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A novel method for analyzing grain facility heat treatment data ☆

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Abstract

Use of elevated temperatures ($\geqslant 50^\circ C$) in food processing facilities for management of stored-product insects is a viable alternative to fumigation with methyl bromide. Effectiveness of heat treatment in controlling insects is determined by attainment of uniform temperatures between 50°C and 60°C. A unique surface area method was proposed and developed to assess the effectiveness of heat distribution. The pilot flour mill at Kansas State University, Manhattan, KS, was heated with natural gas (positive pressure) and electric (neutral pressure) heaters in June and August 1999, respectively. The proposed surface area method compared the two different heating systems and successfully quantified the under- and over-heated sections of the treated rooms at any given time during the treatments. A two-parameter nonlinear log-logistic equation was used to describe and predict the general trend in the floor surface area that is under 50°C as a function of treatment time, and percentage of floor surface area as a function of maximum floor temperature. With electric heating, time delays for temperature increase were considerably shorter than with gas heating. However, electric heating resulted in substantial amounts of under-heated floor areas ($T < 50^\circ$C) throughout the facility at the end of the heat treatment. The methods provided here, especially when coupled with the contour maps of temperature, can be used to design and evaluate heat treatment strategies in grain and food processing facilities.

Keywords: Heat treatment; Temperature distribution; Modeling; Nonlinear regression; Stored-product insects

☆ Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by the USDA implies no approval of the product to the exclusion of others that may also be suitable.

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1. Introduction

Eliminating or reducing the population of insects in grain processing and storage facilities is a formidable task. Methyl bromide, a space fumigant routinely used for disinfestations of food processing facilities, is to be phased out by 2005 in developed nations because of its stratospheric ozone-depleting effect (Makhijani and Gurney, 1995; Fields and White, 2001); therefore, alternatives to replace methyl bromide are urgently needed.

Use of extreme temperatures or heat treatment has long been recognized as an effective control measure for insects associated with food processing facilities such as flour mills (Dean, 1911, 1913; Fields, 1992). During heat treatment, the entire facility or portions of it is heated to 50°–60°C and these temperatures are held for 24–36 h (Imholte and Imholte-Tauscher, 1999). The 24–36 h heat treatment period is necessary for the heat to penetrate equipment and wall voids to kill insects harboring inside. However, to kill exposed insects, exposure at $T > 50$°C for less than 12 h is sufficient (Fields, 1992; Dowdy, 1999; Roesli et al., 2003). Heat treatment does not require toxic chemicals or chemical pesticides; therefore, workers are better protected and there are no regulatory or chemical barriers (Heaps, 1988). Temperatures necessary to kill many species of stored-product insects have been reported and are attainable at most food processing facilities with gas, electric, or steam heaters (Fields, 1992; Dowdy and Fields, 2002; Mahroof et al., 2003a,b; Roesli et al., 2003). Heat treatment to control stored-product insects was widely used at the turn of the 20th century but later avoided due to equipment and structural damage (Heaps, 1994; Heaps and Black, 1994). Most modern food and grain buildings can withstand temperatures of 50°–60°C for extended periods of time. Caution should still be exercised, to prevent damage to heat-sensitive equipment. Ideally heat treatment should be done according to need, not on a calendar basis, and must be worked into a facility's master plan of sanitation for pest control along with housekeeping and competent inspections (Heaps, 1996; Sheppard, 1998).

In this study, a new method was developed to evaluate and compare the performance of two heat treatment systems (natural gas heating versus electric heating) at different floors of a pilot grain facility. Specific objectives were: (1) to develop a new method for evaluating heat treatments based on analysis of (a) percentages of floor surface areas that were less than 50°C as the treatments progress, and (b) percentages of floor surface areas that do not reach 50°C at the end of the treatments; (2) to correlate the percentage of floor surface area to maximum floor temperature; and (3) to investigate temperature distributions across the heat-treated rooms with use of contour plots.

2. Materials and methods

The pilot flour mill and cleaning house of the first, second, third, and fourth floors of the Department of Grain Science and Industry, Kansas State University (Manhattan, KS) were heat treated. Dimensions of the first floor of the mill were 24 m × 21 m × 4 m. Dimensions of the second, third, and fourth floor of the mill were 17 m × 12 m × 4 m. Treatments were performed at two different dates in 1999, June 25–27 with gas heaters and August 4–6 with electric heaters. Minimum, maximum and average ambient outside temperatures during the days of the heat treatments for June were 18°C, 32.2°C, and 25.1°C, respectively. Minimum, maximum and