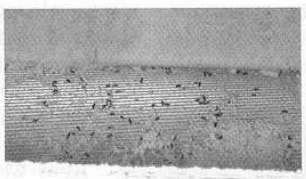
Heat treatment: A viable alternative to methyl bromide for managing insects

by Anil Menon, Bhadriraju Subramanyam, Alan K. Dowdy and Rennie Roesli

Methyl bromide has been used for decades as a space fumigant to disinfest flour mills, feed mills and other food-processing plants. With the impending phase-out of methyl bromide by both the developed and developing nations, effective alternatives are being sought as a replacement.

The use of high temperatures (at or above 122°F or 50°C) has been an effective, safe and viable alternative to methyl bromide fumigation for insect management in food-handling establishments. The use of this technology, however, is not new.



Red flour beetles killed in flour mill roll stands after a heat treatment.

Heat from the sun (sun drying) has been used since ancient times for killing stored-grain insects. The first report of the use of heat in a U.S. flour mill dates back to 1901. A miller used heat to control flour-infesting insects after he observed insects dying in the vicinity of steam pipes leading to a corn dryer.

In 1911, G.A. Dean investigated the practical application of heat and its effectiveness on insects. He proposed a method that was successfully adopted by some mills across the country. However, this technology never gained widespread acceptance because of warping and cracking of wooden structural components and equipment.

EFFECT OF HEAT ON INSECTS.

Insects are susceptible to extremely low or high temperatures. Generally, across all stored-product insects, development stops at or below 61°F (16°C) and at or above 100°F (38°C). The optimum temperatures for maximum survival, faster development and maximum reproduction range from 82° to 93°F (28° to 34°C).

High temperatures kill or adversely affect the development of eggs, larvae, pupae and adults of stored-product insects (see table below). However, the magnitude of adverse effects vary with the insect species and the developmental stage exposed.

How does heat kill insects? Death may be due to desiccation/dehydration, or adverse changes in the structure of proteins and lipids. Although exposures to temperatures at or above 122°F (50°C) are required to cause rapid death, insects may experience problems in development, survival, and reproduction between 104° and 122°F (40° and 50°C).

To effectively suppress insect populations in food-handling establishments, it is essential to raise the temperatures to about 122°F and hold it at this level for about 24 hours. Depending on the insect species and the life stage exposed, death can occur within minutes or a few hours at these high temperatures.

It is important to provide enough time for the heat to penetrate all parts of the facility, especially within equipment and hidden spaces. Insects seeking refuge within bulk grain or flour may escape the heat treatment because of poor heat transfer. Therefore, proper sanitation of the plant, including the equipment, is essential for enhancing the efficacy of a heat treatment.

A heat treatment, from set-up to cool down, typically lasts from 30 to 48 hours. Heat treatments are frequently scheduled during a weekend or over holidays so that it does not disrupt regular plant production activities.

ART OR SCIENCE? Heat treatment becomes an art when coupled with past experience, especially for determining the amount of heat required and how best to use fans to distribute heat within a food-handling establishment.

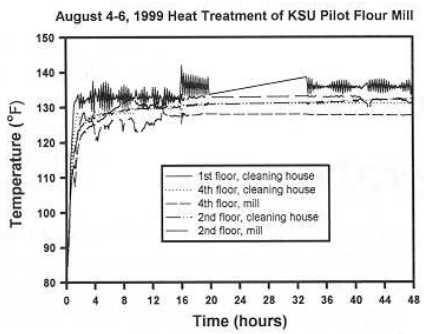
There have been limited scientific studies that deal with the optimum use of heat within a facility, the minimum amount of heat required to kill insects, the role of humidity on insect survival, adverse effects on insects surviving a heat treatment, determining heater requirements and economics of heat treatments. Kansas State University, Manhattan, Kansas, U.S., and the U.S. Department of Agriculture have been conducting experiments to answer a few of these questions.

One experiment simulated heat treatment in programmable ovens to determine the effects of increasing temperatures on developmental time, survival and reproduction of several stored-product insects. The populations of stored-product insects in K-State's pilot flour and feed mills were monitored before and after a heat treatment to provide a quantitative basis for determining effectiveness of heat treatments. If insect populations increased in certain areas of the food-handling establishment, control efforts could be focused in these problematic areas.

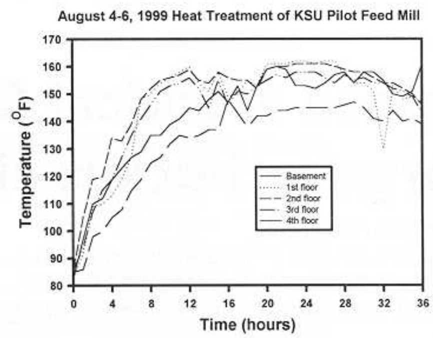
Response of stored-product insects to lethal temperatures

Temperature range (°C)	Effects
122°-140°F (50°C)	Death in minutes
113°F (45°C)	Death in hours
95°F (35°C)	Development stops
91° - 95°F (33°-35°C)	Development time is prolonged; reduced oviposition and survival

Source: Modified from Paul Fields (1992, Journal of Stored Products Research, Vol. 28, pp. 89-118)



Temperature rise in selected floors of the KSU flour mill. (Data courtesy of Aggreko)



Temperature rise in five floors of the KSU feed mill. (Data courtesy of Rupp Industries)

Current experiments deal with calculating costs associated with heat treatments. Coupled with the information on the degree and duration of insect suppression, this information may lead to a more cost-effective means of managing insect populations in food-handling establishments.

A heat treatment workshop held at K-State last August included a heat treatment of the Department of Grain Science and Industry's pilot flour and feed mills.

The flour mill was heated with electric heaters, and the feed mill with gas heaters. The starting temperature was about 85°F (29°C) and the target temperature of 122°F was reached within three hours.

Eggs, larvae, and adults of the red and confused flour beetle were placed in cages, with and without flour, in the flour mill during the treatment. All stages were killed within the first three hours. Dead insects also were observed in roll stands and beneath several pieces of equipment.

OTHER RESEARCH RESULTS. A few months before the workshop, in June 1999, the pilot flour mill was heated with gas heaters. Temperatures in each of the four floors of the cleaning house and flour mill were monitored with 10 temperature measuring devices scattered throughout the floor. Temperatures also were measured during the August heat treatment with electric heaters.

A comparison of contour maps of temperatures obtained across each floor with gas and electric heaters showed the temperature distributions to be essentially similar. Also similar was the time it took to reach 122°F (11 to 24 hours) and the number of hours that temperatures above 122°F — the level at which all exposed life stages of stored product insects are killed — were maintained (13 to 28 hours).

The comparison presented is qualitative, and should not be construed as an endorsement of gas heaters over electric and vice versa. Grain or flour is a poor conductor of heat, and during a heat treatment the high temperatures required to kill insects may not be attained in grain and flour residues. Therefore, sanitation of equipment pieces, spouts and storage bins is important to increase the effectiveness of a heat treatment. Opening up the various pieces of equipment does not significantly improve heat penetration.

Another experiment sought to determine whether humidity affects insect survival during a heat treatment. The mortality of adult red flour beetles at varying humidities (24% to 78%) was studied during a November 1999 steam heat treatment in the pilot flour mill. At temperatures above 110°F (43°C) and exposures greater than 21 hours, there was 100% mortality of the adult beetles, irrespective of the level of humidity.

Pheromone traps also are important pest monitoring tools in food-handling establishments. These traps, baited with specific insect pheromones or lures, are placed within the facility for early detection of insects and also to judge the degree and duration of insect suppression. Depending on the number of traps used, it may be cumbersome to remove traps before and replace them after a heat treatment.

Tests were carried out to determine if heat had any deleterious effect on the condition and efficacy of the pheromone traps. The sticky material in traps was unaffected by exposure to high temperatures. Also, the pheromone concentrations of the Indianmeal moth and the almond moth lures showed very little degradation. However, the concentration of the red/confused flour beetle lures dropped nearly 40% during the heat treatment. Therefore, during a heat treatment, it is not necessary to remove Indianmeal moth and almond moth traps and lures, but it is important to remove and replace the red or confused flour beetle lures.

How quickly do insects return following a heat treatment? Insect populations were reduced after a heat treatment, and hundreds of insects inside the equipment also died, as seen from floor counts of dead insects. However, small numbers of insects of various species were captured in traps within two to four weeks after a heat treatment. The insects may have entered the facility in raw ingredients or may have re-infested from sources within the facility that were not eliminated by heat. A similar rebound in populations also can be observed following a fumigation of the facility. ■

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Information about the 1999 K-State heat treatment workshop is available on CD-ROM. For a copy, log on to http://www.oznet.ksu.edu/dp_grsi and choose the "Heat Treatment Workshop" link. Current research results on heat treatment also are posted at this site.

Questions or comments about this article may be sent to worldgrain@sosland.com.