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RICE MILLING AS AN ALTERNATIVE TO METHYL BROMIDE FOR CONTROL OF THE RICE WEEVIL *SITOPHILUS ORYZAE* (L.)

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ABSTRACT

Few studies have been published on the mechanical effect of shock or impact on insect mortality; furthermore, this effect on insects during rice milling has not been quantified previously. In the search for alternatives to methyl bromide, which, because of its rapid action, is the principal fumigant used on rice, it was deemed opportune to review all the steps of the rice processing procedure to evaluate their insecticidal efficacy. Among these is rice "milling" which, without actually breaking the kernel, shakes it very violently. To evaluate how lethal this procedure might be an initial laboratory study was carried out on two types of micro-millings of rice infested with all stages of the rice weevil, *Sitophilus oryzae* (L.). The efficacy, expressed in Percent Reduction In Emergence (%RIE), showed a remarkable biological efficacy of between 98.4 and 99.5 % RIE depending on the mill. A large-scale trial was carried out to confirm these results. One ton of brown rice was first artificially infested with rice weevils to obtain all stages at the day of the treatment. The rice milling was carried out as usual, i.e., with two series of whiteness and polisher break-rolls. (The 10ºC increase from 22 to 32ºC, as a result of the milling process, was not sufficient to be lethal). Three types of samples were taken at the 3 milling stages: 8 batches of 500 g each were taken after break-rolls 1 and 2 and 20 batches of 500 g each were taken at the outlet spout of the milling process. Results confirmed those obtained in the laboratory, and showed that the main lethal effect (98% RIE) is obtained at the shock of the first break-roll. Insects, which survive this first shock seem to be able to survive the others. This lethal effect is almost equivalent to that of fumigation with MB. Consequently with regard to rice weevil infestations, fumigation after rice milling is unnecessary, since both processes have the same insecticidal efficacy, unless there is a high infestation rate for brown rice, in which case, a double treatment remains useful for rice to be commercialized.

INTRODUCTION

The retail sale of packaged milled rice free from insects requires good disinfestation procedures and for this reason some rice mills systematically fumigate rice with methyl bromide (MB) immediately after processing. This gas will be phased out by the end of the year 2004 and phosphine (PH_3) has been considered to replace it. However, the exposure time required for PH_3 is too long, requiring 5 to 7 days at 20°C and 15°C respectively, rendering its use impractical. Consequently, rice mill managers asked our laboratory to investigate the question of whether the percussion effect of the rice milling process has any insect control effect, even though the grain is not broken, but only shaken.

Some papers have addressed the subject of the efficacy of insect kill by impact machines (Banks, 1987; Plarre *et al.* 1993), or the influence of grain movement by auger or pneumatic conveyor on insect mortality (White *et al*, 1997; Rees *et al.*, 1994). However, we have not found reports on the lethal effect on insects caused by rice milling.

In the first stage, laboratory experiments were carried out on the rice weevil, *Sitophilus oryzae* (L.), using two milling machines. Results showed that the lethal effect of milling against this pest was very high; with a greater than 98% reduction in emergence (RIE). To confirm these results, a large-scale trial was carried out by processing 1 tonne of brown rice previously infested artificially with *S. oryzae*. (Brown rice and not paddy or milled rice is the form normally imported and stored in France and in this stage it is very susceptible to infestation). A series of rice samples were taken during processing to quantify the efficacy of the milling process against the insects. To avoid general contamination of the mill by the possible escape of *S.☐ryzae* adults from the infested grain, a full clean-up of the mill and a MB fumigation were scheduled for the day after the trial was completed.

MATERIAL AND METHODS

Laboratory studies using two types of micro rice milling

Laboratory studies were carried out with two types of micro rice milling equipment using brown rice infested with all stages of *S. oryzae*. The first micro milling experiment took place at the CIRAD research center in Montpellier, and the other at the Rivoire et Carret-Lustucru (RCL) rice milling company in the city of Arles. Five samples of 100 g of infested brown rice were processed in each of the two machines, with two un-milled controls. Before processing, all the samples and controls were sieved to remove the adults. The milling procedure lasted for 1 min (CIRAD) and 2 min (RCL). Following the milling procedure, weight loss was measured, this being a criterion for adjustment of the micro rice milling equipment. Weight loss of well-adjusted mills should be between 10 and 15%.

Commercial-scale trial

The commercial-scale trial was carried out with 1 ton of artificially infested brown rice (cultivar *Indica camargue*) at the RCL rice mill in Arles. The rice was divided into 20 batches of 50 kg in food-grade 120-L plastic barrels. Before introducing the grain, the inner surfaces of the barrels were coated with Teflon® to prevent adults from escaping. The barrels of rice were incubated in an air-conditioned room at 27±1°C and 70±10% r.h. Artificial infestation was carried out at a rate of 10 adults per kg about two months before the large scale trial in order to have all the rice weevil stages at this time.

Rice processing was carried out as in usual practice in the mills, namely, with two series of break rolls (BR). During the process, the temperature increased by 10°C to reach 32°C. This temperature is within the range of *S. oryzae* development and therefore does not have an effect on insect mortality. Three series of milled rice samples were taken:

- After each of the two break rolls (BR1 and BR2), a total of 4 kg in 8 batches of 500 g.
- At the end of the process, i.e. at the outlet-spout from the grain chute, , a total of 10 kg in 20 batches of 500 g.
- The control consisted of 4 kg of infested grain in 8 batches of 500 g. This was used to enable calculation of RIE.

Estimation of milling efficacy in controlling insect infestation

Duration of the development stages is defined according to the following model.

TABLE 1

Relationship between the time after artificial infestation, the sieving time after treatment and the developmental stage, in days of *Sitophilus oryzae* at 27ºC

Time after artificial infestation	7 days	14 days	21 days	28 days	35 days	42 days
Sieving time after treatment	day 42	day 35	day 28	day 21	day 14	day 7
Developmental stage	Eggs and Larvae I	Larvae II and III	Larvae III and IV	Larvae IV and V	Larvae V and Pupae	Pupae and Adults

For the hidden stages, the treatment efficacy is determined by the RIE as a percentage, obtained by dividing the total number of insects, which emerge after treatment by the total number of insects emerging from the untreated control.

Efficacy of MB fumigation on milled rice infested by *S. oryzae*

To compare the insect control efficacy of rice milling with a reference treatment, a MB fumigation was carried out in the laboratory under the same conditions as those

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[Whitening and polishing is carried out by the abrasive action of rubber or leather rollers termed here break-rolls -Eds] used in rice mills, namely: 20g/m^3, at 20°C for 22 h exposure., Two replicates of 20 kg of brown rice were fumigated in 43-L "Altuglas" chambers. The gas was injected by syringe, after which the air-gas mixture was left to homogenize for 1 h. After exposure, the gas was aired-out from the chambers and then a 1 kg sample was taken from each chamber and placed in a rearing room until observations on emergence were completed. A 1 kg non-fumigated sample served as control.

RESULTS

Efficacy of the micro rice millings in the laboratory experiment

Results expressed as % RIE of different stages of *S. oryzae* are presented in Table 2.

TABLE 2
Percentage reduction in emergence of different development stages of *Sitophilus oryzae* during the milling of infested brown rice (average of 5 replicates)

Micro rice millings	Pupae-LV*	LV-LIV	LIV-LIII	LIII-LII	LII-LI	LI-Eggs	Total emergence from control	Reduction in emergence (RIE)
CIRAD	100	100	100	98.9	97.4	97.0	2,888	98.4
RCL	100	100	100	99.7	98.9	99.3	4,397	99.5
Average	100	100	100	99.3	98.1	98.1	3,643	98.9
Newman Keuls test	a	a	a	b	c	c		

*L1 - LV = five larval stages of *S. oryzae*.

Results for the RIE are about the same for both the micro rice millings. Weight loss was the same for all the replicates and amounted to 14%. This implies that there was no significant difference between the two micro rice milling processes of brown rice. A Newman Keuls test on RIE showed a difference in sensitivity to the rice milling procedure, of the developmental stages of *S. oryzae*.

Pupae and old larvae were extremely sensitive with a 100% mortality rate, while some eggs and young larvae survived, at a 98.5% RIE.

Efficacy of milling in the commercial scale trial

The results are based on the average of the replicates given in Table 3.

Rice milling through the first break-roll produced 100% mortality in the three first sievings, these being the older larval and pupal stages (Table 3). Between the first and the second break roll, only a 1% increase in RIE was recorded. The efficacy of RIE in the younger stages was also very high, as shown in sievings 4-6, with a total RIE of 99.8%.

Comparison between milling and MB fumigation

A comparison between the RIE of developmental stages of *S. oryzae* produced by milling, with that produced by MB fumigation is presented in Table 4.

TABLE 3

Percentage reduction in emergence of different developmental stages of *Sitophilus oryzae* after commercial-scale milling

Time of sieving (in days)	Emergence from control (adults per kg)	% RIE after break-roll 1	% RIE after break-roll 2	% RIE at end of process
7	154	100	100	100
14	44	100	100	100
21	41	100	100	100
28	88	99.0	99.9	99.9
35	407	98.6	99.7	99.7
42	606	98.7	99.5	99.7
All stages	1340	98.9	99.6	99.8

TABLE 4

Percentage RIE for different developmental stages of *Sitophilus oryzae* after MB fumigation for 20 hours at 20ºC, at a dose of 20 g/m^3 (for a two-trial average)

Dose g/m^3	Ct product g.h m^{-3}	% RIE of developmental stages						Total emergence from control	Net reduction in emergence
		Pupae-LV	LV-LIV	LIV-LIII	LIII-LII	LII-LI	LI-Eggs		
20	770	100	100	99.5	100	99.2	100	1263	99.85

The RIE figures fail to show a difference in sensitivity of the different developmental stages between the milling treatment and MB fumigation. At a Ct ≥ 770 g.h m^{-3}, MB has a strong biological efficacy against all development stages of the weevil (RIE = 99.85). It does not, however, eradicate the entire population.

DISCUSSION

The results of micro milling of rice indicate that weevil pupae and old larvae are extremely sensitive to this treatment and have a 100% mortality rate, while some eggs and young larvae survive, at a 98.5% RIE. The large-scale trial confirmed this result and revealed an even higher RIE that reached an average of 99.8%. Consequently, it would appear that there is no substantial difference between the results of MB fumigation (RIE of 99.85%) and the mechanical shock caused by rice milling. Development of the insect within the rice grain would seem at certain stages to protect it from shock, while at others it becomes more vulnerable to the intensity of the percussion. The difference would seem to depend on the size of the cavity the insect inhabits: An egg is wedged-in tightly, whereas a pupae gets bounced about with each impact. The fact is that in our trials, total mortality was not attained.

The commercial scale study on the efficacy of mechanical shocks during the milling of brown rice infested with *S. oryzae* confirms the results obtained by micro rice milling. Here too, the milling procedure was highly effective with an average RIE of 99.8%, equivalent to classical fumigation with MB.

Consequently rice milling is totally effective against older stages, (larvae, and pupae) of *S. oryzae*, as soon as they pass the first break roll while only a 1% gain in RIE is achieved between the first and second break rolls. Although control of the other stages was extremely high, it was not complete.

It can be concluded that where the rice weevil *S .oryzae* is the infesting species, fumigation after milling is unnecessary, since both processes have the same effectiveness in controlling this species, unless there is a high infestation rate of the brown rice, in which case, a double treatment remains useful before white or polished rice is commercialized.

Finally, the results of this study reveal that rice need not be fumigated after milling if the initial infestation rate of *S. oryzae* is less than 10 insects of any given stage per kg, or approximately one visible adult per kg by sieving.

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