Bulletin of Insectology **62** *(1): 103-106, 2009*
ISSN 1721-8861

Preferences of *Sitophilus zeamais* to different types of Italian commercial rice and cereal pasta

Pasquale TREMATERRA
Dipartimento di Scienze Animali, Vegetali e dell'Ambiente, Università degli Studi del Molise, Campobasso, Italy

Abstract

Bioassays by means of modified Flit-Track M^2 trap-device were carried out on the maize weevil *Sitophilus zeamais* Motschulsky (Coleoptera Curculionidae) adults. Different types of Italian rice and cereal pasta were tested. Attraction of *S. zeamais* to comune (variety Originario), semifino (variety Padano), fino (variety Ribe), superfino (variety Arborio), pre-cooked (fino, variety Ribe), enriched rice, parboiled (fino, variety Ribe), integrale (variety Ribe) and expanded rice were compared. Superfino and parboiled rice were more attractive than the other rice categories; on the contrary pre-cooked rice and enriched rice were less attractive to maize weevil adults. Eight different types of cereal pasta were also compared: barley, buckwheat, durum wheat, five cereals (a mixture of durum wheat, barley, spelt, oat, and rye), kamut, corn, rice and spelt. In this case the choice tests demonstrated that corn pasta was more attractive than the buckwheat pasta, durum wheat pasta and rice type; barley pasta, kamut pasta, spelt pasta, and five cereals pasta were less attractive to maize weevil adults.

Key words: rice, cereal pasta, maize weevil, bioassays.

Introduction

Rice-mills and pasta factories, as any other food industries, can be infested by insects, leading to negative economic and commercial consequences. Infestations can occur during the storage process in industries, warehouses, general stores and retail shops already colonized by insects deriving from other products (Süss and Locatelli, 1999; Riudavets *et al.*, 2002; Locatelli and Süss, 2004; Barros *et al.*, 2003; Stejskal *et al.*, 2004; Trematerra, 2004; Trematerra *et al.*, 2004; Trematerra and Süss, 2006; Mancini *et al.*, 2007; Murata *et al.*, 2008).

Among other insects maize weevil *Sitophilus zeamais* Motschulsky (Coleoptera Curculionidae) is universally regarded as one of the most destructive primary pests of stored cereals. It does not often breed in non cereal foods, although it does attack split peas and pasta. It can attack cereal plants in the fields. Voracious feeding on whole grains by this insect causes weight loss, fungal growth, quality loss through an increase in free fatty acids and it can even completely destroy stored grain in all types of storage. Invasion by this primary coloniser may facilitate the establishment of secondary coloniser and mite pests and stored products pathogens (Trematerra *et al.*, 2007). *S. zeamais* is an invader and enters packages (e.g. commercial rice or pasta) through existing openings that are created from poor seals, openings made by other insects or mechanical damage (Murata, 2008).

Most food products available on the market are packaged so as to prevent infestation; yet, contamination by *S. zeamais* is frequent. This tarnishes brand image in the eyes of consumers, resulting in serious economic damage to food companies. To prevent insect contamination, it is important to understand when, where, and how insects invade food products. Because olfactory sense in *S. zeamais* plays an important role on the infestation of a food in response to food odours, in the present work we investigated in arena the responses of adult maize weevil to nine different categories of commercial Italian rice and eight different types of commercial Italian cereal pasta, in order to understand the attractiveness of the different products.

Materials and methods

The adults of *S. zeamais* used in the bioassays were obtained from the population that emerged from the laboratory in whole corn provided by a farm stores during 2007, with no history of exposure to insecticides. This population was reared on corn under conditions of 27 ± 1 °C and 65 ± 5% relative humidity (R.H.). Unsexed, mixed-age adults 1 to 2 weeks old were used in all experiments.

Attraction of *S. zeamais* adults was studied by comparing nine different categories of commercial Italian rice from grocery stores: comune rice (variety Originario), semifino rice (variety Padano), fino rice (variety Ribe), superfino rice (variety Arborio), pre-cooked rice (variety Ribe), enriched (vitamin) rice, parboiled rice (variety Ribe), integrale (brown) rice (variety Ribe), expanded rice (table 1). Eight different types of commercial Italian cereal pasta were also compared [barley pasta, buckwheat pasta, corn pasta, durum wheat pasta, five cereals pasta (a mixture of durum wheat, barley, spelt, oat, and rye), kamut pasta, rice pasta, and spelt pasta] (table 2).

The tests were carried out in cylindrical arenas of Plexiglas (80 cm diameter x 40 cm high) for bioassays. In each arena nine modified Flit-Track M^2 trap-devices (Trécé Inc, USA) were placed. Teflon paint was applied to the internal part of the arena and of the trap-devices to prevent beetles from escaping. In each trial 100 adult beetles of mixed sex were released at the centre of the arena (Trematerra *et al.*, 2000). The number of trapped insects was checked 15 h after their introduction into the arena. Fourteen replicates for rice tests and fourteen rep-

Table 1. Nutrition facts of the nine different categories of commercial Italian rice used in the tests.

Rice categories	Rice variety	Proteins g/100 g	Carbohydrates g/100 g	Fats g/100 g	Cooking time minutes	Kcal 100 g
Comune rice	Originario	6.4	80.5	0.9	14	356
Semifino rice	Padano	6.7	76.9	1.0	14-16	343
Fino rice	Ribe	5.9	81.0	0.7	14	354
Superfino rice	Arborio	6.8	79.8	1.4	16	359
Pre-cooked rice	Ribe	7.9	75.4	0.8	5	340
Enriched rice	-	6.5	78.5	1.6	4-5	354
Parboiled rice	Ribe	6.9	82.2	0.6	15	362
Integrale rice	Ribe	8	76	2	18	354
Expanded rice	-	9.7	83	0.45	0	375

Table 2. Nutrition facts of the eight different types of commercial Italian cereal pasta used in the tests.

Pasta type	Proteins g/100 g	Carbohydrates g/100 g	Fats g/100 g	Cooking time minutes	Kcal 100 g
Barley pasta	11.6	59.3	1.9	7	300
Buckwheat pasta	7.8	75.4	2.2	5-7	353
Corn pasta	5.7	78.0	1.2	8	346
Durum wheat pasta	14.0	70.2	1.5	12	350
Five cereals pasta	13.0	68.2	1.5	11	338
Kamut pasta	10.5	74.7	0.9	10-11	349
Rice pasta	1.2	85.4	0.7	6-8	353
Spelt pasta	13.8	69.9	2,0	10-11	353

licates for pasta tests were performed, using a total of 2800 insects (1400 in rice tests and 1400 for pasta tests). In order to measure the different attractiveness of each rice categories or pasta type, 20 grams of rice or 20 grams of short pasta were used as bait for each trap-device. In all experiments trap-devices positions were randomized and trap-devices contents were renewed after each replication. The tests were undertaken in incubators, under controlled conditions: 27 ± 1 °C, 65 ± 5% R.H.

Data analysis

The data were submitted to the calculation of Kendall's W association coefficient (Leach, 1979) and to a classic one-way ANOVA analysis. A multiple regression analysis was also performed in order to assess if any distinctive features of the rice or pasta may influence insects choices. The resulting statistic represents the level of agreement among the groups in ranking the items.

Results and comments

Rice products

Results obtained during bioassay tests using Italian commercial rice are reported in the table 3. Kendall's W statistic was used to provide a global measure of the association among many different classifications; the 14 ranks, one for each experimental trial, have therefore been derived, by assigning value 1 to the rice preferred in a given trial, 2 to the quality with the second higher frequency, and so on. The resulting statistic is W = 0.1643; this values indicates that in the different trials the insects chose different types of rice. Nevertheless, overall results indicate that insects show, on the average, a preference: this is clearly confirmed by the one-way ANOVA analysis performed on the nine groups formed by the rice in the 14 experimental trials. The very low p-value (P = 0.0061) indicates that the between groups means are very unlikely to be equal. Maize weevil adults showed preferences, in decreasing order, for: superfino rice (variety Arborio) (14.4%), parboiled rice (variety Ribe) (13.51%), integrale rice (variety Ribe) (11.71%), fino rice (variety Ribe) (11.34%), expanded rice (10.89%), comune rice (variety Originario) (10.74%), semifino rice (variety Padano) (10.59%), pre-cooked rice (variety Ribe) (9.23%), and enriched rice (7.96%). Superfino and parboiled rice are more attractive than the other rice categories; on the contrary pre-cooked rice and enriched rice are less attractive to maize weevil adults. In an attempt to identify the main factors influencing the choices, the total preferences have been considered as the dependent variable in the context of a multiple regression analysis; the five explanatory variables put into the model concerned the organoleptic properties and characteristics of the rice: proteins (g/100 g of rice), carbohydrates (g/100 g of rice), fats (g/100 g of rice), cooking time (min), and energetic value (Kcal/100 g of rice). The method employed has been a stepwise regression, with the calculation of the adjusted R^2 in order to stop the procedure. The results showed that the variables significantly influencing the insects' choice are related to cooking times and energetic value (quantity of amylose in rice) (Kcal/100 g); these two predictors alone account for approximately 70% of the global variance (R^2 = 0.6955). The relationship between

Table 3. Distribution of insects in the bioassay tests on rice.

Rice categories	Insects trapped N.	Mean	SE
Superfino rice	187	13.36	0.87
Parboiled rice	180	12.86	1.08
Integrale rice	156	11.14	1.16
Fino rice	151	10.79	0.99
Expanded rice	145	10.36	1.44
Comune rice	143	10.21	0.83
Semifino rice	141	10.07	0.91
Pre-cooked rice	123	8.79	1.14
Enriched rice	106	7.57	1.04

Table 4. Distribution of insects in the bioassay tests on pasta.

Pasta type	Insects trapped N.	Mean	SE
Corn pasta	250	17.86	1.86
Buckwheat pasta	215	15.36	2.26
Durum wheat pasta	209	14.93	1.32
Rice pasta	195	13.93	1.57
Barley pasta	117	8.36	1.25
Kamut pasta	113	8.07	1.36
Spelt pasta	88	6.28	0.83
Five cereals pasta	81	5.78	1.32
Control	39	2.79	0.51

the preferences and cooking times is particularly strong, as is shown by the high correlation coefficient between these two variables (r = 0.6251).

Pasta products

We have had at our disposal 14 different experimental results, each in the form of frequencies (number of insects preferring a certain type of pasta). We considered this kind of data as a series of K different classifications of N objects (the eight different types of pasta, plus the control trap). In this case, the resulting value was W = 0.5327; this is quite a high value, indicating that the choices among the trials have been similar; in other words, the insects tended to show the same choices in any trial. In order to verify if the differences among the final results could be considered expression of a real preference, a classical one-way ANOVA analysis was performed on the nine groups formed by the different pasta types in the 14 experimental trials; results are reported in the table 4. The extremely low p-value indicates that the between groups means are very unlikely to be equal. Altogether, the results obtained in bioassay tests demonstrated that *S. zeamais* adults revealed preferences in decreasing order for corn pasta (19.13%), buckwheat pasta (16.45%), durum wheat pasta (15.99%), rice pasta (14.92%), barley pasta (8.95%), kamut pasta (8.65%), spelt pasta (6.73%), and five cereals pasta (6.20%). In an attempt to identify the main factors influencing the choices of maize weevil, the total preferences have been considered as the dependent variable in the context of a multiple regression analysis; the five explanatory variables put into the model concerned the characteristics of the pasta: proteins (g/100 g of pasta), carbohydrates (g/100 g of pasta), fats (g/100 g of pasta), cooking time (min), energetic value (Kcal/100 g of pasta). The control trap wasn't taken into account; this is not a severe lack for the analysis, since the resulting total preferences of the insects show that the confounding effect of a void trap is practically absent. The method employed has been a stepwise regression, with the calculation of the adjusted R^2 in order to stop the procedure. The results showed that none of the variables considered influences significantly insects choices; this means that the principal characteristics of pasta can't be considered as "appealing" for infesting insects, on the contrary maize weevil adults are able to respond selectively to semiochemicals from pasta. Corn pasta is more attractive than buckwheat pasta, durum wheat pasta and rice pasta; on the contrary barley pasta, kamut pasta, spelt pasta, and five cereals pasta are less attractive to maize weevil adults.

Conclusions

Results of bioassay tests to different types of Italian rice and cereal pasta suggested that adults of *S. zeamais* are able to respond selectively to odours coming from different rice categories and pasta types considered. In fact seuperfino and parboiled rice resulted more attractive than the other rice categories; on the contrary pre-cooked rice and enriched rice were less attractive to adults. Regarding pasta types the bioassay demonstrated that corn pasta is more attractive than the buckwheat pasta, durum wheat pasta and rice pasta type; barley pasta, kamut pasta, spelt pasta, and five cereals pasta are less attractive to adults. Their action on tested insects can be attributed to the active volatile components presents in these foods.

Rice and pasta products are susceptible to become infested by *S. zeamais* adults at any point in the marketing channel, infestations can occur during the storage process in industries, warehouses, general stores and retail shops already colonized by insects deriving from other products (Trematerra, 2004; Mancini *et al*., 2007). Murata *et al*. (2008) noted that *S. zeamais* adults are able to damage the pasta products, even though this population had been maintained on brown rice for 30 years in a laboratory. This confirmed that *S. zeamais* is not only a rice pest but also a pasta pest.

From a practical view point in accordance with the application of the Hazard Analysis and Critical Control Points (HACCP) procedures in many Italian rice-mills and pasta factories, Integrated Pest Management (IPM) has been suggested for the prevention and control of *S. zeamais* and other pests. Despite these provisions, risks of rice and pasta infestation along the processing cycle, from field raw material to the consumer remains unresolved because of specific aspects of packaging, negligence in warehouses and stores and to the long average shelf-life of the products.

They are, however, most likely to become infested in warehouses where they are often stored for long periods, frequently under less than ideal conditions. Inspections carried out in several shops where infested rice and pasta were bought, showed that usually the stores were neglected, the shelves dusty and infestations in progress (Trematerra, 2004; Mancini *et al*., 2007).

Also for these reasons, it could be necessary to give more attention to packaging and to material used in the packaging must be resistant to *S. zeamais* attack. Unfortunately there is no perfect package that will provide the protection needed for all products under all conditions.

In the case of rice the recent introduction on market of vacuum-packaging reduced infestation risks because the odours are prevented from escaping from the package, resulting in the package being "invisible" to the potential infesting insects (Mullen, 1994; Parkin, 2008). Such vacuum-packaging is not used in the pasta market. On the contrary, pasta is generally packed in a cardboard box, not sealed, or with multilayer plastic film (e.g. polypropylene) with a presence of numerous vent micro-holes. In these cases odours released by pasta escaping from the packages can be detect and followed by insect pests (like *S. zeamais* adults) increasing the infestation risk. *S. zeamais* were attracted by the pasta odour released through the vent micro-holes and subsequently nibbled on the holes to try to get inside. In the intact packages, adults of *S. zeamais* were observed to have nibbled around the air vent micro-holes in the polypropylene film (Riudavets *et al*., 2007; Murata *et al*., 2008).

A means of preventing insect infestation is through the use of resistant and sealed packages, the use of odour barriers (e.g. repellents) or the use of antifeedants compounds, but semiochemicals implicated in that situation requires further research (Weaver and Subramanyam, 2000; Hou *et al*., 2004).

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Author address: Pasquale TREMATERRA (trema@unimol.it), Dipartimento di Scienze Animali, Vegetali e dell'Ambiente, Università degli Studi del Molise, via De Sanctis, I-86100 Campobasso, Italy.

Received December 5, 2008. Accepted April 3, 2009.