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Influence of grain mass temperature on ozone toxicity to *Sitophilus zeamais* (Coleoptera: Curculionidae)

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Abstract

Considering that grain mass temperature can influence the exposition time to fumigants, the objective of this work was to evaluate the influence of grain mass temperature during the ozonization on the ozone toxicity to *Sitophilus zeamais* Mots. (Coleoptera: Curculionidae). Corn grains were placed into PVC cylindrical containers with an ozone gas injection-exhaustion system. The insects were restrained in cages placed in the medium layer of the grain mass and subjected to an atmosphere modified with 50 ppm ozone, 8 L min^{-1} flow, at grain mass temperature of 20, 30, 35 and 40 °C. Insects were exposed to ozone for 24 and 48-h at each temperature. Insect mortality was calculated at the end of each assay. During the period of 24-h exposition the ozone toxicity increased with the increase in the grain mass temperature, in which insect mortality was higher at 35 and 40 °C. In the-48 h exposition period there was 100% insect mortality.

Key words: corn weevil, control, ozone, storage, grains.

Introduction

The severe attack of insect-pests during grain storage is responsible for substantial losses in the grain storage sector all over the world. The corn weevil - *Sitophilus zeamais* Mots. (Coleoptera: Curculionidae) - is one of the first species to appear in products recently harvested and stored. It is one of the most important stored grain pests for attacking intact grains, resulting in quality loss in the final product (Rees, 1996).

Aluminum phosphide fumigant insecticide, active principle phosphine, has been used to control *S. zeamais*. The continuous use of a particular insecticide for a long time combined with inadequate application techniques represent a great risk for the development of resistance to the product, which may increase the selection pressure of resistant individuals (McKenzie, 1996). Besides the knowledge about resistance, the growing consumer concern with food quality demands for the development of new techniques for stored-product insect management.

Among the main alternatives to phosphine, is the use of atmosphere modified by ozone gas (O_3) as controlling agent, a strong oxidizer agent with proven biocide efficacy against stored-grain insect-pests (Kells et al., 2001; Zhanggui et al., 2003). This is becoming an attractive alternative in agriculture as it can be produced at the workplace and the degradation product, oxygen (O_2), does not leave residues in the grains (Mendez et al., 2003), however, very little is known regarding the abiotic agents that can

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interfere with its efficiency.

The relationship between temperature and insecticide toxicity in insects have been extensively studied (Scott, 1995). Mass grain temperature is one of the determinants of the rhythm of insect metabolic activity, seeing that higher temperature turn the insects more susceptible to the fumigant action (Faroni et al., 2002), consequently, the exposition time needed to obtain efficient insect control can be reduced by knowing the optimal temperature for application (White and Leesch, 1996), maximizing the economic viability of a particular product.

Considering that mass grain temperature interferes with ozone insecticide action during application, the objective of this work was to investigate the influence of the grain mass temperature in the ozone exposition periods of 24 and 48-h on *S. zeamais* mortality.

Materials and methods

The experiments were conducted at the Agricultural Product Pre-processing and Storage Sector, Department of Agricultural Engineering, Federal University of Viçosa (UFV). The influence of growing mass grain temperature (20, 30, 35 and 40 °C) with the ozone exposition periods of 24 and 48-h on *S. zeamais* mortality, using 50 ppm ozone in a 8 L min^{-1} flow was investigated. Three repetitions were used for each temperature and exposition period. Evaluation of insect mortality was carried out 48-h after the end of each treatment. *Grain packing and insect restraining*

Corn grains (25 kg) were placed into 0.2 m diameter x 1 m high PVC cylindrical containers. A metallic screen was placed 0.1 m above the bottom of each container to hold the grains and form a chamber for a better gas distribution. At the top and bottom cylinder lids connections for a gas injection-exhaustion system were installed, and a sensor for grain mass temperature monitoring was inserted into the cylinder body. To keep the insects in the middle layer of the grain mass, 20 *S. zeamais* adults were placed into 0.15 m diameter x 0.03 m high circular PVC cages with 0.33 kg of corn grains. The bottom and the lid of the cages were made with *voil* fabric to allow ozone or atmospheric air to pass through and avoid insect escape.

Grain mass temperature control

The cylinders containing corn were taken to climatic chambers with air temperature controlled according to the grain mass temperature, which was monitored by a *1-Wire^{TM}* Temperature/Data Logger system. This system consists of a data transmission network using software to allow the communication between the computer and the grain mass temperature sensors with only one conductive cable (Martins et al., 2004).

Ozone and atmospheric air supply

Ozone gas was obtained from a generator developed by the Physics Department of the Aeronautics Technological Institute (ITA). In the gas generation process, dry atmospheric air (dew point below -40 ^{o}C) was used as input, passing through a dieletric barrier discharge (DBD) refrigerated reactor. This type of discharge is produced by applying a discharge voltage between two parallel electrodes, having between them a glass dieletric capacitator and a free space where the dry air or the oxygen flows through. In this free space a filament discharge is produced, where electrons are generated with enough energy to break down the oxygen molecules forming ozone (O_3).

The dry air used as input was obtained from an air compressor installed together with an aluminum filter. A two-outlet connection was installed in the filter outlet: one passing through the ozone generator and the other going directly to the atmospheric air system (control). Ozone production was regulated as a function of applied power, adjusted by the generator power variator. Dry airflow was monitored by an air flow meter. Ozone concentration was accurately measured through an espectrophotometer with 0.1 g m^{-3}

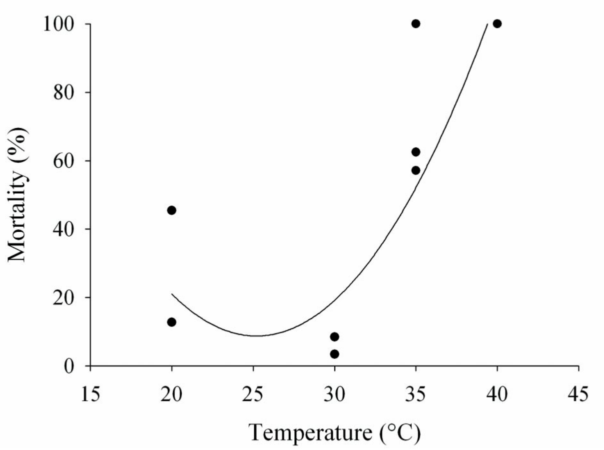
accuracy. To increase the accuracy of O_3 concentration readings, a multimeter was connected to the espectrophotometer to enable the establishment of a relationship between the values read in the espectrophotometer (g m^{-3}) and the electric current (mA).

Data analysis

In order to compare possible differences among treatments, data on *S. zemais* mortality for the two ozone exposition periods were subjected to regression analysis as a function of grain mass temperature using the SAS software (SAS Institute, 1989).

Results

In the 24-h exposition period, the toxicity of ozone was affected by the increase in grain mass temperature during the ozonization process, with a tendency for ozone toxicity to increase with the grain mass temperature increase (Figure 1). In this exposition period the average insect mortality at temperature of 20, 30, 35 and 40 °C were 12.7 %, 3.95 %, 73.21 % and 100 % respectively. In the 48-h exposition period, 100 % insect mortality was found.



Y = 296,4675 - 22,8312x + 0,4529x^2 (F = 16,8069; P< 0,0009; R^2= 0,8881), Where Y - mortality (%), X – grain mass temperature.

Figure 1. *S. zeamais* mortality in the 24-h ozone exposition period at different grain mass temperatures at the time of ozonization.

Discussion

Among the factors that affected the fumigant exposition period, grain mass temperature was important for having a direct relationship with insect susceptibility (Throne et al., 2000) and for acting as an agent for insecticide degradation (Pimentel et al., 2005). From the biological point of view, the increase in insect susceptibility, as a function of temperature increase, is due to their breathing rate increase (Throne et al., 2000), along with increase in metabolic activity (O_2 consumption and CO_2 production) (Celaro, 2002), which can result in unbalanced gas exchange in insects. This causes higher energy expending for maintaining homeostasis (Hostetler et al., 1994; Harak et al., 1999), which is the process responsible for the maintenance of the cell's internal environment integrity (Nation, 2002). Thus, it is possible that the highest ozone toxicity found at grain mass temperatures of 35 and 40 °C, in the 24-h exposition period, is due to a higher insect sensibility to these temperatures, since the optimal *S. zeamais* development temperature is 27 °C (Rees, 1996). Soderstrom et al. (1992) also verified the influence of temperature on the toxicity of modified atmospheres. The authors found increase in the mortality of *Tribolium castaneum* (Coleoptera: Tenebrionidae) larvae at temperatures equal or above 38 °C, combined with CO_2 enriched or O_2 deficient atmospheres.

Regarding the ozone toxicity in the 48 h period of ozonization, it is likely that the 100 % insect mortality in all the grain mass temperature is related with the results found by Kells et al. (2001). They found that the ozone fumigation process has two different stages: first, there is fast ozone degradation and slow flow through the grain mass; second, ozone flows freely through the grain mass with little degradation, because on that moment the sites responsible for the ozone degradation are saturated. It is possible therefore that the highest efficiency found with 48-h ozone exposition, at all the temperatures, is due to the natural saturation occurring during the second stage of the ozonization process.

Overall, the results of this investigation are promising, as they show that higher temperatures can contribute to make insects more susceptible to ozone gas. Thus, there is need for additional investigations on the exposition period to achieve efficient control of *S. zeamais* at the levels of temperature tested in this work, as well as studies that correlate the benefits of using higher grain mass temperature prevailing in tropical regions.

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