OZONATION AS NON-CHEMICAL STORED PRODUCT PROTECTION TECHNOLOGY

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Insects and molds cause a significant amount of damage to grain each year producing economic losses that affect farmers, elevators managers and processors throughout the world (Leesch, 2002). Stored grain protection relies heavily on the use of phosphine and methyl bromine to control pests. Due to the increased concern over the use of post-harvest chemicals worldwide, there is much interest in the development and use of non-chemical treatments such as temperature, moisture management, modified atmospheres, heat treatment of empty structures, physical exclusion, non-chemical protectants, biological controls and ozonation to control stored product pests.

Ozonation is a powerful oxidant that reduces or inhibits mold spore development and kills stored product insects, therefore serving as a non-chemical alternative for stored grain protection (EPA, 1999; Mendez et al., 2003). Ozone has the tendency to transform or decay into two molecules of oxygen within 20 to 50 minutes (Law and Kiss, 1991). Therefore, a special ozone air delivery and return system design is required for an ozonation treatment of a storage facility. A recirculation system is needed so ozone is not wasted once the leading font exits the grain mass and is not just exhausted into the environment. The ozone generator needs to be capable of producing ozone at a constant rate and at the capacity needed for the grain mass to be treated. Among the advantages of ozonation compared to traditional fumigation for pest control are that it can be generated on the treatment site and no residue on the treated product (Mendez et al. 2003). The initial ozonation treatment of a grain mass takes more time to complete than subsequent treatments on the same grain mass (as long as it is not moved and recontaminated with dust, etc) because ozone reacts with the cell structures of mold spores, insects, bacteria and other biological matter attached to the grain kernel surface and contained within the grain mass. Completion of the sterilizing ozonation effect depends on the quantity of biological matter to be reacted with, the quantity of ozone available to react, and the supply of ozone to complete the reaction process throughout the grain mass within a timely manner.

After this reaction process, ozone will move faster and more freely in the grain mass increasing in concentration. The initial sterilization phase is until the target treatment concentration of 50 ppm is reached in the bottom layer of the grain mass. Once the ozone reaches the desirable concentration of 50 ppm, ozonated air must be moved through the grain mass and kept constant for three days to complete the ozonation treatment (Kells et al. 2001). Mendez et al. (2003) reported that a minimum air velocity of 0.03 m/s must move through the grain mass to achieve an optimal ozone concentration. The primary objective of this research was to perform scale-up and demonstration trials and confirm the efficacy of ozonation to control insect pests in stored bulk grain. These scale-up and demonstration trials were conducted at different locations using yellow maize, popcorn and organic maize. The first set of trials were conducted at the pilot bin facility of the Purdue University Post-Harvest Education & Research Center with yellow maize using three bins containing 9.6-tonnes and two other bins containing 60-tonnes of maize. The trials were performed using insect bioassays with adults of maize weevil (MW) and red flour beetle (RFB) that were placed 0.6 m below the grain surface and in the plenum of each treatment and control bin. Ozone monitoring lines were placed in the headspace and plenum of each bin.

The second set of trials was conducted at popcorn food storage and processing facility using two bins containing 644-tonnes of popcorn. The trials were performed using insect bioassays with MW and RFB adults were placed 0.6 m below the grain surface and in the plenum of each treatment and control bin. Ozone monitoring lines were placed in the headspace and plenum of each bin.

The basic setup for ozonation at these sites consisted of generating ozone with commercially available generators, introduction in the headspace, drawdown to the plenum with a suction fan, and re-circulation of ozone back into the bin headspace. Ozonation was done to attain an ozone concentration of 50 ppm in the plenum and maintained for a period of 3 days to achieve mortality of insects comparable to phosphine fumigation.

Ozone was produced by a four chamber generator model: 97D4 made by O3Co. (Aberdeen, ID) that has a capacity of producing 260 g/h of ozone. The ozone was introduced to each bin through 2.5 cm diameter hoses. The ozone concentration was monitored using an ozone analyzer model IN-2000 made by INUSA (Boston, MA) that has a monitoring range from 0 to 2000 ppm of ozone concentration. The data from the ozone analyzer was recorded using a data acquisition unit model (Hydra logger 2620A, Fluke Everett, WA). In all bins and locations, a recirculation system was used to recover the ozone exiting at the bottom of each bin (plenum or base) and injected back into the top of each bin (headspace). This eliminated ozone leakage to the environment and optimized the performance of the ozone generator.

In the trials at PHERC, the target ozone concentration of 50 ppm in the plenum was reached in 8 days and held for 3 days in bin A (Figure 1) and 6 days and held for 3 days in bin B and C. In the second ozonation, the 50 ppm target concentration at the plenum was reached in 36, 16 and 6 hours and held for 3 days for bins A (Figure 2), B, and C, respectively. During the initial ozonation, ozone reacted with the biological matter contained in the grain mass which allowed ozone to move through the grain mass within hours during the subsequent re-ozonation.

The insect bioassay results (Table 1) showed that 100% mortality was achieved for both MW and RFB located 0.6 m below the grain surface. The insect bioassays located in the plenum during initial ozonation the results were for MW 91%, 36% and 100%, respectively for bin A, B and C and for RFB, the results were 100%, 37% and 93%, for bin A, B and C, respectively. The unusually low mortality in the plenum of bin B was caused by the bioassays being exposed to water that accumulated in the plenum due to a rainstorm. The bioassays caked over and prevented the ozone to penetrate. Thus, the data was excluded from the average calculation that was 95.5% for MW and 96.5% for RFB. The control samples showed on average more than 95% survival.

In the trials at the popcorn facility, the results for the insect stored product bioassays located 0.6 m below the grain surface showed 100% kill for MW and RFB, while the control insect bioassays showed almost 100% insect survival.

The quality tests of popping volume for the popcorn was confirmed that end use values were unaffected by the exposure to ozone. Ozonation proved to be an effective non-chemical stored product pest control technology without affecting the end use quality of the treated grain. A properly designed ozonated air recirculation system is important for the effective drawdown of ozone through the grain mass and the avoidance of exhausting ozone to the environment.

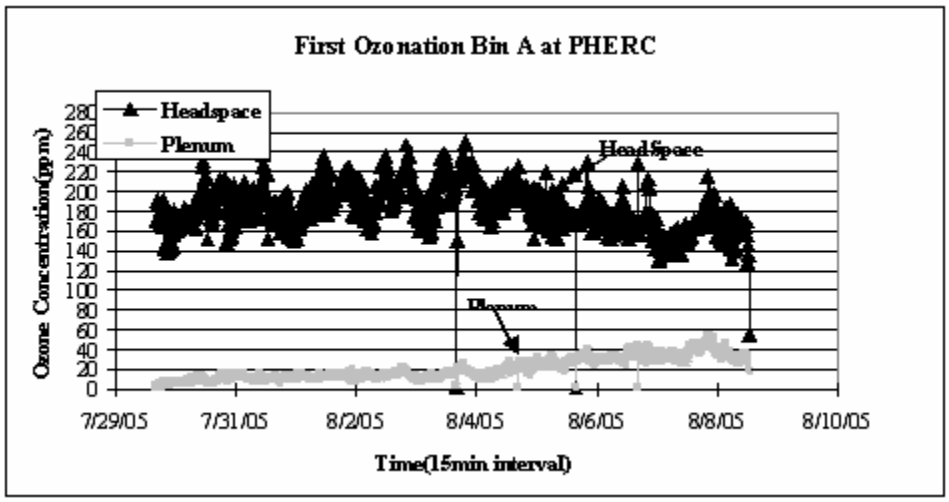

Figure 1.Ozone concentration profile Bin A at PHERC for the first phase ozonation of maize

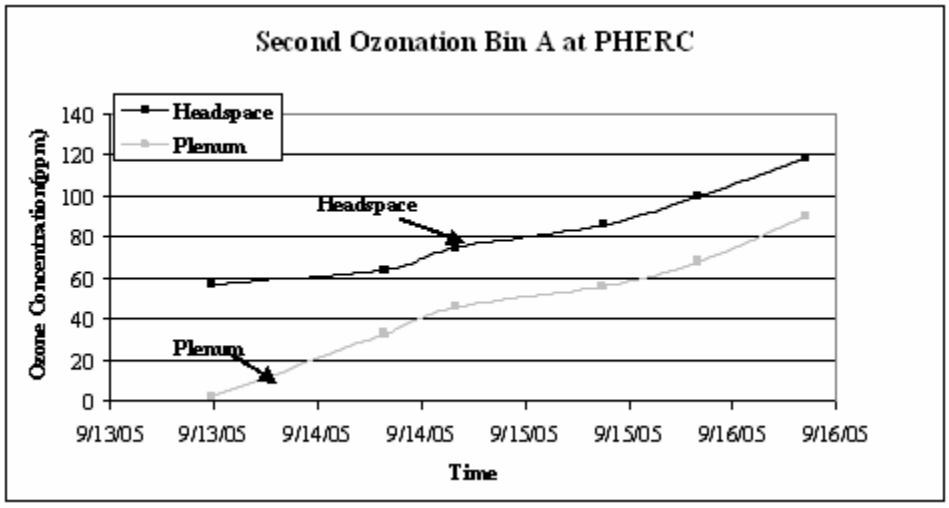

Figure 2. Ozone concentration profile in the head space and plenum of Bin A at PHERC for the second phase re-ozonation of maize