemical was deregistered in the USA because of residue problems (Anon. 1984).

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Modern hot-air treatments for fruit involve temperatures between 44 and 47°C often held for times ranging from a few minutes to some hours (Sugimoto et al. 1983; Armstrong et al. 1989; Corcoran et al. 1993).

Although heat treatment effects have been shown to be the product of time and temperature, there are indications that the relationship is not linear (Baker 1939). This is not unexpected as more than one physiological system is likely to be affected, each with a differing threshold. Similarly, the responses of insect species can differ in a non-parallel fashion (Fig. 1).

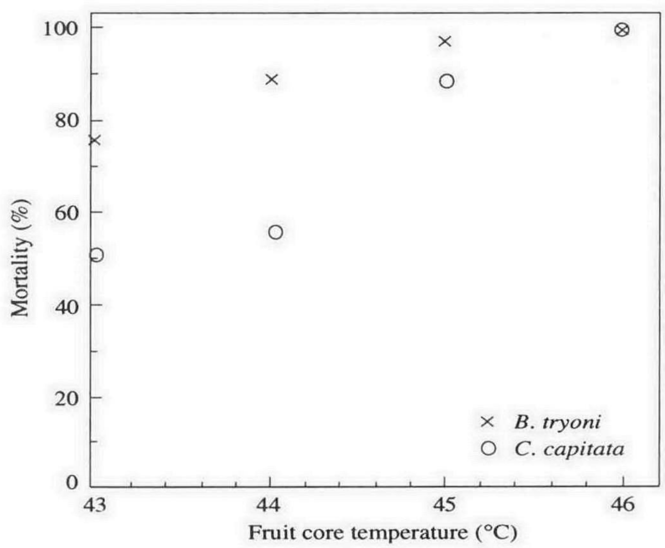

Fig. 1. Responses of two fruit fly species to lethal heat in fruit.

Studies on the responses of grain insects to heat have been either within the developmental range, with upper limits of 35–40°C (White 1987), or in the rapidly lethal range of 60–80°C (Evans and Dermott 1978). While population studies can sometimes be used to identify temperatures at which development ceases there appears to be a definite possibility of using heating to disinfest grain, in the mode of fruit, at temperatures between these two ranges where extended heating times are possible.

The source of heating within these temperature ranges for stored grain is probably limited to ambient air. In regions such as Queensland, ambient air in excess of 40°C is frequently available in summer, and headspace air in horizontal storages can exceed 50°C for many days in summer months (White 1987). This raises the possibility of using existing aeration technology. Aeration has a major advantage of homogenising grain temperatures in a bulk, and may be used for this purpose on summer nights when no cooling advantage is available. Subject to no disadvantage to grain moisture, this is considered to have previously unexploited possibilities. For seeds, the methodology for treating fruit against fruit flies may have some application. Typical fruit disinfestation methodology is described in the next part of this paper.

The efficacies required for quarantine disinfestation of fruit are typically of the order of 99.99 to 99.9968% (Probit 8.7 to 9). These are much higher than for stored grain where 99.9% is considered very efficacious. This gives some assurance that the treatments are likely to be applicable to the differing ordinal groups which infest stored grain. However, actual efficacies would need to be determined.

Fruit Fly Disinfestation

Because of the low incidence of fruit fly permissible in commerce, treatments need to be proven on laboratory infested fruit. It is normal to do small-scale trials on eggs and instars to determine the most tolerant stage. Prior development studies in the fruit need to be done to enable each stage to be targeted. These are followed by larger-scale trials to determine the time and temperature combination required to achieve the required treatment efficacy. Finally, large-scale trials are done using the most tolerant stage (for fruit flies, normally mature eggs). For an efficacy of 99.99% at the 95% confidence level 30000 insects need to be treated without survivors and for 99.9968%, 100000 (Couey and Chew 1986). For mangoes 46.5 or 47°C is needed, for citrus and tomatoes 44°C, and for zucchini 45°C.

Hot-Air Disinfestation Units

For fruit, these units typically blow or draw air vertically through fruit stacked in trays. These trays have meshed bottoms but closed sides and columns up to 3 metres high can be treated. The air flow can be by means of a fan at the top of the stack or the flow may be reversed depending on the design. Fans in the treatment chamber ensure homogeneity of temperature and humidity. Heating energy is typically gas, oil, electricity or industrial steam.

Air is re-conditioned in a plenum separate from the treatment chamber by heating and humidifying. Depending on the fruit to be treated, humidity can be kept below dewpoint on the fruit or at higher humidities up to fully saturated. Precise control is achieved by computer software.

These enable temperature differentials as low as 1°C between treatment air and final product temperature. Commercial units in general use can treat up to 20 t in a 2–4 hour cycle. Fruit damage can occur depending on maturity and growing history but the incidence of damage is low and manageable.

Response of Insects to Heat at Disinfestation Temperatures

Studies using hot-water dipping by Jang (1986), Heard et al. (1991) and Corcoran (1993) have shown that the response of eggs and other stages varies with developmental age. Also, response lines for different temperatures are not parallel (Corcoran 1993).

Corresponding studies with stored-product insects would be necessary. However, because of the extended time envisaged to treat grain, all developmental stages would be exposed to the conditions. A further effect requiring investigation would be acclimation for the heating patterns experienced. It is not unusual for fruit flies to show two types of lethal effect, one acute, the other chronic. Chronic effects on eggs and larvae can be delayed until the pupal stage, with failure of adults to eclode most common.

General discussion

This paper is conceptual in nature. It is suggested that the heat disinfestation schedules now well established for fruit flies in fruit, could have applicability. If hot air in head spaces or even hot external ambient summer air could be utilised, costs could be very low, especially if convection systems could be devised. The method would have more applicability to horizontal than to vertical storages due to the greater volume of hot air available. Enhancement of head space temperatures could be obtained temporarily by black sheeting.

An important consideration would be the effects on grain and seeds. For grain, the temperatures envisaged are no higher than would be experienced normally in parts of grain bulks during summer months in Australia (White 1988a). These do not cause unacceptable, if any, loss of quality. Harty and Heather (1984) found evidence that most seeds would tolerate temperatures of 50°C for short periods. Therefore, although extended treatment times may not be desirable, heat disinfestation systems such as those used for heat treating fruit with low humidity air could provide quick, reliable residue free treatment. These would have special benefits where alternative chemical disinfestation systems have known phytotoxic effects.

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