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Cold temperature disinfestation of bagged flour

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ABSTRACT

We conducted studies using a commercial freezer maintained at −17.8 °C to determine the time needed to kill *Tribolium castaneum* eggs in a pallet of flour. Each bag weighed 22.7 kg, and there were 5 bags in each of 10 layers. The dimensions of the pallet were 109-cm wide by 132-cm long by 123-cm tall, and the weight of the stacked pallet was approximately 1152 kg. We conducted tests for nine internal goal temperatures of −12, −10, −8, −6, −4, −2, 0, 4 and 8 °C. Internal temperatures in the most central location of the flour pallet reached: −11.0, −9.4, −6.9, −5.0, −3.5, −1.6, −0.1, 3.3, and 5.6 °C and were achieved after 11.0, 9.1, 8.9, 7.2, 6.7, 5.8, 5.5, 5.2, and 4.2 days, respectively. For treatments where the goal temperature for the center bag ranged from −12 to 4 °C, egg mortality was 100% in bags located in both the periphery and in the center of the pallet. When the temperature goal for the center bag was 8 °C, 7 ± 2.5% of the eggs survived in bags located near the center of the pallet. Our data showed that temperatures that follow the dynamic temperature curve that takes place over 24.2 days (cool down and warm up for the 0 °C temperature goal) resulted in 100% mortality of *T. castaneum* eggs. The reason for the difference in mortality for a static compared to a dynamic temperature treatment may be due to the fact that the dynamic temperature treatment occurs over a much longer duration. The fact that the treatment only required 5.5 days in the freezer before it could be shipped makes it a practical method to disinfest pallets of flour, especially because the bags do not need to be removed from the pallet and no chemicals are used.

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1. Introduction

Tribolium castaneum (Herbst), the red flour beetle, and *Tribolium confusum* Jacqueline duVal, the confused flour beetle, are two major stored-product insect pests of flour mills in the United States (US). Insect pest management strategies for these beetles and other stored-product beetles in general can include the use of contact insecticides as surface treatments, aerosols, and fumigants (Arthur, 2012; Boina and Subramanyam, 2012). Eggs are generally considered to be the life stage most tolerant to fumigants (Bell and Savvidou, 1999) and aerosols (Arthur, 2010) although less data are available for susceptibility to aerosols compared to fumigants.

Since 2005 the fumigant methyl bromide as a structural treatment for mills has been in the process of being phased out in most developed countries, under the terms outlined in the Montreal Protocol (Fields and White, 2002). Whole plant treatments as alternatives to methyl bromide include use of the fumigants sulfuryl fluoride and some cylinderized applications of phosphine (Arthur, 2012). Another alternative to fumigants is the use of heat treatments, and there has been considerable research on using heat as a structural treatment for stored-product insects (Subramanyam et al., 2011).

The use of cool or cold temperatures to manage stored grain can be an important component of insect pest management programs for bulk grains (Navarro et al., 2002, 2012). Development of most insect pests of stored grain is limited at or below 15 °C (Fields, 1992), and there are strategies for using different temperature thresholds to progressively cool the grain mass (Arthur and Casada, 2010). Bulk grain is an excellent insulator, and the center of the grain mass will take longer to transfer temperatures compared to the peripheral and top regions of the grain (Jian et al., 2009; Jian and Jayas, 2012). Aeration with low-volume ambient air is rarely used to kill insects; instead the goal is to limit insect development by modification of the bulk grain mass (Navarro et al., 2012). Computer models have been developed that predict insect population growth in grain bins using different aeration strategies to

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cool the grain (Flinn et al., 1997).

Using cold temperatures or grain chilling to kill insects is also a potential control option for bulk grains (Rulon et al., 1999; Navarro, 2012), but the use of cold to disinfest palletized bulk bagged commodities has not been extensively researched. Stacked bagged commodities such as flour would be expected to have similar heat transfer processes as what has been observed for bulk grain, i. e., the center region of a stacked pallet would take longer to cool than the peripheral regions. Using cold temperatures to disinfest an entire facility may be potentially possible in colder climates (Worden, 1987), but this strategy would be limited throughout most of the temperate and southern regions of the US for much of the year. A more promising approach would be investigating the use of cold temperatures to disinfest a pallet or several pallets of goods that are suspected of being infested by flour beetles, using a large freezer. Commercial freezers have options for determining a set point, but sources from the milling industry in the USA state that an industry standard is −17.8 °C. There are no recent studies in the scientific literature investigating cold temperatures as a disinfestation treatment for bulk commodities such as bagged flour. Therefore, the objectives of this study were to determine: 1) cooling patterns in a pallet load of bulk bagged flour, using a set threshold of −17.8 °C, 2) time and temperature required to kill *T. castaneum* eggs, based on determination of the cooling patterns described in objective 1, and 3) differences in cooling rates of the bulk and peripheral regions, and the resulting effect on egg mortality.

2. Materials and methods

Studies were conducted to determine the time needed to kill *T. castaneum* eggs contained in 5 ml vials inserted into 22.7 kg bags of flour (approximate dimensions of 61 × 41 × 10 cm, enriched bakery flour, Stafford County Flour Mill, KS) at target temperatures of −12, −10, −8, −6, −4, −2, 0, 4 and 8 °C for the most central location in the pallet. We used the egg stage of *T. castaneum* in our study because that is the species and life stage of most concern to the milling industry in the USA. Twenty *T. castaneum* eggs that were approximately 1-day-old were added to a 5 ml conical snap cap vial that contained 3 g of pre-sieved flour (#50 sieve with 8-mm openings). The eggs were obtained from a strain collected from a food warehouse in 2005 and had been reared at the USDA-ARS Center for Grain and Animal Health Research (CGAHR) since that time. This strain was reared on a diet of 95% all-purpose flour and 5% Brewer's yeast in an incubator set at 27 °C in total darkness. An 8-mm hole was made in each vial lid. A small piece of silkscreen was laid across the top of the vial, and it was held in place by the vial top. Four flour bags, (A1, J1, E2, and F2) were selected to have vials containing eggs inserted into them (Fig. 1). We selected these bags because they represented the two most peripheral and central bags in the pallet. We used two monitoring positions in the two most center bags (E2 and F2). In addition to inserting 5 vials into the center of these bags, we also inserted 5 vials and a thermistor into a location that represented the center of the flour mass for the pallet (E2Q and F2Q). A small v-shaped flap was made in the center front of the flour bag to insert the vials into the flour. Five vials were inserted into the center of each bag, a Hobo TMCx-HD thermistor cable (Onset Computers, Bourne, MA, USA) was inserted between the 5 vials, and then the paper flap on the bag was sealed using plastic packaging tape. We assembled the pallet by laying five bags on a 122 × 102 cm wooden pallet (Fig. 1). Five additional bags were then added for each layer for a total of 10 layers. The sides of the pallet were then wrapped with plastic film to help hold the bags in place and to protect the bags from damage (this is normally done for commercial shipments). The final dimensions of the pallet were about 1.09 m wide by 1.32 m long by 1.23 m tall. The weight of the stacked pallet was approximately 1152 kg. The thermistor cables from each bag of flour were then connected to U12-006 Hobo data loggers, 4 cables per logger (Onset, Bourne MA). Temperatures were recorded at 10 min intervals. We also monitored real-time temperature in the center bags of the pallet using a Hobo ZW-006 wireless data node and a ZW-RCVR Hobo data receiver (Onset, Bourne, MA, USA). Real-time data were needed to determine when to stop the cold temperature treatments at predetermined temperature thresholds, and to avoid disturbing the treatment.

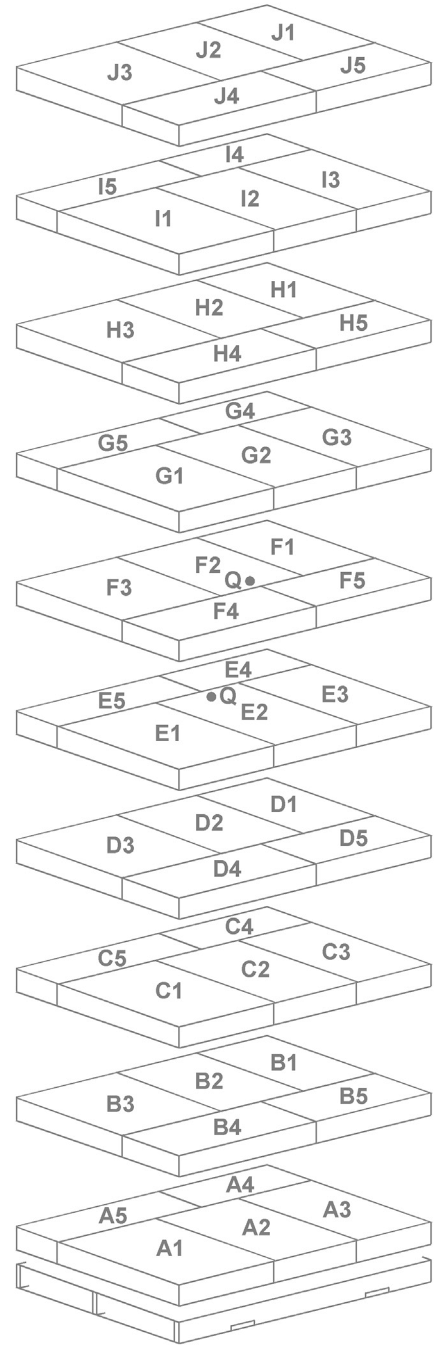

Fig. 1. Arrangement of flour bags on the pallet.

The pallet was then moved into a 3.1 × 4.9 m walk-in freezer (Polar King International, Inc. Fort Wayne, IN) located at CGAHR that was set at −17.8 °C. Three bags of flour were used as a control,