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Ionizing Radiation and the Influence of Package to Control of *Sitophilus Oryzae* in Rice

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ABSTRACT
Objective: This study aimed to use the gamma radiation from Cobalt-60 to control of *Sitophilus oryzae* in package with previously infested rice and artificial reinfestation. **Material and Methods:** In the research, 3 types of sample were used: 2 commercial rice packages and 1 in crystal sugar packages. The samples were irradiated with a dose of 1.0kGy to promote disinfestations under a dose rate of 0.560 Gy/h. After 60 days were counted the number of live and dead insects in each package. **Results:** We concluded that the package containing holes for gases exchange from inside to outside of the package showed easily penetration of insects, while the two packages without holes prevented the reinfestation of insects. **Conclusion:** The dose of 1.0 kGy was sufficient to do the disinfestations of rice.

INTRODUCTION

Rice weevil, *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) is a major pest of stored rice, wheat, oats, rye, barley and corn worldwide (Campos, 2005; Sabbour, 2012, Zhou *et al*., 2015). Most domestic and export markets have zero tolerance to grain contamination by insects such as rice weevil. Fumigation treatment with phosphine or other chemical fumigants ensures that grain can be stored and exported in a clean and uninfested condition. However, resistance to phosphine has created a major challenge to the control of rice weevil and other stored product pests (Lee *et al*., 2001), and alternative control measures are needed.

This pest can cause damages to the products as weight loss and commercial devaluation, loss of nutritional value, contamination by the penetration of other organisms such as fungi through openings left by them, presence of mold, among others in packages (Fontes and Arthur, 1994).

Various authors applied doses to prevent reproduction of stored product pests, including *S. oryzae* (Hoedaya *et al*., 1973; Ignatowicz, 2004; Tilton *et al*., 1966; Tuncbilek, 1995; Arthur and Arthur, 2003 Arthur and Arthur, 2004; Follet *et al*., 2013).

Follett *et al.*, (2013) in dose–response tests to post-harvest using radiation treatment to *S. oryzae*, infest with adult or immature weevils in the doses of 30, 60, 90 and 120 Gy. The authors observed that loss of the rice infested with immature or adult weevils was significantly reduced by the irradiation treatment at 60 Gy and 120 Gy. In a large-scale confirmatory test, a radiation dose of 120 Gy applied to 38.025 adult weevils in rice resulted in no reproduction, thus provide quarantine security for the control of rice weevil, prevent post-irradiation weight loss.

In research to immediate kill, doses in the range of 0.05 kGy for *Tenebrio molitor* L. to 0.45 kGy for *Sitotroga cereallela* L. were sufficient to reached 100% of mortality these pests (Hallman, 2013).

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The objective of the radiation treatment in stored products is the control of losses by bacterial action, thus the main function of the package is to prevent the recontamination of the food, in other cases the function can be to prevent the loss or gain of humidity, keeping an atmosphere different from the air, protecting the impacts of food or just keep it clean (Follett *et al*., 2013). Thus the objective of this study was to use gamma radiation from Cobalt-60 for the control of *Sitophilus oryzae* in packages with rice previously infested and artificially reinfested to control of this specie of insect.

MATERIAL AND METHODS

The rice samples were obtained in the Piracicaba city market and taken in Laboratory of Radiobiology and Environment of Center for Nuclear Energy in Agriculture – CENA/USP, the commercial rice was used in three types of packaging with and without holes for this study: two samples in package of rice and one sample in a crystal sugar package (Table 1).

Irradiation Process:

For each experiment had 2 treatment the control and the dose of 1.0 kGy with 3 repetition (packages) with small holes and without hole each one containing 200g of whole grain rice and 10 insects, totalizing 30 per treatment**.** Posteriorly the packages were closed and irradiated in a Cobalt-60 source, Gammacell-220, under a dose rate of 0.560 kGy/hour, with doses of 0 (control) and 1.0kGy.

After irradiation, the packages containing the samples were placed in plastics trays, inside were add 900 adult insects in the same bottle to induce reinfestation. After 60 days was evaluated the number of living and dead insects of each package type. The experiment was developed in a room with temperature 25±5ºC and relative humidity of 60±5% (Figure 1). The experimental design was completely random. The data was submitted to analysis of variance and averages compared by Tukey test at 5% level of probability.

Table 1: Samples Submitted for Treatment

Sample	Package types
Rice “1”	Without hole
Rice “2”	With hole
Rice “3”	Crystal sugar package

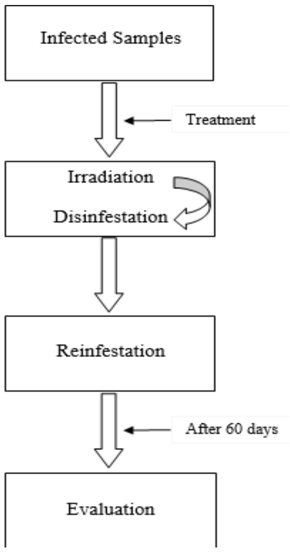

Fig. 1: Process diagram.

RESULTS AND DISCUSSION

Table 2 shows the development of *S. oryzae*, treatment and mean number of insects during storage after irradiation of the whole meal rice packages of the commercial rice with roles (1) without roles (2) and package of crystal sugar without holes (3). Was considerate the mean number of 10 dead insects in all treatments.

Table 2: Mean number of *Sithophilus oryzae* L after 60 days in package of commercial rice and package of crystal sugar.

Treatment	Package of commercial rice	
with roles (1)		
Dose	Live insects	Dead insects
Control	194.0 ± 1.01[a]	10.0 ± 0.0[a]
1.0 kGy	156.0 ± 0.81[b]	10.0 ± 0.0[a]
Treatment	Package of commercial rice	
without roles (2)		
Dose	Live insects	Dead insects
Control	178.0 ± 0.30[a]	10.0 ± 0.0[a]
1.0 kGy	0.0 ± 0.0[b]	10.0 ± 0.0[a]
Treatment	Package of commercial crystal sugar	
without Holes (3)		
Dose	Live insects	Dead insects
Control	149.0 ± 0.74[a]	10.0 ± 0.0[a]
1.0 kGy	0.0 ± 0.0[b]	10.0 ± 0.0[a]
F	70	69
P Value	0.01	0.01

*Mean with different letters in the column differ significantly at the level of 5%.

The table 2 showed a significant difference between treatments, we can observed in the control sample 194 living insects and in the irradiated sample 156, the results show that the presence of holes in the package of commercial rice facility the penetration of insects.

Can also be observed the inefficiency of the radiation when occur the reinfestation of the sample by insects, this occurs because the irradiation doesn't leave toxics residues in the products. The results are agreed with the obtained in *Acanthoscelides obtectus* in bean package in same dose (Arthur and Arthur, 2004).

For the treatments with packages of commercial rice and package of crystal sugar without holes, we observed a significant difference between treatment control and the dose of 1.0 kGy, only in the control was found the great number the living insects, which did not occur in the irradiated samples, there was not reinfestation because the packages were resistant. These results agree with those of Arthur and Arthur (2003), Arthur and Arthur (2004) who tested the resistance of package that are used in trades to prevented the attack of bean by insects *Zabrotes subfasciatus* and *Acanthoscelides obtectus*. The packages containing the bean *Phaseolus vulgaris* L. black type were irradiated with a dose of 1.0 kGy to the disinfection of possible infestation dormant. The authors concluded that there were not larvae live of *Z. subfasciatus* and *A. obtectus* in packages tested, not even in some package susceptible to this insect, demonstrated that the choice of packages against reinfestation was of fundamental importance in the quarantine treatment of grain and products stored.

In relation to the dose of radiation, some researchers observed that 120 Gy is a sufficient dose to control the rice weevil *Sithopilus oryzae*, nevertheless this species also feeds of rice in the adult stage causing damage depending of the number of the insets that is attacking the product. When if use a dose of 1.0 kGy the mortality of insects will be immediate after some days (Arthur *et al*., 2012).

This results are similar with others authors to rice weevil and other stored product insects that may require much higher doses, in the range of 1.0 – 3.0 kGy (Darfour *et al*., 2012; Ignatowicz, 2004; Khaghani *et al*., 2010; Tuncbilek *et al*., 2003).

The use of the radiation gamma, especially in the dose of 1.0 kGy, showed significant difference ($p < 0.05$) in the paste properties, was the dose in which provided larger acceptance for the fitting room. This dose of irradiation not affects the physiochemical composition of the rice, guaranteeing increasing the shelf life against the attack of insects. Therefore, this dose is recommended for the conservation of the rice (Zanão, 2009).

According to Phillps and Thorone (2010), Wiendl *et al*., (1974) there are three objections to stored product irradiation: 1) Public concerns about the safety of facilities using radioactive isotopes. 2) Perception that irradiated foods becomes radioactive, 3) Zero tolerance for live insects as adults in treated product by importing countries and the public at large.

In this case, the results show that lethal dose to kill insects of stored products are higher, however stored products can support these doses because they have a percentage of humidity around of 10% - 12%. This mean that the gamma radiation effects are more pronounced when there is this range of humidity in the products.

Conclusions:

The use of gamma radiation for immediate kill was efficient until 60 days, also reduced the infestation of pest in packages that not resulted in a better control.

In commercial rice and sugar package when irradiated showed be more resistant to penetration of insects than not irradiated.

By the results we can concluded that the dose of 1.0 kGy to package without holes showed the best results not permit the new reinfestation of pests and thus can be used for consumers for until 60 days period. However, the packages with holes were more susceptible to reinfestation same irradiated and not can used for future consume, due to presence of *S. oryzae* pests in rice.

These results show that future studies on stored products pests must consider tests on larger packages to that a more insects quantity and other types of packages be tested.

Author biography:

The Msc. Andre Machi contributed for identification and writing of the manuscript, Dra. Márcia Harder, Paula Arthur and Suely Franco contributed for the analysis in packages and writing, while Professor Dr. Valter Arthur contributed for corrections and writing of manuscript.

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