Environmentally friendly technologies to maintain stored paddy rice quality

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Abstract

Exports of processed rice have been increasing every year, as well as legislative restrictions and consumer demand for certified chemical free rice, pressing the rice processing industry to new challenges. The objective of this work was the implementation of a Rice Quality Certification Program. The package includes the association of a rigorous sanitation program and safe environmentally friendly control measures. It was accomplished in a large paddy rice facility with 40 silos during the 2008/09 rice crop. Silo sanitation was done by washing with pressurized water the conveyor belt structure above the silo roof, around the externals walls and thorough aspiration of the aeration system. During silo filling, the lower and top portions of the rice grain were treated with a mixture of diatomaceous earth (DE) and powder deltamethrin. Artificial chilling was applied as soon as the top layer of the grain mass was leveled by insufflating cool air (6 to 8ºC) with a large cooling machine through the aeration system. The grain mass temperature stabilized at about 12-14ºC, and kept this range of temperature for about 60 d. As the temperature of the grain mass increased, mainly on the top layer, aeration was performed with natural air from the cold fronts during the winter months. After 8 months on storage the rice was free of external insects, as proved by the grain sampling just before processing. For the 2009/10 crop season, the rice quality program will be repeated on 60 silos with few adjustments.

Keywords: Chilled aeration, Inert dust, Physical insect control, Rice quality maintenance.

1. Introduction

Processed rice exports have been increasing every year challenging the rice processing industry to adapt to new legislative restrictions and to attend the demand from the consumers for certified chemical free rice. Among the many problems in grain storage, pest infestation demands constant attention and efficient control measures, especially in large scale storage facilities under tropical/subtropical conditions (Trematerra, 2004; Lazzari et al., 2006; Lazzari et al., 2007; Ceruti et al., 2008; Vayas, 2009; Barbosa and Adler, 2007).

The control of insect and mite pests in stored rice using fumigation and residual insecticides is still the most common practice in Brazil; however, these methods may not be the most cost effective. Also, the residues of active ingredients can be risky for people and domestic animals, cause environmental contamination, and result in resistance of insect populations (Subramanyam and Hagstrum, 1995; Collins et al., 2000; Fields, 2006).

Post-harvest integrated pest management (IPM) focuses greatly on structure modifications, sanitation of the facilities and target pest control. Clean and sanitized structures are less likely to be favorable to pest establishment (Subramanyam et al., 2005).

The combination of physical and chemical methods has been used worldwide for insect control, including applications of diatomaceous earth (DE) (Fields, 1992; 2000; Athanassiou, 2007). Deltamethrin is a pyrethroid of low mammalian toxicity and can be used as dust or liquid in combination with DE (Ceruti and Lazzari, 2005). Chilling aeration is another physical method that presents several advantages mainly during the warmer periods of the year in warm climates (Maier and Navarro, 2002; Navarro, 2007; Adler, 2007). Evaluation with infrared radiation from flameless catalytic heater shows potential for killing insects inside rice kernels (Subramanyam, 2007). Therefore, there is a need for a diverse set of integrated measures including natural and environmentally friendly procedures to guarantee grain rice quality for the industrial processes. The main objective of the present study is to establish and apply a technological package or Rice Quality Program, as we call it, comprising a series of coordinated actions and measures in order to achieve an insecticide-free rice certification by 2011.

2. Materials and methods

This technological package is being carried out in a large rice receiving, drying, storage and processing facility (Figure 1) in the county of São Borja, State of Rio Grande do Sul, Brazil (28º 39’ 38’’ S and 56º 00’ 16’’ W; 96 m above sea level). For this large scale procedure, 40 silos with capacity for 3500 tons each of paddy rice from the crop season of 2008/09 were treated as follow.

Figure 1 Receiving, drying, storing and processing rice facility in São Borja, State of Rio Grande do Sul, Brazil, where the Rice Quality Program is being applied, since April 2008.

Silos were thoroughly cleaned from the roof to bottom, inside and outside, by washing, with pressurized water, the conveyor belt structure above the silo roof to remove starch dust, broken kernels, fines and clumps of grain. Also; application of water under pressure was done to clean external walls. The next step was spraying the external walls with DE plus deltamethrin (Figure 2 and 3). In each silo, the bottom and top layers, of about 60 tons of rice, were treated with a combination of 300 ppm diatomaceous earth (DE) (commercial name KEEPDRY) and 30 ppm of powder deltamethrin 2% a.i. (commercial name K-obiol 2 P) per t of rice. The treatment was applied as the grain was being transported to the silo by a transportation system including a bucked elevator, a screw, and a conveyor belt. After the bottom portion of the silo was filled with about 60 tons of treated grain it was leveled and the silo filled with untreated grain until close to the top. The top layer that consisted of about 60 tons of treated rice was then leveled.

Figure 2 Buildings and silo sanitation. Prior grain filling silos were washed with pressurized water and a mixture of diatomaceous earth + deltamethrin was applied on the outside walls of buildings and silos.

Figure 3 Application of diatomaceous earth + deltamethrin on the rice transported to the silos. Silos floor and internal walls were treated as the treated rice mass dropped from 25 m high.

After the silos were completely filled, artificially chilled air was insufflated throughout the aeration system with airflow at 30.000 m3/h (Figure 4). The temperature of the air insufflated into the grain mass was between 5-8ºC and 65-70% r.h. The grain mass reached a temperature range between 11 and 12ºC after 86 h of continuous applications of chilled air. Natural air was used to maintain the rice mass cool by using the cold fronts available from May through August mainly during the night. Monitoring of the grain mass temperature was performed with thermocouples installed in each silo.

Figure 4 Artificial chilling equipment used to insufflate chilled air through the aeration system of the silos.

Food-baited cage traps were placed on several spots near the silos in order to monitor the resident and migrant insect populations. The top layer of the rice mass was checked periodically and superficial grain samples were taken for insect detection. Before the milling of the rice from each treated silo, screenings from the cleaning machine were evaluated for live insect detection. The package also includes periodical training in order to instruct and change the attitude of the personnel involved with monitoring, control application and in charge of the rice stocks.

3. Results

Trappings revealed that only 15% of the insects captured in the cage traps were directly associated with grains and about 76% were sap beetles, Carpophilus spp. Among the insects collected were the Coleoptera: *Sitophilus oryzae* (L.) (Curculionidae), *S. zeamais* Motschulsky, *Oryzaephilus surinamensis* (L.) (Silvanidae), *Rhyzopertha dominica* (F.) (Bostrichidae) and *Tribolium castaneum* (Herbst) (Tenebrionidae).

From February to May 2009 all the silos and the lots of rice received were prepared for long term storage. After 8 months of rice storage, 29 silos were processed and none of them showed any external infestation of stored grain insects. The evaluation was done by checking the screenings of the cleaning machines during the expedition of rice to the mills. Only a residual population of R. dominica was found outside of a silo, but it was promptly controlled with DE + deltamethrin. The source of this infestation was not found.

Table 1 and Figure 5 show the temperature conditions outside and inside of a silo. Temperatures were taken with the thermocouples inside the grain mass at different levels of every 1.5 m: ambient air temperature, temperature inside the silo near the surface under the metallic sheath, temperature at 0.5 m above the grain mass, chilled air temperature and temperature at 0.3 m below the grain. The ambient air temperature from March 19th to 31st varied from 26 to 36ºC. The average temperature in March (end of summer in the region) was 34ºC. Temperatures inside the silo and just beneath the metallic ceiling of the silo ranged from 26 to 68ºC. The temperature at 0.5 m above the grain mass ranged from 17.7 to 42.6ºC, reaching the lowest point of 16.8ºC at 4 d after chilled air application. However, at the 5th day the temperature increased to 36.8ºC, due to the effect of head space heat trapped inside the silo. Figure 5 shows the temperature fluctuation during the period of this preliminary test. Chilled air was insufflated for about 4 d bringing temperatures down at all points inside the silo, despite the ambient temperature. Grain mass temperature was kept below 20oC for about 10 d without further chilled air insufflation; however at the upper layers and at the ceiling temperatures started increasing again following external ambient temperature.

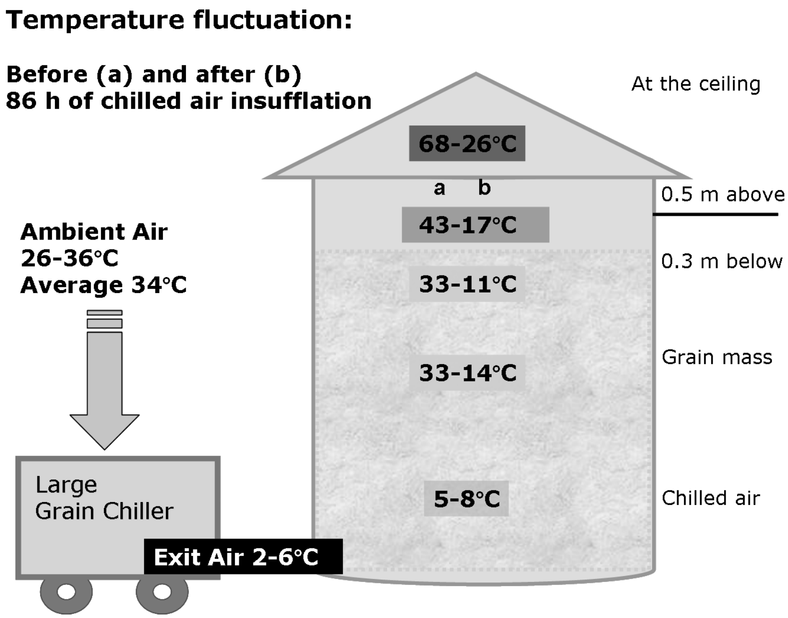

Figure 5 Scheme of the silo showing the application of artificial cold air and temperature profile at different points inside the rice mass before and after 86 h of chilling.

Table 1 Ambient air temperature, temperature of chilled air entering the grain mass, average temperature of the grain mass, temperature at 0.3 m below the grain surface, temperature at 0.5 m above the grain mass, temperature inside the silo near the metallic sheath, from 30 points of temperatures during March 2009 in metallic silo with paddy rice submitted to artificial chilling in São Borja, RS, Brazil.

Dates in March 2009	Temperature (ºC)					
	Air ambient	Entering chilled air	Grain mass (average)	0.3 m inside grain	0.5 m above grain	Under metallic sheath
19	29.6	7.7	32.9	33	31.9	68
20	34	8.4	20.7	21.9	24.2	55
21	33.3	6.8	14.8	19.1	21.7	51
22	35	6.3	14.8	12.1	17.7	48
23	33.6	4.9	14.3	10.9	16.8	45.3
24	32.5	-	14.1	11.2	36.7	50.6
25	32	-	14.3	12.5	38	51.5
26	25.5	-	13.5	17.8	28.7	26
27	30.8	-	14.4	22	40.8	57.3
28	33.7	-	14.8	26.8	40.4	52.8
29	35	-	15.3	28.7	42.6	55.2
30	35.5	-	15.1	29.4	41.7	46.8
31	35.3	-	18.0	30.1	34.8	41.8

4. Discussion

The rigorous sanitation program implemented by washing most of the structure with pressurized water presented satisfactory results in terms of suppressing insect populations and a significant reduction on the level of infestation of the rice going to be processed.

The removal of crusted dust, broken kernels, whole kernels, sprouted seeds inside the metallic U shaped structure, washing the silos walls and the application of DE + deltamethrin were important to reduce migrant insect pressure from outside of the silos.

The treatment of the rice with powder DE+ deltamethrin as the silo was being filled, leveling the upper surface of the rice mass, and the use of artificial chilling combined with aeration with natural cold air showed to be a very efficient integration of technologies. After 8 months of storage no insects were found in the rice samples and screenings taken before processing.

The system to maintain rice quality during storage using natural cold air from the cold fronts especially during the winter months can bring great benefits such as, reduce insect infestation and consumers complains, and keep storage costs low. The temperature inside the rice grain mass was kept low; however, at the top layer of the rice mass it warmed quite quickly. The challenge in this situation is to maintain the temperature near the grain surface at a range that will make it possible to suppress insect development and prevent oviposition. Other measures will be taken, such as painting the roofs of the silos white, adding insulation, mechanical removal of the hot air, in order to find a way to control the temperature on the top layer of the grain mass.

New formulations and combinations of DE with other natural insecticides, such as Beauveria, spinosad, Metarhizium, growth regulators, and vegetable essences, should be tested as insect control measures.

The program to maintain rice quality at very large scale should be kept simple, and include efficient, safe and cost effective strategies, focusing on all the steps, from receiving to packing of the rice. For the 2009/10 crop season, heat treatment will be used by insufflating the heat through the aeration system of the silos to suppress any pest infestation before filling with new rice. Some roofs will be painted white to reduce the head space temperature, and a motorized fan with a thermostat will be placed on the very top of the roof of some silos to remove the moist hot air to avoid condensation. Before packing, white rice will be treated with infrared radiation, produced by a flameless catalytic heater to kill eggs, larvae, and pupae inside the polished rice kernels.

The technological package we are establishing is demonstrating very promising results towards the certification of insecticide-free rice for 2011 in this rice plant.

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