Ability to penetrate through pasta packaging of the maize weevil, *Sitophilus zeamais* Motschulsky

Trematerra, P.*#[1], Savoldelli, S.[2]
[1]Department Agricultural, Environmental and Food Sciences, University of Molise, via De Sanctis, 86100 Campobasso, Italy
[2]Department of Food, Environmental and Nutritional Sciences, University of Milano, via Celoria 2, 20133 Milano, Italy

*Corresponding author, Email: trema@unimol.it
#Presenting author, Email: trema@unimol.it

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Abstract

The ability of maize weevil, *Sitophilus zeamais* Motschulsky, adults to penetrate pasta packages was studied. Infestations can occur during the storage process in manufacturing facilties, warehouses, general stores and retail shops. Sixteen different types of commercial pasta was tested: barley, buckwheat, durum wheat, five cereals (a mixture of durum wheat, barley, spelt, oat, and rye), kamut, corn, rice, spelt, barley and buckwheat, dietetic, egg pasta, gluten free, spelt and lentils, tricolour pasta (a mixture of semolina, tomato, and spinach), vitamin enriched, and whole wheat semolina. The pasta packages were divided into five categories depending on packaging characteristics: folded carton box (tube style) with end flaps tucked and glued, with a clear window of PP film; plastic pillow pouch with gussets, lap seal; plastic pillow pouch with gussets, fin seal; plastic pillow pouch with gussets, fin seal re-sealed; plastic pillow pouch without gussets, fin seal. Maize weevil adults were found inside packages of barley and buckwheat pasta, durum wheat pasta, egg pasta, five cereals pasta, kamut pasta, rice pasta, spelt pasta, spelt and lentils pasta, tricoloure pasta, vitamin enriched pasta, and whole wheat pasta. They entered into carton boxes and infested the pasta through openings not well sealed by glue. *S. zeamais* were also able to enter several types of plastic pasta packaging through large or enlarged air vent micro-holes present on polypropylene pasta packages. The results show that adult maize weevil prefer entry by already existing holes. New holes have never been detected but only a few signs of jaw attacks on some packaging. No infestation was observed inside packages of barley pasta, buckwheat pasta, corn pasta, dietetic pasta with fibre, or gluten free pasta.

Keywords: *Sitophilus zeamais*, maize weevil, pasta infestations, packaging materials

1. Introduction

Several insect species can infest pasta factories leading to negative economic and commercial consequences. Infestations can occur during the storage process in manufacturing facilties, warehouses, general stores and retail shops already colonized by insects deriving from other products (Süss and Locatelli, 1999; Riudavets et al., 2002; Barros et al., 2003; Trematerra and Süss, 2006). Pasta products may be infested by the maize weevil, *Sitophilus zeamais* Motschulsky, during shipment in trucks, railcars, and ships as well as during retail storage, or even in the consumer's home (Trematerra, 2004, 2009, 2013; Süss and Savoldelli, 2011). Adults enter packages of commercial pasta through openings made by other insects, existing openings created from poor seals or mechanical damage (Cline, 1978; Locatelli and Süss, 2004; Stejskal et al., 2004; Riudavets et al., 2007; Murata et al., 2008; Parkin, 2008; Trematerra, 2009; Athanassiou et al., 2011). Most food products available on the market are packaged so as to prevent infestation (Laudani and Davis, 1955; Brooke and Lomax, 1967;

Dal Monte, 1967; Batth, 1970; Wohlgemuth, 1979; New and Rees, 1988; Highland, 1991; Adler, 2008; Trematerra, 2009; Athanassiou et al., 2011; VanRyckeghem, 2011; Mullen et al., 2012), although contamination by insects is still frequent. One means to further prevent infestation could be the use of resistant and sealed packages. Paper and board packaging are the most common materials and generally considered the most susceptible to insect attack (Trematerra and Savoldelli, 2014). The widespread use of these susceptible packaging materials for food products should be carefully evaluated, because losses from insect infestation of packaged foods are the cost sum of growing, harvesting, transportation, processing, and packaging (Mullen and Mowery, 2006; Sutton et al., 2011). In this paper we tested the ability of *S. zeamais* adults to enter 16 commercial pasta packages, either folded carton boxes or plastic pillow pouches with gussets.

2. Materials and Methods

Procedures were done as described by Trematerra (2009). Unsexed, mixed-age adults 1–2 weeks old, obtained from a population of *S. zeamais* reared in the laboratory on whole corn, with no history of exposure to insecticides, were used in all tests. This population was reared on corn under conditions of 27±1°C and 65±5% relative humidity (r.h.). Sixteen commercial pasta products were collected to evaluate the ability of *S. zeamais* adults to enter different types of packaging (Table 1). Depending on packaging characteristics the pasta packages were divided into five categories: folded carton box (tube style) with end flaps tucked and glued, with a clear window of PP film; plastic pillow pouch with gussets, lap seal; plastic pillow pouch with gussets, fin seal; plastic pillow pouch with gussets, fin seal re-sealed; plastic pillow pouch without gussets, fin seal. In each test 20 *S. zeamais* adults were used. Each pasta package was enclosed together with adult *S. zeamais* in a plastic container with a lid (39 cm x 30 cm x 13 cm) for 2 weeks. After 2 weeks the adults outside were counted and the pasta packages were carefully examined using a stereo microscope to check for the presence of both mechanical holes and holes due to insect activity. The packages were then opened and the adults inside the package were counted. Two tests were made for each pasta package.

3. Results

S. zeamais adults were able to enter several kinds of pasta packaging (Table 2). Among pasta packaged in folded carton boxes, only dietetic pasta with fibre (durum wheat) was not infested; on the contrary, barley and buckwheat pasta, five cereals pasta (wheat, spelt, barley, oats, rye), rice pasta, spelt and lentil pasta were all infested by *S. oryzae* adults. In this case there were no mechanical holes in the carton packages but adults entered inside and infested the pasta through openings not well sealed by glue.

Generally polypropylene pasta packages have one or two rows of mechanical air vent micro-holes on the back for the release of air. These holes also facilitate the entry of adult insects. Egg pasta, tricolour pasta and whole wheat pasta protected in plastic pillow pouches with gussets and a lap seal allowed infestation by adult *S. zeamais*, while barley pasta protected with the same packaging was not infested (Table 2). Air vent micro-holes were not present on packages of barley pasta. They were present, in quantities of 42, 17 and 18, respectively, in tricolour pasta, egg pasta and whole wheat pasta packages. They had a diameter varying from 1.63 to 2.55 mm. In this case we observed that *Sitophilus* adult entered into the different packages through these pre-existing mechanical holes. The package of egg pasta was the one with the most holes, and also the package type the most adult insects

entered. It had 42 mechanical holes with an average size of 2.55 mm and a mean number of 5.5 *S. zeamais* were found inside these packages (Table 2).

Table 1 Packaging description, package characteristics and pasta characteristics.

Packaging description	**Material description**	**Thickness µm total and partial**
Folded carton box (tube style) with end flaps tucked and glued; with clear window of PP film	Carton	460
	Carton	480
	Carton	460
	Carton	470
	Carton	460
Plastic pillow pouch with gussets, lap seal	PP coex	58 (26/32)
	PP cast	62 (29/5.5/27)
	PP cast; OPP	60 (5/24/3.5/28)
	PP cast; OPP	69 (24/3.8/42)
Plastic pillow pouch with gussets, fin seal	PP cast; OPP	60 (28/32)
	PP cast; OPP	60 (28/32)
Plastic pillow pouch with gussets, fin seal re-sealed	PP coex	60 (28/32)
Plastic pillow pouch without gussets, fin seal	PP cast; OPP	52 (24.5/3.5/25)
	PP cast; PP coex	53 (30/23)
	PP coex	53 (30/23)
	PP cast; OPP	51 (28/24)

[a]Depth x width x length for board boxes. Width x length for pouches, measured flat (without gussets) and within the seals. PP coex = copolymer polypropylene and others polyolefins; PP cast = 100% polypropylene; OPP = oriented polypropylene.

Corn pasta and gluten free pasta packaged in plastic pillow pouches with gussets and a fin seal (PP cast; OPP) were not infested by adult *S. zeamais*. Similarly, buckwheat pasta in plastic pillow pouch with gussets, fin seal, re-sealed (PP coex) was not infested. In this case adult *S. zeamais* were unable to enlarge and cross the air vent micro-holes, which were present at a reduced number of only 7–8, with diameters varying from 1.22 to 1.42 mm. In packages consisting of plastic pillow pouches without gussets and a fin seal, durum wheat pasta (PP cast; OPP), kamut pasta (PP cast; PP coex), spelt pasta (PP coex), and vitamin enriched pasta (PP cast; OPP) were visited by adult *S. zeamais*. These packages presented from 17 to 20 mechanical holes each; adults entered into the package through these mechanical holes, which had diameters from 1.90 to 2.37 mm (Table 2).

Table 2 Number of *Sitophilus zeamais* adults into pasta packages (in). Number of mechanical holes on packages and average size of holes in mm.

Material description	Pasta type	Air vent micro-holes N.	Air vent micro-holes mm	Enlarged holes mm	Average adults (in)
Carton	Barley and buckwheat pasta	-	-	-	4.0
Carton	Dietetic pasta with fibre (durum wheat)	-	-	-	0
Carton	Five cereals pasta (wheat, spelt, barley, oats, rye)	-	-	-	1.5
Carton	Rice pasta	-	-	-	1.0
Carton	Spelt and lentils pasta	-	-	-	2.5
PPcoex	Barley pasta	0	0	-	0
PPcast	Egg pasta	42	2.55±0.17	2.70	5.5
PPcast; OPP	Tricolour pasta (tomato and spinach)	17	1.63±0.04	1.725	1.5
PPcast; OPP	Whole wheat pasta	18	2.01±0.61	2.40	2.5
PPcast; OPP	Corn pasta	8	1.22±0.14	-	0
PPcast; OPP	Glutenfree pasta (corn)	8	1.26±0.13	-	0
PPcoex	Buckwheat pasta	7	1.42±0.21	-	0
PPcast; OPP	Durum wheat pasta	17	2.07±0.10	2.40	3.0
PPcast;PPcoex	Kamut pasta	20	2.19±0.13	2.75	0.5
PPcoex	Spelt pasta	20	2.37±0.07	2.55	0.5
PPcast; OPP	Vitamin enriched pasta	20	1.90±0.20	-	1.5

[a]Depth x width x length for board boxes. Width x length for pouches, measured flat (without gussets) and within the seals. PP coex = copolymer polypropylene and others polyolefins; PP cast = 100% polypropylene; OPP = oriented polypropylene.

Plastic packages of egg pasta, tricolour pasta, whole wheat pasta, durum wheat pasta, and spelt pasta revealed enlarged holes ranging from 1.725 mm to 2.75 mm (Table 2).

The results show that adult *S. zeamais* prefer entry by already existing holes, widening them if necessary. We never detected new holes but only a few signs of jaw attacks on some packaging, because adults of *S. zeamais* were not able to penetrate different packaging materials.

4. Discussion

Our tests on different types of pasta products suggest that adults of *S. zeamais* are able to respond selectively to odours coming from different pastas. The attractiveness of pasta products for insects can be attributed to the active volatile components released by the food (Maga, 1978; Germinara et al., 2008; Trematerra, 2009). Olfaction is the means by which *Sitophilus* identify packaged food products as a location in which to carry out important life

functions such as finding food or a mate and oviposition (Trematerra et al., 2007; Trematerra, 2013). This means that infestations can occur during the storage process in manufacturing plants, warehouses, general stores and retail shops already colonized by insects deriving from other products, and also at the consumer's home (Trematerra, 2004, 2009; Athanassiou et al., 2011; Süss and Savoldelli, 2011).

We observed that *S. zeamais* were able to enter several types of pasta packaging. Adults were found inside packages of barley and buckwheat pasta, durum wheat pasta, egg pasta, five cereals pasta, kamut pasta, rice pasta, spelt pasta, spelt and lentils pasta, tricolour pasta, vitamin enriched pasta, and whole wheat pasta. No infestation was observed inside packages of barley pasta, buckwheat pasta, corn pasta, dietetic pasta with fibre, or gluten free pasta. In the case of folded carton boxes, adults entered inside and infested the pasta through openings not well sealed by glue; if overwraps are not completely sealed, insects can often gain entry at the corners of the folded flaps. Seals and closures could be improved by changing glue patterns or the type of glue used (Figure 1).

Openings in packaging may also be made deliberately by the manufacturer in the form of "vents" to allow pressure equalization. In this way, the manufacturer can avoid bursting or shrinking of food packages during shipment over changing altitudes and temperatures. In polypropylene pasta packages that had one or two rows of mechanical air vent micro-holes on the back, the holes facilitated the entry of adult insects.

In our tests *S. zeamais* adults were observed inside polypropylene packaging when the number of micro-holes per package ranged from 17 to 42; no infestation was observed with a more limited number of micro-holes in the package (7-8). The diameter of the micro-holes assumes a particular importance; specifically, infestation was observed in packages with hole diameters varying from 1.63 to 2.55 mm but no infestation was present with diameters varying from 1.22 to 1.42 mm. Thus reducing the size of the holes or even eliminating the holes in the package could help to drastically reduce infestation levels. Insect resistance can also be improved by over-wrapping the packages with materials such as oriented polypropylene films.

In order to discourage insect infestations, food odours may be prevented from escaping the package through the use of barrier materials. Flexible packaging with acrylic, polyvinylidene chloride (PVdC), or ethylene vinyl alcohol (EVOH) can improve odour retention. Several authors have referred to the importance of preventing insect infestation through the use of resistant and sealed packages, the use of odour barriers (e.g. repellents) or the use of antifeedant compounds (Sreenathan et al., 1960; Rao et al., 1972; Highland, 1978; Shukla et al., 1993; Mullen, 1994; Hu et al., 1998; Davis and Pettitt, 2002; Hou et al., 2004; Wong et al., 2005; Mullen and Mowery, 2006; Mohan et al., 2007; Germinara et al., 2010; Savoldelli and Trematerra, 2011; Licciardello et al., 2013). These compounds included neem oil, methyl salicylate, DEET derivatives, and insect growth regulators (VanRyckeghem, 2011). Hou et al. (2004) successfully tested insect repellents that were applied to packages, while application of low risk insecticides may also be effective. In 2009 the US Environmental Protection Agency approved ProvisionGard™, which uses IGR methoprene and is now being considered for use in many package applications (VanRyckeghem, 2011). Many companies have implemented package-testing programs to improve the resistance of packages to insect attack. Currently several materials are commercially available for this purpose (Mullen and Mowery, 2006; Navarro et al., 2007; Mullen et al., 2012).

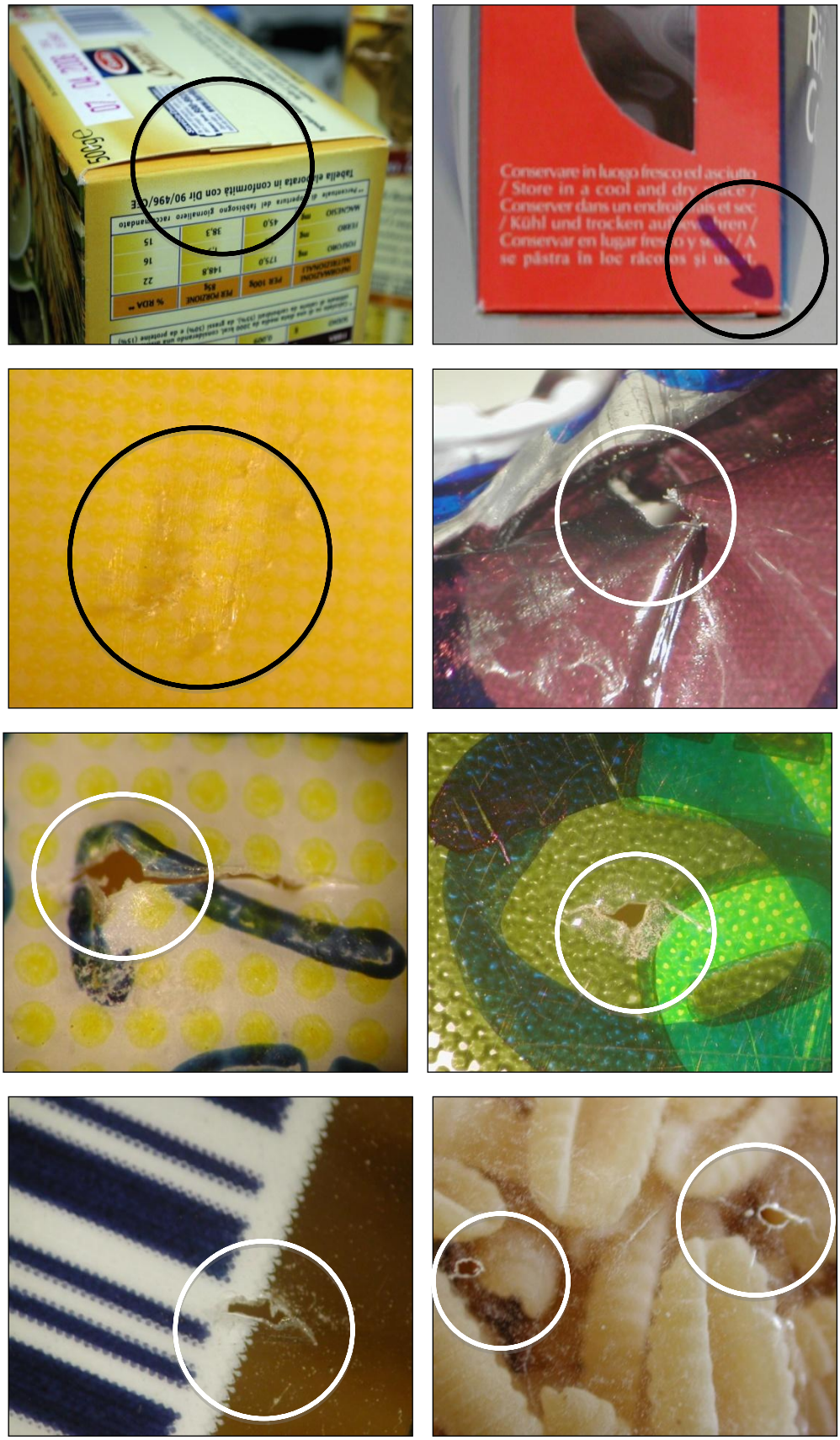

Figure 1 Folded carton boxes not well sealed by glue which facilitate the entry of *Sitophilus zeamais* adults and damages produced by adults on polypropylene pasta packages.

The mechanical holes present in packages allow the diffusion of volatile components that attract insects and facilitate the entry of adults. When the holes were large enough, adult maize weevils entered without difficulty; in other cases, as revealed in our tests, clear signs of insect mandibles were observed. Riudavets et al. (2007) overviewed the characteristics of the entrance or exit holes that are produced by some major stored-product beetle species. In the intact packages, adult *S. zeamais* were observed to have nibbled around the air vent micro-holes in the polypropylene film (Murata et al., 2008). In this regard, Highland (1991) separated package pests into two categories, penetrators and invaders. When faced with pasta packages, both penetrators and invaders will take advantage of any sort of opening in a packaging material in order to gain entry. These openings may form as a result of the chewing of penetrators, or as rips, tears, or punctures resulting from normal wear and tear throughout the handling process. According to Mullen et al. (2012) most infestations are the result of invasion through seams and closures, and rarely through direct penetration.

Riudavets et al. (2007) tested the ability of *Lasioderma serricorne* (F.), *Rhyzopertha dominica* (F.) and *Sitophilus oryzae* (L.) to penetrate different packaging materials. At the adult stage, all three species were considered penetrators of polyethylene (50-µm thick), polypropylene (25-µm thick) and polyester (12-µm thick). *L. serricorne* and *R. dominica* were able to penetrate plastic films better than adult *S. oryzae*. Shukla et al. (1993) noted that adults of *Callosobruchus maculatus* (F.), *Oryzaephilus surinamensis* (L.), *R. dominica*, *S. oryzae*, *Tribolium castaneum* (Herbst) and *Trogoderma granarium* Everts were able to penetrate polyethylene that was less than 0.08 mm in thickness. Generally, among multilayer, polyester, polyethylene and polypropylene the available data clearly indicate that multilayer and polyethylene are by far the least and most susceptible to penetration, respectively, by stored-product beetle species (Riudavets et al., 2007). Wohlgemuth (1979) and Adler (2008) noted that, with the exception of young larvae, most species that are usually found in packaged products cannot pass through holes less than 0.71 mm in diameter. First instars are able to invade polyethylene, polypropylene and polyvinyl chloride through holes of minimal size, which are often less than 0.5 mm in diameter. VanRyckeghem (2011) listed several commonly used packaging materials and their resistance to penetration by insects: impervious to attack (vacuum sealed jar and tin cans); insect proof (polycarbonate, polyethylene terephthalate, polyester, nylon plastics); insect resistant [cellulose acetate, polyamide, polyethylene (250 microns = 10 mil), polypropylene, polyvinyl chloride]; susceptible to attack [acrylonitrile, polylactic acid, polyethylene (125 microns)]; no protection from attack [ethylene vinyl acetate, kraft paper, corrugated paperboard, paper/foil/polyethylene, polyethylene (25–100 microns = 1–4 mil), polyvinylidene chloride].

Risks of pasta infestation along the processing cycle, from field raw material to the consumer, remain unresolved because of specific aspects of negligence in warehouses and stores and due to the long shelf life of the products. Also for these reasons, it could be necessary to give more attention to packaging and the material used in the packaging must be resistant to insect attack.

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