# Non-chemical alternative in rice storage: the use of refrigeration for insect control and quality maintenance of paddy rice

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Abstract

Trials were conducted to evaluate the potential effects of refrigeration in controlling insect infestations of *Sitophilus zeamais* and *S. oryzae* on stored rice. In the rice storage and processing industry use of aeration systems during winter and refrigeration units under summer conditions can provide a good solution to reduce paddy temperature for control of insects and maintenance of paddy quality; though it is restricted by costs of machinery and electric power. Trials were conducted in a rice mill in Portugal close to the Mondego Valley. A granary containing 140 t of paddy (variety Ripallo) was cooled using refrigerated aeration because during the trials ambient temperatures were too high for successful insect control by ambient air aeration. *Sitophilus zeamais* and *S. oryzae* adults reared on brown rice at 28°C and 68±3% r.h. were used as bioassays. Paddy stored in the granary was cooled to below 18ºC from 27 June 2008 to 19 September 2008. The mean ambient temperature during the total period of the trial varied from 12ºC to 27ºC. The moisture content of the paddy in the granary ranged from 12.1% to 13.9% during the same period of time. The total $F_1$ of adult emergence population of *S. zeamais* and *S. oryzae* was counted after the experiments. The $F_1$ adult from parent adults of *S. zeamais* was reduced up to 77%; the $F_1$ adult from eggs of *S. zeamais* and *S. oryzae* were also reduced up to 71% and 45%, respectively, when compared with corresponding untreated controls. Refrigeration of the paddy allowed storage for almost three months at about 18ºC and caused delay in rice weevils development. As a consequence, this negated the necessity for fumigation. Although the energy consumed during refrigeration doubled the cost when compared with cooling using an ambient-air, aeration system during the cold season, refrigeration provided an environmentally sound and user-friendly treatment during warm months of the year.

Keywords: Refrigeration, *Sitophilus zeamais*, *Sitophilus oryzae,* Paddy, Rice mill, Storage

## *1. Introduction*

Currently the most common non-chemical alternative in the rice storage and processing industry is the use of aeration systems that can be effectively run during winter to reduce paddy temperature. Under summer conditions use of refrigeration units provides a good solution for quality maintenance of paddy, but is restricted by costs of machinery and electric power. The objective with aeration and refrigeration systems is to achieve temperatures of less than 18ºC (Navarro, 2007) which significantly reduces insect activity. Aeration using ambient air may not be sufficient to control fungi on moist grain, control mites and insects, prevent self-heating of grain, preserve germination capacity and quality of stored grain in warm climates, or when warm grain is stored immediately after harvest. To address these situations, refrigerated air units for chilling grain have been developed for commodities that can justify the added expense of refrigerated aeration cooling. In this type of aeration process, ambient air is conditioned by passing it through the evaporator coil and a secondary reheat coil of the refrigeration unit, then the chilled air is blown into the grain bulk via the existing aeration system (Navarro, 2007).

Grain chilling is accepted as a grain-conditioning technology in much of Western Europe; currently most new units appear to be marketed in Southeast Asia. In the 1960s grain chillers were primarily used as a means of preserving high moisture (moist, damp) grain. Later, grain chilling was applied to improve storability of sensitive commodities subject to development of heat foci (hot spots), i.e., for soybean and maize, and preserve the quality of high value dry grain, seeds and edible beans, primarily against mites and insects (Navarro and Noyes, 2001).

Consumer and regulatory agencies for environmental protection demand chemical-free and contamination-free products. This is a general tendency that industry finds difficult to conform to because insecticides are often necessary to prevent economic damage. Additionally, in many countries, insects have been developing resistance to contact insecticides and to the fumigant, phosphine.

This project was carried out integrating environmentally sound and sustainable technologies to replace conventional chemical treatments needed for protecting the quality of rice at different phases of post-harvest handling and storage to meet European standards. Trials were conducted to evaluate the potential effects of refrigeration in controlling insect infestations of *Sitophilus zeamais* Motschulsky (Coleloptera: Curculionidae) and *S. oryzae* L. on stored rice.

*2. Materials and methods*

Trials were conducted in a rice mill in Portugal close to the Mondego Valley. A granary (metal bin) containing 140 t of paddy (variety Ripallo) was cooled using refrigerated aeration. Refrigeration was used for cooling the paddy because ambient temperatures were too high for successful insect control by aeration with ambient air. *Sitophilus zeamais* adults reared in polished rice at 28°C and 68% r.h. were used as bioassays. One-week-old adults were placed in clean rice for one week to lay eggs, at the IICT laboratory, in Lisbon. Then the infested rice with immature stages was also used in bioassays. Infested grain with eggs of *S. oryzae* were of integral husked rice. Adults were removed and only eggs or early stage larvae that remained in the rice kernels were used.

Four separate replicates of infested rice with eggs of *S. zeamais* and *S. oryzae* were placed in tubes-type metal cages which had a capacity to contain 16 g of rice; four replicates of 20 one-week-old adults of *S. zeamais* were placed in box- type metal cages which had a capacity to contain 40 g of rice. The location of these metal cages in the granary and big bag is shown in Table 1.

**Table 1** Operational details of the bioassay cages used in the refrigeration trial.

| Bioassay cage | Layout | Location |
|---|---|---|
| 4 tube type metal: eggs of *S. Oryzae*<br>4 tube type metal: eggs of *S. Zeamais*<br>4 box type metal:20 adults of *S. zeamais* | 6 cages 0.5 m from top + 6 cages 1.5 m from bottom | Granary |
| 4 tube type metal: eggs of *S. Oryzae*<br>4 tube type metal: eggs of *S. Zeamais*<br>4 box type metal:20 adults of *S. zeamais* | 3 cages from each type at four different depths | Big bag |
| 4 glass jars: eggs of *S. Oryzae*<br>4 glass jars: eggs of *S. Zeamais*<br>4 glass jars: 20 adults of *S. zeamais* | ------ | Incubator |

Each replicate of both types of infested rice cage was placed in the granary at two depths; 50 cm from the top and 1.5 m from the bottom. Four replicates of each type of infested rice were also placed in four different depths in the big bag containing 1 t stored rice used as control. Another separate group of four replicates in glass jars (Table 1) was maintained in an incubator at the laboratory to observe insect development at 28ºC and 65-70% r.h.

Temperature and r.h. inside the grain bulk and outside the granary were monitored during the experiment using HOBO data and three temperature probes with two points of recording data. The big bag was kept at ambient conditions of the factory and was also equipped with a HOBO within the bag to monitor humidity and temperature throughout the trial. A refrigerated-air unit was connected to the granary and the stored paddy was cooled to below 18ºC. This temperature was maintained from 27 June 2008 to 19 September 2008. At the end of the experiment, insect development was monitored and compared in the granary under refrigeration, the big bag stored at ambient temperature and at laboratory control conditions.

### 3. Results and discussion

During the months (June-September) that trials were carried out, the ambient temperatures fluctuated between 24ºC and 30ºC. The paddy mean temperature, under the influence of the aeration with refrigerated air, was reduced to 17.8±0.4ºC (Table 2). Paddy temperature close to each probe had an average of 17.2±0.3ºC in probe 2, and 18.2±0.4ºC in probe 1. But high paddy temperatures occurred following the cessation of refrigeration, when the refrigeration unit had to be replaced monthly. As a result, there was a rapid increase of paddy temperature up to 27ºC. This increase in temperature may be explained by the warm ambient air blown into the paddy due to aeration with ambient air and without the assistance of the refrigeration unit.

In addition, the limited insulation capabilities of the relatively small bulk of paddy containing only 140 tones also contributed to the rapid increase in temperature, but to a lesser extent. According to Navarro and Noyes (2001) larger bulks of cereal grain of about 1000 t could maintain winter temperatures throughout the summer of the Mediterranean climate with only slight increase in temperature from 15 to 20ºC when ambient day temperatures reached 30ºC. In the present study, temperatures in probe 1 reached 27ºC. On the contrary, in non-aerated big bags the temperature was more stable with a mean of 22ºC and very short interval (minimum 21.6ºC and maximum 21.9ºC).

**Table 2** Mean, standard error of the mean, minimum and maximum temperature registered inside the granary, during refrigeration and inside the big bag, from 27 June to 18 September 2008.

| Data | *Granary* | | | | *Big Bag* |
|---|---|---|---|---|---|
| | *Probe 1* | *Probe 2* | *Probe 3* | *Mean* | *Mean* |
| Mean temp. (ºC) | 18.2 | 17.2 | 17.9 | 17.8 | 22.0 |
| Standard error (±) | 0.4 | 0.3 | 0.4 | 0.4 | 0.0 |
| Minimum | 13.0 | 12.0 | 13.0 | 13.0 | 21.6 |
| Maximum | 27.0 | 24.0 | 26.0 | 25.7 | 21.9 |
| Counts | 66 | 66 | 66 | 66 | 4198 |

At the beginning of the trials samples were collected to determine moisture content. Both paddy stored either in the big bag or granary were 12.1% m.c. During experiments the mean moisture content of paddy inside the big bag was 12.2±0.1% and ranged between 11.9 and 12.5% (in August and July-September, respectively). The mean moisture content of paddy stored under refrigeration was 13.1±0.2% and ranged between 12.1% (at beginning of the experiments) and 13.9% (at the end of experiments).

The increase in moisture content of the paddy probably reflected the collection of samples from sections close to the aeration duct where air with high relative humidity was blown into the granary, and not necessarily the inner layers of the stored paddy bulk. On the contrary, moisture content of paddy stored in the big bag maintained the same moisture content.

The total $F_1$ of adult emergence population of *S. zeamais* and *S. oryzae* was counted after the experiments and numerical differences are shown in Figure 1. The $F_1$ adult from parent adults of *S. zeamais* was reduced up to 77%; the $F_1$ adult from eggs of *S. zeamais* and *S. oryzae* were also reduced up to 71% and 45%, respectively, when compared with corresponding untreated controls from the big bag.

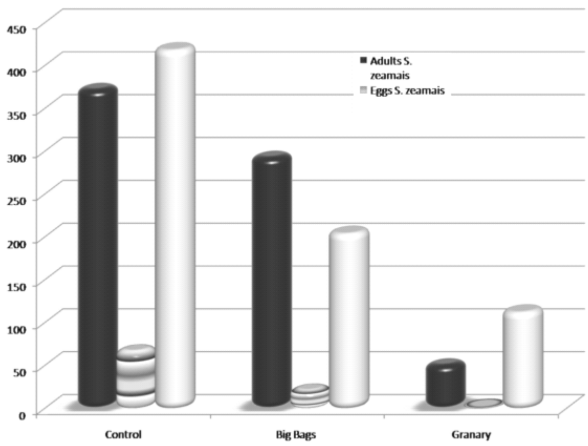


**Figure 1** Total number of adults of *Sitophilus zeamais* and *Sitophilus oryzae* emerged after the experiments: from the control incubator at laboratory conditions; from control big bag under ambient conditions in the rice mill, and from the granary under refrigeration.

Refrigeration enabled to store the paddy during almost three months at around 18ºC and caused the delay of rice weevil development. As a consequence, fumigation applications were not required. Although the energy consumed during the application doubled the cost when compared to ambient-air aeration systems used during the cold season, refrigeration provided an environmentally sound and user friendly treatment.

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