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Research Article

Rodent Control in Urban Industrial Areas: from Research to Action

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Abstract: Pest control measures have an increasing importance due to the rising economic initiatives and urbanization resulting in a growing number of industries facing pest problems. The use of rodenticides is a very common method in rodent control but the bait consumption depends on the environmental alterations in different industry areas. The aim of the present study was to monitor the control of rodents in facilities belonging to various food industries using rodenticide baits and to determine the factors that could directly influence the bait consumption. In the city of Plovdiv and its region, Bulgaria, 89 bait stations were monitored in different industrial sites: glass factory, croissant factory and dairy. The bait consumption was studied using the electronic monitoring *PestScan* method. The results showed that factors such as industry type, the construction and technical implementation of the buildings, the location of the site and the type and formulation of the rodenticide used influence the decision for the exact bait disposal. Understanding environmental conditions influencing the bait consumption could help to plan the pest control for specific sites by matching with specific strategies.

Key words: rodents pest control, urban rodents

Introduction

The centuries-old battle between people and vermin rodents dates back to the dawn of human civilization; however, today their populations of rodents outnumber human populations (Atanasov & Mateva 1980). There are 2,277 species of rodents in 30 extant families worldwide (Lund 2015) but only 5–10% of them are the real vermin in agricultural and urban environments and even less are causing problems in bigger geographic areas (Stenseth et al. 2003). More than 25 species of rodents are registered as vermin in agriculture, inflicting a wide variety of damages and losses of crops. Most of them belong to the family Muridae. Three species are significant as vermin in urban territories, i.e. *Rattus rattus*, *Rattus norvegicus* and *Mus musculus* (Battersby & Webster 2001).

Rodents inflict colossal damages to agriculture – they can consume a huge amount of cereal crops in fields, warehouses, as well as in food-processing factories, shops and homes (Makundi et al. 2007). Every year they consume crops, which can feed 200 million people. Considering that 3.5% (or 3.3 million tons) of stored crops are destroyed by rodents, the part they play in human malnutrition stands out even more (Tasheva & Kontev 1997). Aside from the damages they make, synanthropic rodents are related to various zoonoses. They are reservoirs and hosts of many infectious (including parasitic) diseases both in humans and farm animals. In the last ten centuries, rat-borne diseases have taken more lives than the conduct of all wars (Nowak 1999). Due to the direct and indirect contact of rodents and humans through contaminated fruit, vegetables or objects used in the human's everyday life, there is still danger (Ilieva 2005). The presence of synanthropic rodents in homes leads to other health problems. Carrer et al. (2001) have reported that the presence of rodents in rooms leads to higher levels of indoor allergens causing allergic reactions, asthma and rhino-conjunctivitis. Other studies have shown that asthmatic reactions in humans are connected to allergens carried by rats and mice (Perry et al., 2003). All this highlights the great importance of fighting off the vermin rodents. The deratization is a combination of actions taken for the restriction and extermination of rodents. It is a part of the systematic battle against pests, widely known as "pest control" (Rylnikov et al. 2012).

Rodenticides are the most common, practical and effective measures that exterminate rodents in large areas and because of their low prices. They do not require a lot of work and properly used they can give quick results with minimal impact on the environment and non-targeted living organisms. Anticoagulant rodenticides act through blocking the Vitamin K_1 cycle and disrupting the coagulation (Witmer & Eiseman 2007).

Modern-day requirements, approach and practice of carrying out the pest control in the industrial areas of the food industry have introduced the founding principle of organization and practice of the "integrated pest management". Integrated pest management is not a way of fighting off the vermin. It is a continuous process, a system, continuous monitoring and corrective activities for maintaining the number of rodents at low, safe levels, acceptable with minimal health risk, food safety and economic damage. The main organisational and practical activities that can be conducted are inspection of the facilities of the food industry, monitoring the appearance of rodents and their density. According to the European and worldwide practices the monitoring includes three stages: initial and current inspection of facilities; facility maintenance and current monitoring of the number of rodents and evaluation of their density; information, documentation and archive recordings.

The present study aimed first to identify the effectiveness of deratization in three urban industrial areas in Plovdiv (Bulgaria). In the second stage, study findings were disseminated to appropriate audiences and utilised to direct appropriate rodent control efforts in the city.

Materials and Methods

Study area

The study has been carried out in three facilities of the food industry (Table 1).

Study equipment

We used two types of traps: a deratizational BETA box with a lock, 230 mm x 190 mm x 95 mm; a multi-trap – an alive animal trap for house and field mice, 265 mm x 165 mm x 62 mm. All studies were carried out with rodenticide baits and anticoagulants of second generation produced by leading global companies. These were:

Rodenticide 1 (R1) formulated – a soft paste, ready-for-use bait, active ingredient (AI) 0.005% Brodifacoum and 0.001% denatonium benzoate produced by PelGar International, UK.

Rodenticide 2 (R2) formulated – a soft paste, ready-for-use bait, AI 0.005% bromadiolone and 0.001% denatonium benzoate produced by Kollant S.r.l, Italy.

Storm formulated – blocks, ready-for-use bait, AI 0.005% flocoumafen and 0.001% denatonium benzoate produced by BASF, Switzerland.

Although the toxicity of anticoagulant rodenticides, in some cases, can be different for laboratory and wild rodents, these differences are minimal and the tables can be used for the choice of rodenticide types.

We also used sticky traps, i.e. boards with glue that attract rodents. The commercial name is Catchmaster 72TC (producer by AP CG Co. Inc New York, USA). It is a paper board construction that is covered with non-drying adhesive. It contains bait with peanut butter flavour, 100 mm by 245 mm. It can be for individual use or for multiple captures. In accordance to the Directive 67/548/EC and 1999/45/EC and Regulation (EC) No 1272/2008 (CLP), the product is not classified as dangerous. It is suitable for catching rodents of various sizes in facilities where toxic baits are undesirable or forbidden.

Table 1. Facilities of the food industry examined in 2016 in the course of the present study.

Facility	Location	Object area (m^2)	
		Built-up area	Adjacent area
Glass factory	Plovdiv	40,000	167,000
Croissant factory	Plovdiv	1,543	5,300
Dairy farm	Stamboliyski		
	Factory	2,230	5,950
	Warehouses	624	900

Data collection

The study period included ten months (March 2016 – December 2016). Each facility had its specific deratizational scheme. Permanent poisonous points (PPP) were localised outside the facilities and permanent non-poisonous points (PNP) were localised inside. PPP consisted of a fixated deratizational box with a locking device (BETA) placed on pivotal exit and entrance risk places that rodents could breach. They were loaded with rodenticide bait. PNP were indoor boxes (Multi-trap) that contained non-toxic adhesive with palatable ingredients for rodents with commercial name Catchmaster. They were put into places that are risky and could be breached. Both types of point were monitored at weekly basis. In every outdoor deratizational tool (a box, a tunnel), 60 g of bait were put and its condition was tracked every week. The tracking of the eaten bait was marked in percentages (0%, 25%, 50%, 75% and 100%). On every visit, the outdoor deratizational boxes were loaded with a new amount of fresh bait. PNP boxes were also checked weekly. When checking the indoor PNP, it was also checked for caught rodents. The number of the stuck rodents was recorded and the used adhesive paper boards and boxes were replaced. The attractiveness of the adhesive trap lasted three months. All the findings were entered with a tablet or a smartphone in the software program PestScan. On the graphics, the eaten amount of bait was marked as an attack. In "attacks 3", 25% of the poisonous bait is eaten; in "attacks 5" – 50%; in "attacks 7" – 75%; in "attacks 10" – 100%. Every month, there were 4 monitoring sessions (every week) in the glass factory; monthly, there were scheduled visits, or in case of emergency, monitoring was carried out at the croissant factory and the dairy farm. In every monitoring session, the eaten baits were recorded. The accumulated consumption was also recorded. Based on the eaten bait quantity, the number and activity of the population of rodents could be evaluated monthly and on a trimester; the number of caught rodents provided information on the effectiveness of the conducted deratizational activities.

For each factory, the deratizational schemes, observations and the rodenticides used were as follows:

Glass factory. Rodenticides: R1 paste in March – July 2016 and R 2 paste in August – December 2016. The deratizational scheme consisted of 49 PPP and 34 PNP.

Croissant factory. Rodenticides: R1 paste in March – July 2016 and Storm blocks in August – December 2016. A barrier of 6 external deratization boxes with locking devices loaded with rodenticidal bait (permanent poison points, POT) was built around the building (factory and warehouses). Indoors, on the risky exits and entrances, 10 PNP Catchmaster adhesive traps were placed.

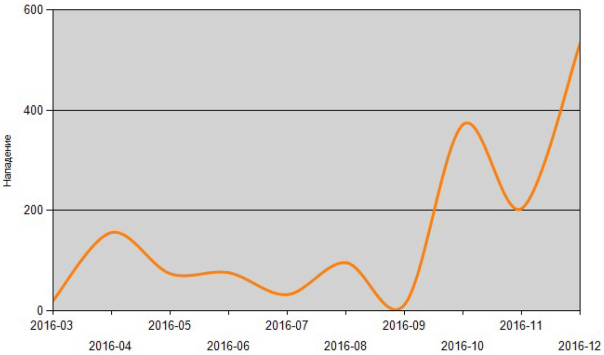
Dairy farm. Rodenticides: R1 paste in March – July 2016; Storm blocks in August – December 2016. In accordance with the Bulgarian Food Safety Agency's requirements, only an outdoor barrier deratization with anticoagulant rodenticides was done. PPP of the factory were 28 placed on the risky zones around exits and entrances. PPP of the warehouses were six. Eleven visits were made in the factory and twelve in the warehouses.

Data analysis

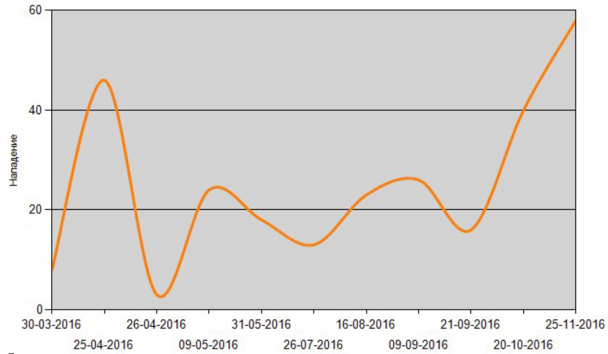
The data about bait consumption were first tested for both normal distribution (D'Agostino and Pearson omnibus normality test) and homogeneity of variance (Levene, F-test). Since the data did pass the normality test ($p < 0.0001$), one-way ANOVA, followed by Tukey's multiple comparison post-test, was applied for comparison of more than two samples. For comparing two samples, two-paired t-test was used.

Results

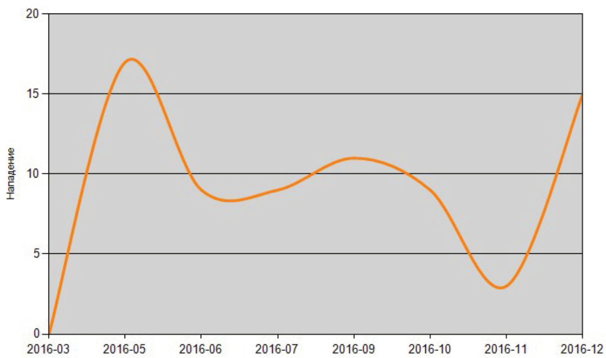
Data from the barrier deratization (from all PPP in the three factories) valued by the relative percentage of the bait consumption accumulated on monthly basis (Fig. 1) revealed that the lowest activity of rodents was registered in September in the glass factory (Fig. 1a) and in March in the croissant factory (Fig. 1b). Throughout the study period, the highest activity of the rodents was found in December in the glass factory and in the dairy farm ($p \leq 0.05$), while the population abundance was highest in May in the croissant factory ($p \leq 0.05$). In the glass factory, the activity was registered in all 49 PPPs. The highest activities of the PPP recorded were in December (index 30) and October (index 23, consumption of the Ratibrom 2). The lowest activity index was registered in September. In the croissant factory, there was activity at every control point and the highest activity was with a total index 27 of PPP found in May, while the lowest, with an index 3 of the PPP (consumption of rodenticidal bait R1), was found in July. In the production area of the dairy farm, activity of rodents was observed at 89.29% of the PPPs. The highest activity index of rodents found from PPP was 21 in April (R1 paste), in September and in November (Storm block). The lowest index of consumption at PPP was 3, recorded in April. In the



a

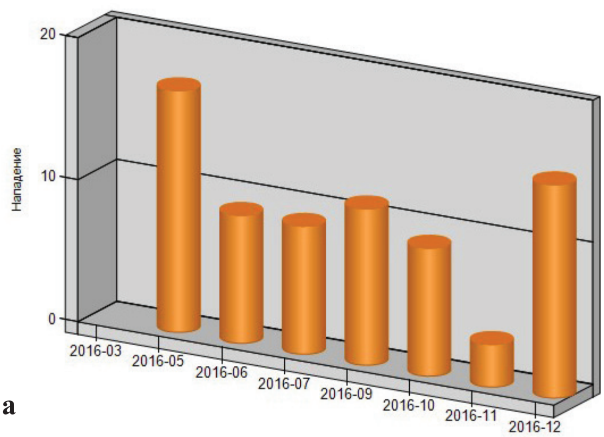


b

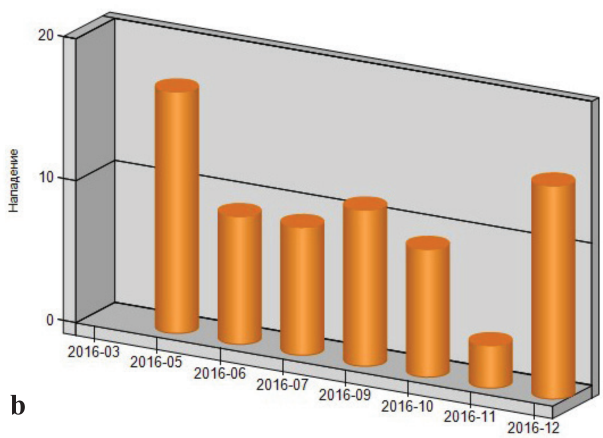


c

Fig. 1. The accumulated consumption by months for all PPP in the barrier deratization in: (a) glass factory; (b) croissant factory; (c) dairy farm – factory; (d) dairy farm – warehouses.



a



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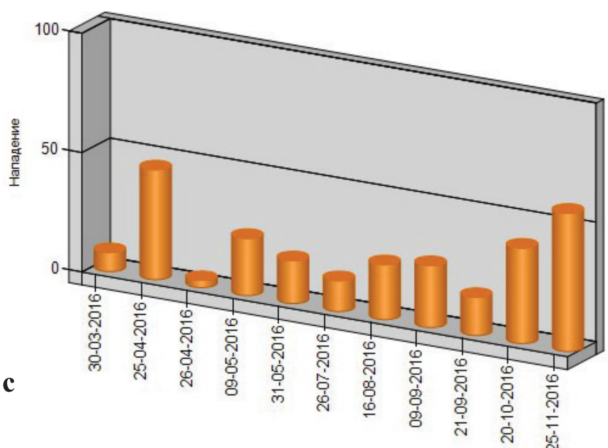

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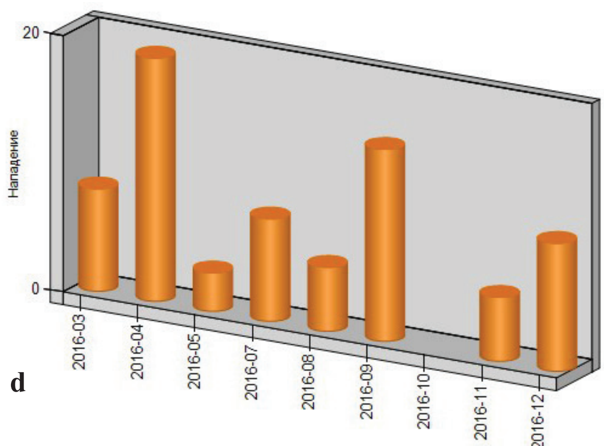

d

Fig. 2. Barrier deratization of production with accumulated consumption of rodenticide bait during a trimester: (a) Glass factory; (b) Croissant factory; (c) Dairy farm – factory; (d) Dairy farm – warehouses.

warehouses of the dairy farm, the highest abundance was registered in April. There was consumption of rodenticide in 66.67% at PPP. The lowest activity of the rodents was found in May. In October, there was not registered any consumption of poisonous bait.

The barrier deratization in the three factories with accumulated consumption of rodenticide bait per trimester (Fig. 2) demonstrated that, in the glass factory, the highest activity was registered during the fourth trimester (October – December), with the highest index of PPP 46. The lowest activity of the rodents was found in the third trimester (July – September). The study started in March, so the summarised data of the first trimester were ignored. In the croissant factory, barrier deratization with accumulated consumption of Storm block rodenticide per trimester showed the highest activity with a total index of 30 in the fourth trimester. In the factory of the dairy farm, activity was observed during the first trimester in only two PPP during in March, with index 3 (25% of the consumption of R1 paste) for the first, and with index 5 (50% of the consummation of R1 paste) for the second trimester. The highest activity was found during the fourth trimester, with a total index of 98 from the consumption of Storm blocks. The second trimester had a total index of activity of the rodents 91, and the index of the third trimester was 78. In the warehouses of the dairy farm, the highest activity with an index of consumption 13 was observed during the third trimester at PPP 1. Only in PPP 2 and PPP 3 (33.3% of PPP), the consumption was recorded during the fourth trimester.

The relative analysis of rodent activity, evaluated through the quantity of the consumed bait, showed the highest activity in the glass factory, with a total index of 1569, and the lowest – in the croissant factory, with a total index of 73. In the factory of the dairy farm, during the monitored period, the total index of consumption was 275, and the total index of the warehouse was 73. The average activity (index) of the rodents in the factory in all PPPs was 32.02. In the croissant factory, the average index of activity of PPP is 12.17. In the factory of the dairy farm, with activity found at 25 PPP (of all 28 PPPs), the average index was 11. In the warehouses, the average activity of the active PPP was 18.25.

In the glass factory, throughout the study period, in 26.47% of the traps with adhesive (PNPs) there, we did not register caught rodents. In 20.56% of all PNPs, throughout the period, only one rodent was caught. In 29.41% of all PNPs, there were only two rodents caught in October and December, and in 23.56% of all indoor PNPs there were registered more than two cases of caught rodent. In the fourth trimester, the highest number of rodents was caught (53) – 86.89% of all rodents caught. Almost no breaches in the indoor facilities were registered during the second and the third trimesters (four stuck caught in the first trimester and four stuck caught in the fourth trimester). In the croissant factory, throughout the research period, in 60% of the indoor PNPs with adhesive, there were no stuck rodents. Fifty percent of the rodents caught were found during the fourth trimester (in December).

Discussion

This analysis revealed that rodents are perceived to be a significant problem in urban industrial areas, especially in the enterprises of the food industry – croissant factory and dairy. Numerous factors were found to be independently associated with increased prevalence of rodents, including the construction and technical implementation of the buildings of the site, the nature of the production (type of site tested), the location of the site and the type and formulation of the rodenticide used.

At the present stage of the development of science for the control of harmful rodents, experts from many countries are united in the opinion that a specialised monitoring on rodent populations could achieve a more successful and long-term control over the numbers and species composition of their populations (Singleton et al. 2004). The research work has proved this opinion. The use of systems for monitoring helps conducting an effective control because it allows the detection of rodents despite their low numbers, helps with their quick species identification, localising the places of their habitat and specifying the optimal time for the completing of an effective deratization. These efforts lead to reducing rodent population, economic losses and health risks.

The life activity of rodents is subordinated to the basic instincts for self-preservation and species continuation that shape their behaviour – cognitive, defensive, nutritional, sexual and parental. Under different conditions of life, behaviours change according to the peculiarities of the environment. These changes predetermine, for a specific type of site, the territorial distribution of the populations of harmful rodent populations and the formation of condition-specific biological activity (Singleton et al. 2004). In artificial ecosystems, food and safe places as factors for rodents, being determined by the human activity, are at a very low level of dependence on environmental conditions. When this activity is not compliant with the possibilities of breaching and settlement and inaccessibility to food, rodents and especially syntanthropic species quickly occupy an ecological niche. Where resources are abundant, rodents thrive and, *vice versa*, where resources are scarce, animals either migrate or die (Tobin et al. 2004).

The most effective tool for limiting the damages caused on the buildings and constructions by rodents is to prevent their initial entering (Tobin et al. 2004). The buildings should be carefully inspected, so the potential points of breaching to be found. Cracks and holes in the foundations, holes around waterpipes, electrical cables, sewer pipes and ventilation pipes in the buildings should be tightly sealed to prevent breaches. The facilities in this study are characterised by a range of appropriate parameters of construction and technical implementation and are sufficiently adapted to the requirements of tightness. There are holes, insufficient door seal, almost constant repair works are observed in the glass factory. This leads to a certain percent of breaching of rodents into the indoor facilities, even though a weekly monitoring has been carried out and deratization has been conducted. The factors "shelter" and the ability of creating suitable "nesting territories" predetermine the breaching of vermin in the facilities of this factory despite the lack of a nutrient environment. The effectiveness of controlling rodents through barrier deratization is judged by the lack of indication of their presence in the interior of buildings such as no rodent caught on sticky baits, no movement of rodents, defecation and traces of movement.

The rodenticides, which are anticoagulant (second generation), that have been used show a very good attractiveness and acceptance from rodents. There was not observed any reaction of rejection of the rodents to these rodenticides. The main preconditions of success in the battle with the rodents are the effectiveness and attractiveness of the poisonous bait. The rodenticides with AI bromadiolone, brodifacoum, flocoumafen, formulated pastes and blocks used during the study, were consumed without any showings of neophobia and resistance.

The systematic gathering of data about the population of rodents through a continuous monitoring reflects the influence of abiotic and biotic factors, which allows control measures for limiting the breaching into food industry facilities. Based on the research done, it has been found that in facilities of the food industry, without applying a permanent control on rodents, it is practically impossible to guarantee the quality and safety of the production. An undisturbed continuous deratization leads to unstable populations and low numbers. A permanent barrier deratization leads to making a contact and consumption of rodenticides before their breaching into enclosed areas and prevents their permanent settlement and creating a population.

The method used, PestScan, for analysing the effectiveness of various anticoagulants of second generation and the graphic analyses done create an integrated program that provides information, documents and archives during the ongoing deratization of the area. PestScan is a well-functioning working software that directly and electronically streams checklists about the situation of different means of control and monitoring in the moment of visit. The integrated schemes for vermin control in the facilities from our study are effective, economical and they protect the environment and untargeted organisms with a purpose of control of the vermin through maintaining their density to safe levels.

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