	T	TNT	T	TNT	T	TNT
T 1	0	0,25	2	2,5	0	0
T 2	0,25*	1	2,75	2,5	0*	3,25
T 3	0,25*	1,5	3,5	3,75	0*	2,75
T 4	0,5*	2	4	4	0*	2,5
T5	0,5*	3,25	4	4	0,25*	4

P. interpunctella was not able to develop on organic litter, indeed young larvae failed to develop in any replicates. *O. surinamensis* too showed difficulties in develop on organic litter and only one adult emerged by one replicates in all the test.

T. confusum showed a significative difference in development only in the first assessment. The following assessments showed no significant difference to the control.

3. Discussion

These data confirmed and integrated the avaible information in literature about the influence of diet on development of stored pest, with reference to *P. interpunctella* and *O. surinamensis* (Fields *et al.*, 1992; Johnson *et al.,* 1995, Hagstrum and Milliken, 1988; Waldbauer and Bhattacharya, 1973).

With reference to *T. confusum*, this study showed that it was able to complete successfully his development on organic litter. These data are preliminary and require further investigations on the possible development on organic litter by other stored food pest in addition to adjustments to the experimental protocol.

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Unusual cases of product contamination by 'wandering' larvae of the Indian meal moth, *Plodia interpunctella* (Lepidoptera: Pyralidae)

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ABSTRACT

Upon hatching, the larvae of the Indian meal moth (IMM), *Plodia interpunctella*, disperse vigorously. Within a few hours, they establish themselves on the crevices of food or enter packaged product through small openings and cracks. When on food the larvae intensively feed in or near a tunnel-like case made of frass and silk they web together. The number of larval instars varies from five to seven, depending on temperature, humidity and available food quality. Most mature larvae leave the food medium and search for a suitable place to spin a cocoon in which they pupate or hibernating (diapause). At the end of larval development, the larvae usually chews a hole in a packaging foil, and leave the medium to pupate outside in corners and cracks and also behind items on walls. Fully grown larvae of the IMM may travel a considerable distance before pupating in a location that is frequently away from the larval food source. It will be proven and illustrated that during this time larvae the IMM may penetrate the packaging material of some household items that were not their food source. Unusual cases of product contamination by 'wandering' larvae will be described. Client claims are thus frequent as only a few larvae in a package with their webbing and frass are very repulsive to homeowners. Impact of product contamination by 'wandering' larvae of the IMM to the firm marketing the products will be discussed.

Key words: Indian meal moth, *Plodia interpunctella*, larva, food products, contamination, client claims

1. Introduction

Females of the Indian meal moth (IMM), *Plodia interpunctella* (Hübner), lay 200-400 eggs singly or in a small batches on food products or near them (Mullen and Arbogast, 1977), sometimes spatially aggregated in some fashion (Arbogast and Mullen, 1978). These eggs are rounded or elongated (0.3 x 0.6 mm) and white, turning orange over time. The larvae (L1) that emerge from these eggs are very small and barely visible to the human eye. They usually disperse vigorously in a search for food, and after detection of the food odor they move into its direction and find food source finally (Sedlacek et al., 1996). Within a few hours, they establish themselves on the crevices of food or enter packaging through cracks and crevices. The larvae eat the stored products in or near a tunnel-like case of frass and silk they web together (Mueller, 2010). Larvae feed greedily on various food products, grow quickly and molt. Fully grown larvae called also the ‘wandering larvae’ are 9-19 mm in length, with an average of about 1,25 cm. Their color is usually dirty white, but may range from pink to brown to a greenish tinge. The number of larval instars varies from five (Allotey and Goswami, 1990) to seven, depending on temperature and available food (Tzanakakis, 1959).

Thus, the IMM larvae contaminate food products with their presence and webbing containing larval excreta (frass) and exuvia (cast skins). Customers usually find the food product to be infested when larvae grow up and produced a vast amount of webbing.

What is more, the fully grown larvae of the IMM (the wandering larvae) leave the food medium, and they may travel a considerable distance before pupating in a location that is frequently away from the larval food source. Before and during this migration the larvae may penetrate the packaging material of many household foods (Robinson, 1996). Simply, some products (food and non-food) kept in storage are indirectly contaminated by wandering larvae that usually search not for food, but for pupation sites. The presence of larvae within these products causes consumer complaints and rejection of these products.

This paper will prove and illustrate the cases that during search for pupation sites larvae of the IMM may penetrate the packaging material of some household items that were not their food source. Unusual cases of product contamination by 'wandering' larvae will be described. Client claims are thus frequent as only a few larvae with their webbing and frass in a package are very repulsive to homeowners. Therefore, the impact of product contamination by 'wandering' larvae of the IMM to the firm marketing the products will be also discussed.

2. Materials and Methods

Within last 3 years, a company “Trojszyk” Entomological Consulting, Warsaw, Poland, received various products contaminated by pests or sometimes pictures illustrating the pest contamination as customer complaints. These were provided with the orders of manufacturers to determine an insect pest to the species, and to explain each case of product contamination. Among requests there were some cases of unusual contamination of different food and non-food products, and they were accompanied by the repulsive customer claim. These non-typical cases were selected, analyzed and presented in this paper. Cases were illustrated with the pictures, a part of them done by the customers, therefore some of them are of low quality.

3. Results

The typical and unusual cases of collateral contamination product by IMM larvae from another food sources are illustrated and described below.

Case No. 1:

A consumer provided a chocolate bar that was contaminated only with large fecal pellets (frass) and delicate webbing that were produced by the fully grown IMM larvae. No larvae and no other signs of pest activity were noticed.

This chocolate bar was traditionally packed, and the aluminium foil and paper were used as packaging materials. Wrapping materials did not constituted a barrier that prevented the larval invasion. Thus, fully grown larvae visited the product for a short time, and they laid down only fecal pellets and a few threads of silk webbing on the surface of chocolate bar. Probably, a nearby product was infested and it formed a source of wandering larvae.

Fig. 1 Excreta (frass) of the IMM larvae on the surface of the chocolate bar with no other signs of the larval activity.

Case No. 2

Chocolate and nut candies were provided for the evaluation. The thorough investigation of these candies under a microscope revealed that these candies were contaminated only on the external surface of candy wrappers (Fig. 2 & 3). No signs of pest activity were found on the candy surfaces.

A live pupa of the IMM (Fig. 2) and remains of pupal skin (Fig. 3) left by an emerging moth were found in spaces of the wrapper that were suitable for pupation. Silk cocoon was produced during warm months as it was made of delicate silk webbing. The product was contaminated by the fully grown larvae that were interested only to find no food but a proper space for pupation. Some other products (may be other candies of the same lot) were contaminated by the pest, and these products were a source of larvae.

Case No. 3

IMM larva was found under a cap of the bottle with mineral water (Fig. 4). It was fully grown larva (wandering stage) within the cocoon made of delicate silk webbing. Thus, the cocoon was produced during the summer months. Mineral water as a content of the plastic bottle was not contaminated by larva or larval excretes. Possible entries to the space confided by a cap are indicated in Fig. 5 with arrows. This is essentially collateral damage from another food product.

Fig. 2 A live pupa of the IMM within the candy wrappers.

Fig. 3 Remains of pupal skin left by an emerged IMM moth

Case No. 4:

A customer consumed one third of content of the ketchup jar, and on the following day found larva under the jar lid (Fig. 6). The consumer documented this case of product contamination by the picture, and reported a complaint to the manufacturer.

The larva found under the jar lid build already a delicate cocoon, indicating the summer contamination. This larva seems to be freshly pupating, thus it contaminated ketchup jar 1-2 days ago, and it happened in the customer house, not at a premise of the manufacturer nor in the retail food store.

Fig. 4 Larva of the Indian meal moth under the cap of bottle with mineral water.

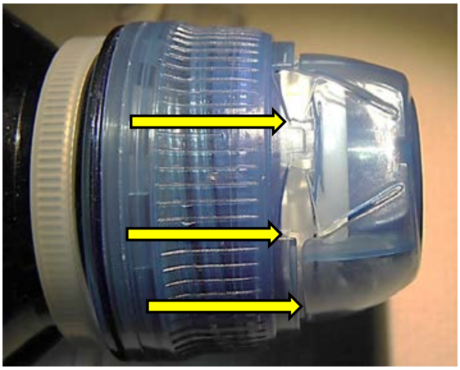

Fig. 5 Possible entries for the larva of the Indian meal moth

Fig. 6 IMM larva in a pupal cocoon found under jar lid.

Fig. 7 Pupa of the IMM in a hibernation cocoon found under lid of jam jar

Case No. 5

The Case No. 5 is similar to the Case No. 4. A pupa of the IMM was found under a lid of the jam jar (Fig. 7) that was freshly bought at the local retail food shop. The pupa was alive, and its body color was deep brown. Pupa was confined within a dense silk cocoon. Pupal stage of the IMM lasts 15-20 days under prevailing room temperatures about 20oC (Sedlacek et al., 1996). Thus, the cocoon was spun during a cold month (made of a dense webbing), and development of pupal stage was advanced (deep brown coloration of pupa). The customer provided the receipt indicating that the jam jar was purchased a few days ago. All these facts prove that the pest contaminated the jam jar at the retail food shop.

Again, the final product was contaminated by wandering larva of the IMM. That larva left the product in which it was feeding and developing, and after searching around for the hiding place larva finally found a proper place under the lid of glass jar, constructed a silk cocoon there and pupated.

Case No. 6

An unusual food contamination by live larvae of the IMM was reported on November 2016 by a customer which opened the originally closed glass jar, and found two moving larvae on the surface of jam (Fig. 8). Label data indicate that jam was manufactured on March 2016. Thus, the product was not infested at the manufacturer site, as it was not possible for IMM larvae to survive more than a half of year on the surface of jam kept in a tightly closed glass jar.

Simply, larvae of the IMM fall down on the surface of jam when a customer removed a lid off the jar, devastating a silk construction of the cocoon that was formed outside of jar, just under its lid.

Fig. 7 Pupa of the IMM in a hibernation cocoon found under lid of jam jar

Fig. 8 Two live larvae of the Indian meal moth on the surface of the final product

Case No. 7

The most unusual case of product contamination is illustrated by Fig. 9. It presents several fully grown larvae of the IMM within the diapers (baby nappies). Packaging of diapers was not insect-proof, and wandering larvae readily penetrated into the bag with diapers. They were not searching for food, but only for a good hiding place for pupation. A nearby product was heavily infested by larvae of the IMM, and it should be removed from a premise as soon as possible to prevent the further spreading of wandering larvae.

Discussion

Indian meal moth (IMM) is a world-wide insect pest of stored products and processed food commodities. Cox and Bell (1991) noted that this moth 'has the widest distribution of all moths generally infesting stored foods and is truly a global pest'. Also, it is one of the most troublesome pests in retail shops or private households. Infestation of the stored food products by IMM can cause a direct product loss and indirect economic costs through pest control costs, quality losses, and considerable amount of consumer complaints.

The cause of consumer complaints are the IMM larvae or pupae in cocoons found within the product. Only one larva or a few larvae in a package with their webbing and frass are very repulsive to homeowners, and very costly to the companies that market the products. Consumer complaints about the presence of insects on or in packaged products can affect the reputation of the brand or manufacturer.

Fig. 8 Two live larvae of the Indian meal moth on the surface of the final product

Fig. 9 The wandering larvae of the IMM found a good hiding place for pupation within the diapers (nappies).

When full grown, IMM larvae usually leave by the hole chewed in packaging material of the product and pupate in a suitable place outside the package (Robinson, 1996). They then emerge from their food source and can travel some distance before spinning their cocoons in various crevices or at wall/ceiling junctions. Pupation usually occurs not only in the vicinity of their food (Mueller, 2010), but also away from their food source. Some larvae spin their cocoons in the food medium just below the surface, but cracks, crevices or other protected places, typically in dark locations, are preferred by the others. One infested package of product in a store can be a source of larvae that search out other products usually to pupate on the surface or interior spaces of the other packages. Thus, a collateral contamination with pest from another food products should be considered (Fig. 1-9). Therefore, control treatment with insecticides should be followed by the advanced inspection including a search for pupal cocoons in corners and cracks and even … behind items on walls. All food and non-food product must to be checked, even those perfectly sealed packages that contain non-food for the IMM larvae (Fig. 6 & 7) as well as the diapers (baby nappies) (Fig. 9).

Cocoons spun by the pupating larvae can be differentiated from those made by the hibernating or diapausing larvae. The hibernaculum (i.e., hibernation cocoon) is dense and completely closed (Fig. 7), whereas the pupal cocoon is flimsy, loose fitting, tapering, and opens anteriorly to permit exit of the adult (Fig. 6). Following hibernation, the larva opens a hole in the hibernaculum and either spins its pupal cocoon inside, or comes out and constructs the pupal cocoon nearby. It appears that larvae spin pupal cocoons outside the hibernaculum only when the hibernaculum is not large enough to include the pupal cocoon (Sedlacek et al., 1996). The differentiation between the pupal cocoons and dense hibernation cocoons should be always conducted when we want to explain the case of product contamination by IMM. For example, when a product was produced in February and some pupal cocoons were found in August, then one may conclude that the product was not contaminated at the manufacturer site.

Diapause provides a means for the species to overwinter or survive periods of adverse environmental conditions at higher latitudes in unheated situations. The extent to which different strains diapause varies greatly, and those from the tropics or long reared in laboratories showing a reduced capacity. Diapause induced in response to short photoperiods (Bell, 1976), low temperature, or high population pressure (Tsuji, 1963) may greatly extend the developmental periods. At the limits of its range, IMM may have only one to two generations per year, but as many as eight generations per year may occur in warmer climates (Tzanakakis, 1959; Stratil & Reichmuth, 1984). Therefore, the use of the larval developmental time under the prevailing room temperatures is cumbersome to determine the moment of the product contamination by the IMM larvae. Only during warm months it is possible to indicate the time (and place) of product contamination when live larvae of the IMM or live pupae in the pupal cocoons are found within the infested product.

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Susceptibility of dried berries to infestation by *Plodia interpunctella* (Lepidoptera: Pyralidae) in correlation with total sugar content

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Abstract

By assessing the degree of resistance of stored products to infestation by insect pests and correlating it with physical, chemical and nutritional characteristics of products, we could gain a real insight in these pests feeding preferences, and consequently in their biology and ecology. The aim of this study was to assess the degree of resistance of five dried berry species (strawberry, raspberry, blackberry, black chokeberry and cranberry) to infestation caused by the major pest of dried berries, *Plodia interpunctella*. Susceptibility was rated based on the Index of susceptibility (IS) for insect development and the Susceptibility rating. Dried cranberries were