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# Ozone: A new control strategy for stored grain

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## Abstract

Due to the Montreal Protocol, pesticide resistance and the increased demand for organic grains, food manufacturers and grain handlers are looking for new ways to control insects and pathogens in stored commodities. Ozone, a powerful oxidant, has numerous beneficial applications. We have evaluated the efficacy of ozone to control pests of stored grain, the flow characteristics of ozone through various grains and the effects of long exposure times to higher concentrations on the chemical composition and processing performance of various food quality grains. A summary of this work will be presented as well as a discussion of other potential uses for this alternative pest treatment.


*Key words*: Ozone, Insect Pests, Fungal Pests, Fumigation Alternative,

Due to the Montreal Protocol, pesticide resistance and the increased demand for organic grains, food manufacturers and grain handlers around the world are looking for novel ways to control insects and pathogens in stored commodities (Zettler et al., 1989; Zettler and Cuperus, 1990). Currently, bulk commodities are often fumigated but the number of fumigants registered around the world are extremely limited and very few of the new treatments are acceptable for all applications. Additionally, the growing demand for organic grains has generated a need for control strategies for this niche market.

Ozone, a powerful oxidant, has numerous beneficial applications and is very familiar to the food processing industry. It has been long been used in food processing as a water treatment to disinfect, eliminate odors, taste and color (Kim et al., 1999; Legeron, 1984; Suffet et al., 1986; EPA, 1999). Ozone ($O_3$) is an allotrope of oxygen, which can be generated by UV-light and electrical discharges in air (corona-discharge). Ozone generation by electrical discharge is most common and has several advantages, including greater sustainability of the unit, higher ozone production and higher cost affectivity. Ozone has a half-life of 20-50 min, rapidly decomposing to diatomic oxygen, a natural component in the atmosphere. Because ozone can be easily generated at the treatment site using only electricity and air, it offers several safety advantages over conventional post-harvest pesticides. First, there are no stores of toxic chemicals, chemical mixing hazards, or disposal of left over insecticides or containers (Law and Kiss, 1991). Second, with a short half-life, it reverts back to naturally occurring oxygen leaving no residue on the product or to dispose of. Third, if needed it would


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be possible to neutralize ozone through techniques such as thermal activated charcoal, as well as catalytic and chemical abatement (Law and Kiss, 1991).

Ozone is a very unstable molecule and rapidly decays into $O_2$ releasing a single oxygen atom that is highly reactive. This single oxygen reacts with the cell membrane of bacteria or virus attacking cellular components and disrupting normal cellular activity. If ozone contacts a volatile organic compound the free oxygen atom reacts with it, removing the odor (http://www.ozone-industries.co.uk/ozone_generation.html).

Ozone has regulatory acceptance by the Food and Drug Administration (USA) (FDA 2001) and the Environmental Protection Agency's (USA) MSDS defines it as "pure air". The Occupational Safety & Health Administration in the United States has established safe ozone concentration levels in the work place of 0.1 ppm and for short durations of 0.3 ppm. Ozone is approved in the U.S. and is generally recognized as safe (GRAS) (FDA 1982) (http://www.o3co.com/aboutozone_facts.php).

Most of the initial published research and current use of ozone is for water purification for control of microorganisms. The use of ozone in agriculture is more recent. Published research indicates that ozone has several possibilities. Potential applications include deodorizing poultry, swine-waste lagoons, and pathogen reduction in storage of grapes, potatoes, and onions. Additional benefits go beyond insect management; and included mold and mycotoxin reduction and odor control. Except for a few published papers in the 1960's and 80's little is known about the effects on ozone on fungi (Dollear et al., 1968; Maeba et al., 1988; Rich and Tomlinson, 1968).and even less is known about the influence of ozone on insects. Erdman (1980) found ozone to be lethal on all stages of flour beetles (*Tribolium confusum* and *T. castaneum*).

The Post Harvest Team at Purdue University (West Lafayette, IN USA) have evaluated the efficacy of ozone to control a variety of pests of stored grain, the flow characteristics of ozone through various grains and the effects of long exposure times to higher concentrations on the chemical composition and processing performance of various food quality grains. The research summarized in this paper is a product of the students, post-docs and faculty that make-up the Purdue Post Harvest Team. Initial studies examined the mortality rates of major stored product pests in laboratory and simulated field studies.

Laboratory studies were conducted exposing unsexed adult *T. confusum* and *Oryzaephilus surinamensis* in micro-centrifuge tubes containing a flour/cornmeal mix to 5 ppm ozone for a total of 5 days (Mason et al., 1997). Significant difference between the treated versus control flour beetles was found after three days of exposure. Differences continued to increase for the next two days. One hundred percent mortality was achieved by day 5. Ozone had a much quicker effect on *O. surinamensis*. Significant differences were found within 24 hours and 100 % mortality was achieved by day 3.

Radial growth of *Aspergillus flavus and Fusarium moniliforme* in agar media was inhibited for the first 2 days, however after 3 days of ozone exposure, growth paralleled that of the control (Mason et al. 1997). Hyphal growth and sporulation were both completely inhibited by an ozone environment. This data seemed to indicate that ozone did not penetrate the surface of the agar media. Aflatoxin production by *A. flavus* was also reduced by more than 97% in ozone exposed cultures.

The next phase of the research examined the efficacy of ozone against adult flour beetles (*T. confusum* and *T. castaneum*), maize weevils (*Sitophilus zeamais*) and larval Indianmeal moths (*Plodia interpunctella*) in 50 ml centrifuge tubes buried in 12.5 liter buckets containing 0.7 bu of corn. Insects were exposed to ozone concentrations of 10 to 50 ppm continuously until 100 % mortality was achieved. To determine if insects could survive a sublethal dose – insects were held under ozone environment for 4 d at 10 ppm or 1 day at 50 ppm and then remove to an environmental chamber for up to 28 days for observations. Adult confused flour beetles first exhibited mortality after 4 days, with 100 % mortality after 12 days at 10 ppm (Strait, 1998). Red flour beetles were more susceptible than confused flour beetles. Mortality was noted after 1 day and 100 % mortality after 9 days. Maize weevils were the most susceptible, reaching 100 % after 4 days. Larval Indianmeal moths were similar to red flour beetles with first mortality noted at 2 days and 100 % after 9 days.

When concentration was increased to 50 ppm, a large decrease in treatment time occurred for all species examined (Strait, 1998). Confused flour beetles decreased from 12 days to 3 days, red flour beetles from 9 days to 6, 4 to 3 days for maize weevils and 9 to 3 days for Indianmeal moths. Insects receiving a sublethal dose behaved very differently than untreated insects. Treated insects were sluggish and uncoordinated. Mortality was higher than controls for 10 ppm (34 % percent for treated) and those that survived were able to reproduce. At 50 ppm for 1 day the post treatment mortality rate for confused flour beetles was higher (63 %) than the controls and sterility was absolute. Indianmeal moth adult emergence was affected by short ozone treatments. A 4 day 10 ppm exposure reduced adult emergence from 85 % to 6 % and a 1 day exposure to 50 ppm reduced emergence from 90 % to 13 % (Strait, 1998).

This early research confirmed that ozone was efficacious against stored product insects in a laboratory setting. The next phase of the research was to expand the scale of the experiments and move from the laboratory to the field. This research was conducted in a 8.9 tonne capacity steel barrels with caged adult red flour beetles, maize weevils and Indianmeal moths exposed for either 3 days at 50 ppm or 5 days at 25 ppm (Kells et al., 2001). Large scaled research resulted in 92-100 % mortality of larvae of Indianmeal moth, and adult red flour beetles, in infested corn when fumigated with 50 ppm ozone for three days (Kells et al., 2001). The same treatment also significantly reduced the viability of fungi on the kernel surface (Kells et al., 2001). This three-day ozonation is similar to the time needed for conventional phosphine fumigations.

The final question remaining was the influence of high ozone concentrations on the chemical composition and processing performance of food grains. Mendez et al. (2002) showed that treatment of grains with 50 ppm ozone for 30 d had no detrimental effect on popping volume of popcorn, fatty acid and amino acid composition of corn, and milling characteristics of corn. These data indicate that if repeated ozone treatments are needed, such treatment should not decrease the quality of grain for end-users. These results suggest that ozonation is a potential alternative to conventional pest control treatments. A number of food grain producers and handlers have expressed interest in ozonation technology and generators are becoming available for use. Current research on the used of ozone in the post harvest arena is directed at decreasing treatment time by increasing the concentration of ozone as well as engineering solutions to decreasing treatment time to hours rather than days.

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