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Original Contribution

A SURVEY OF THE DISTRIBUTION OF SYNANTHROPIC COCKROACHES IN ANIMAL FARMS AND FOOD PROCESSING PLANTS IN BULGARIA

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ABSTRACT
Cockroaches are pests of veterinary and public health importance with their role as pathogen spreaders. The aim of the present study was to determine the distribution of synanthropic species of cockroaches in animal farms (AFs) and food processing plants (FPPs). The survey was carried out in 52 sites (42 AFs and 10 FPPs), by questionnaire-visual survey and monitoring catch method. The presence of cockroaches was found in 78.57% of AFs and 0% of FPPs. The industrial pig farms are the most frequently and highly affected – all of them were infested in high density. The oriental cockroach (*Blatta orientalis* L.) was the dominant species. An inhomogeneous distribution was found in invased pig farms with preferred areas of localization in the new-born sectors and sanitary filters. The obtained results are proof of the need to strengthen insect monitoring and pest control in animal farming, especially in pig farms.

Key words: cockroaches, health risk, animal farms, food processing plants, *Blatta orientalis*

INTRODUCTION

Cockroaches are insects of the order *Blattaria* or *Blattodea* with over 4500 identified species (1). Most of these species live in tropical and subtropical regions and are not defined as pests (2). About 25-30 species are synanthropic in nature and are associated with the human habitat and are considered as global pests (3). Cockroaches have been around for over 350 million years and have changed very little over the years. Fossilized cockroaches from 250 million years ago look the same as cockroaches today, which is evidence of their optimal bio-ecological characteristics and perfect adaptation to the changing environment (4). Cockroaches are omnivorous, consuming a wide variety of organic matter (plants, vegetables and fruits), various food sources such as sweets, cheese, meat products, starches and fats (5). Eating contaminates food products, they leaving a persistent characteristic odor (4).

Adult cockroaches have the ability to survive without food for several weeks. Under suitable environmental conditions, they are capable of year-round reproduction, leading to rapid exponential growth in numbers with delayed control action. These characteristics of cockroaches, along with their nocturnal activity, make them widespread. The unprecedented increase in the cockroach population over decades in public places around the world has been documented in our country as well (6).

The risk to human and animal health has so far been underestimated, if any given the paucity of available entomological and epidemiological information (7). Convincing evidence implicating cockroaches as vectors of infectious pathogens was found in a study by Tarshis (8) in the 1950s, which reported an association between a lack of cockroach control and the incidence of infectious hepatitis in Los Angeles, Southern California. The oriental cockroaches are involved in the spread of infectious diseases, damage the substrates on which they feed or defecate, and cause concern in humans (9). Major experimental evidence supporting the role of cockroaches as vectors of pathogens was established in a 1993 study by Kopanic (10). In this study, experiments were conducted to determine whether transmission

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of a resistant strain of *Salmonella* Typhimurium could occur between a contaminated food source and uninfected cockroaches, food, and water. In 2003 Imamura (11) provided further experimental evidence establishing the vector role of cockroaches and the microbial pathogen – *Helicobacter pylori*.

Reports by Hahn & Ascerno (12) reveal that correct identification of cockroaches is very important for the accurate determination of the species, sex, stage of development, etc., which have a significant impact on the effectiveness of disinsection treatments (13-18).

The survey-visual and the monitoring catching of cockroaches are the main methods for surveying the terrain for cockroaches, monitoring the number and density of their populations, as well as for controlling the effectiveness of insecticide treatments. The live catch and the sticky traps are the most commonly used in practice, not only by homeowners but also by pest control professionals (19-22). As a monitoring tool, they provide information on cockroach distribution and population density, thus aiding in the correct selection and application of insecticides (23). Because of their safety, easy way of use, and non-toxicity, sticky traps are even considered a valuable tool in integrated pest management (IPM) programs (24). Their application for the detection of Oriental cockroaches is encouraged, as this species has been found to be much more readily captured in sticky traps than other species of cockroaches (21).

The information about the distribution of synanthropic cockroaches in the different animal farms and FPPs, not only in our country, is insufficient and incomplete. Most of the studies focused on the distribution of the German cockroach (25).

The high health significance of invasions with synanthropic cockroaches, their widespread distribution and their difficult fight, against the background of the insufficient scientific information on their distribution in the animal farms and FPPs on the territory of the Republic of Bulgaria, were grounds for conducting larger-scale and targeted studies to illuminate the problem. The aim of the present study was to determine the distribution of synanthropic species of cockroaches in animal farms (AFs) and food processing plants (FPPs).

MATERIALS AND METHODS

A total of 42 animal farms from all over the country were surveyed, which included: pig farms (n=7), cow farms (n=13), sheep and goat farms (n=13), buffalo farms (n=3), horse farms (n=1), ostrich farms (n=1), deer farms (n=1), poultry farms (n=3) as well as 10 food processing plants: dairy processing plants (n=4) and meat processing plants (n=6). The geographic localization of the investigated objects is presented in **Figure 1.**

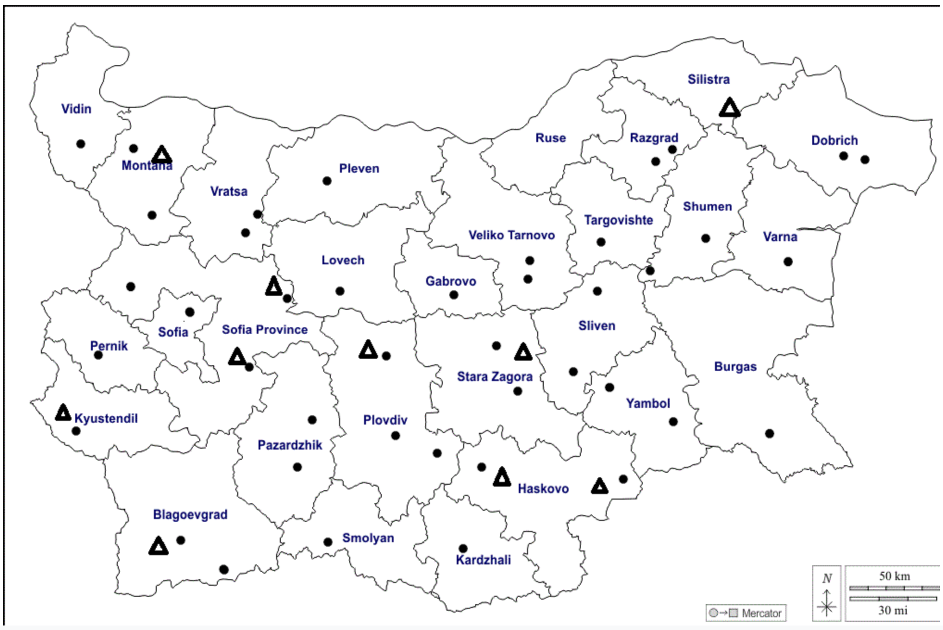

Figure 1. Geographic localization of the investigated animal farms and food processing plants (●-Animals farms, ▲- food processing plants).

The survey of the objects for cockroach infestation was carried out by questionnaire-visual inspection and monitoring trap catch.

1. Questionnaire-visual inspection method:
The method included the collection of preliminary information on the type, structure and technological features of the objects, as well as anamnestic data related to the presence of cockroach infestation. The data were collected from the owners/managers of the sites by filling in previously prepared questionnaires.

A subsequent personal inspection was also carried out in all surveyed objects, during which the signs related to the presence of cockroaches were reported - traces of their life cycle (presence of faecal stains and vomit stains on surfaces, ootheca, feces, etc.), presence of live cockroaches, their carcasses or parts thereof. Depending on the intensity of observed signs, the approximate number and density of the population was judged, as well as the location of their preferred places of residence - the so-called "biologically active zones".

2. Monitoring trap catch method:
Two types of cockroach traps were placed in the surveyed sites. One trap was placed per 10 sq. m. of the floor area of the room for 24 hours**,** according to *NCIPD* (26) criteria. The choice of the type of traps depended on the type of sites in which they were placed.
2.1. Glue (sticky) traps - cardboard panels evenly covered with slow-drying, non-toxic glue and added combined attractant (food sources and sexual pheromones) that increase the efficiency of catching **(Figure 2b, c).**
1.2. Live-catching traps - plastic boxes fitted with food attractant and self-closing inlets allowing multiple catching **(Figure 2a).**

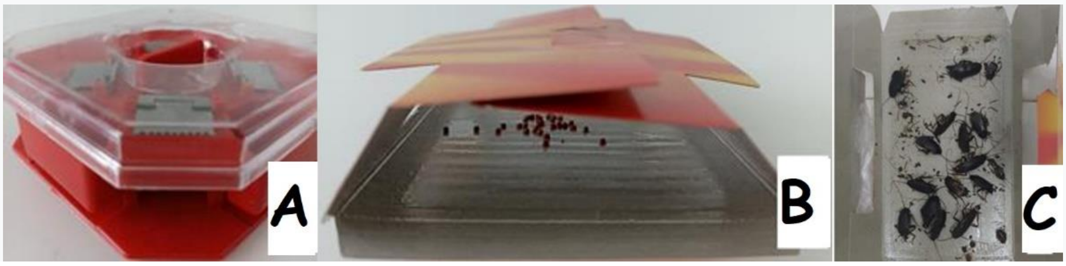

Figure 2. Used live-catching (1) and sticky (2,3) traps

The results obtained from trapping served to determine the parameters of the invasion (intensity and territorial dissemination of invasion, number and density, species composition, spatial distribution, etc.). The *intensity of invasion* was calculated as a percentage ratio between the number of positive traps and all used ones. The *territorial dissemination* was calculated as a ratio between infected units and all of surveyed. The *density* of cockroaches was calculated as the arithmetic mean of the total number of cockroaches caught divided by the number of traps in each unit or site. It was expressed as the total number of cockroaches of all developmental stages per trap for 24 hours surveyed time. The density was evaluated on a five-level scale, according to *NCIPD* (26) criteria - **Table 1.**

***Table 1**. Cockroach population density scale (according to: NCIPD, 2023)*

Species	Density			
	Low (+)	Medium (++)	High (+++)	Very high (++++)
Cockroaches (n per trap for 24 h)	1-2	3-10	11-30	≥30

The species were determined belonging to the cockroaches, based on the external morphological characteristics and somatometric indicators, using the cockroach identifier (27). Species affiliation, development stage, sex and the number of cockroaches caught in a certain number of traps on the adjacent territory were recorded. The obtained data were reported for the entire territory and for a unit of area (28).

Statistical data processing was performed using descriptive statistical methods and Graph Pad software. Indicator values were presented as arithmetic means with their respective standard deviations (Standard Deviation, SD).

RESULTS AND DISCUSSION

Apparent differences were found in the parameters of cockroach infestation in the surveyed sites, both between different AF sites, between different AF units, and between AF and FPPs **(Table 2).**

Table 2. *Cockroach infestation in surveyed animal farms and food processing plants*
Legend: (n – number; FPPs – food processing plants, AFs-animal farms, SD-Standard deviation)

Investegated objects (sites)							Investegated units					
Sites type (n)	Invased sites n (%), Species	Density (%)					Units (n)	Survey-visual method		Trap method		
								Questionnairy Positives n (%), Species	Inspection positive n (%), Species			
			+	++	+++	++++				Traps n	Positive traps n (%), Species	Catched cockroaches Species, n
Pig farms (7)	7 (100), *B. orientalis*	0	0	0	71.43	28.57	84	77 (91.67), *B. orientalis*	76 (90.48), *B. orientalis*	239	218 (91.21), *B. orientalis*	*B.orientalis*,6634
Large ruminants farms (13)	5 (38.5), *B. orientalis*	61.5	38.5	0	0	0	182	71 (39.01), *B. orientalis*	65 (35.71), *B. orientalis*	103	98 (95.14), *B. orientalis*	*B. orientalis* ,191
Small ruminants farms (13)	4 (30.77), *B.orientalis*	69.23	30.77	0	0	0	182	67 (36.81), *B. orientalis*	64 (35.16), *B. orientalis*	98	90 (91.84), *B. orientalis*	*B. orientalis* ,177
Horse farm (1)	0	0	0	0	0	0	8	3 (37.5), *B. orientalis*	1 (12.5), *B. orientalis*	3	0	0
Poultry farms (3)	0	0	0	0	0	0	42	6 (14.28), *B. orientalis*	1 (2.38), *B. orientalis*	6	0	0
Ostrich farm (1)	0	0	0	0	0	0	8	2 (25), *B. orientalis*	0	2	0	0
Deer farm (1)	0	0	0	0	0	0	8	1 (12.5), *B. orientalis*	0	3	0	0
Buffalo farm (1)	0	0	0	0	0	0	42	1 (2.38), *B. orientalis*	0	3	0	0
AFs –species mean ±SD	2±2.88 (38.1) *B.orientalis*	-	-	-	-	-	556	28.5±35.88(41.01), *B.orientalis*	25.88±35.34(37.23) *B.orientalis*	457	50.75±79.84(88.84), *B.orientalis*	*B. orientalis* 875.25±2328.37
FPPs-milk (4)	0	0	0	0	0	0	48	1 (2.08), *B. orientalis*	0	3	0	0
FPPs-meat (6)	0	0	0	0	0	0	72	2 (2.78), *B. orientalis*	0	3	0	0
FPPs –species mean±SD	0	0	0	0	0	0	0	1.50±0.71 (2.5), *B.orientalis*	0	6	0	0

The most frequent and severe infestations with cockroaches were observed in livestock breeding sites for raising pigs – all surveyed farms (100%) were infested with average prevalent high (+++) density and 27.76 cockroaches per trap for 24 h. The infestations in AF for ruminants where significantly less frequent (38.5% and 30.77% respectively for large and small ruminants) and mild with average low (+) density and between 1.85 and 1.81 cockroaches per trap for 24 h **(Figure 3).** In the remaining AF, despite the presence of anamnestic data on traces suggested rare and low density of cockroaches, no live specimens were found. We assume that they are due to old invasions, giving importance to the non-specificity of some traces, such as the presence of feces, stains, etc. However, we consider the questionnaire-visual inspection method to be the first and important step to detect potentially infested sites where we would recommend secondary trapping to evaluation of the situation.

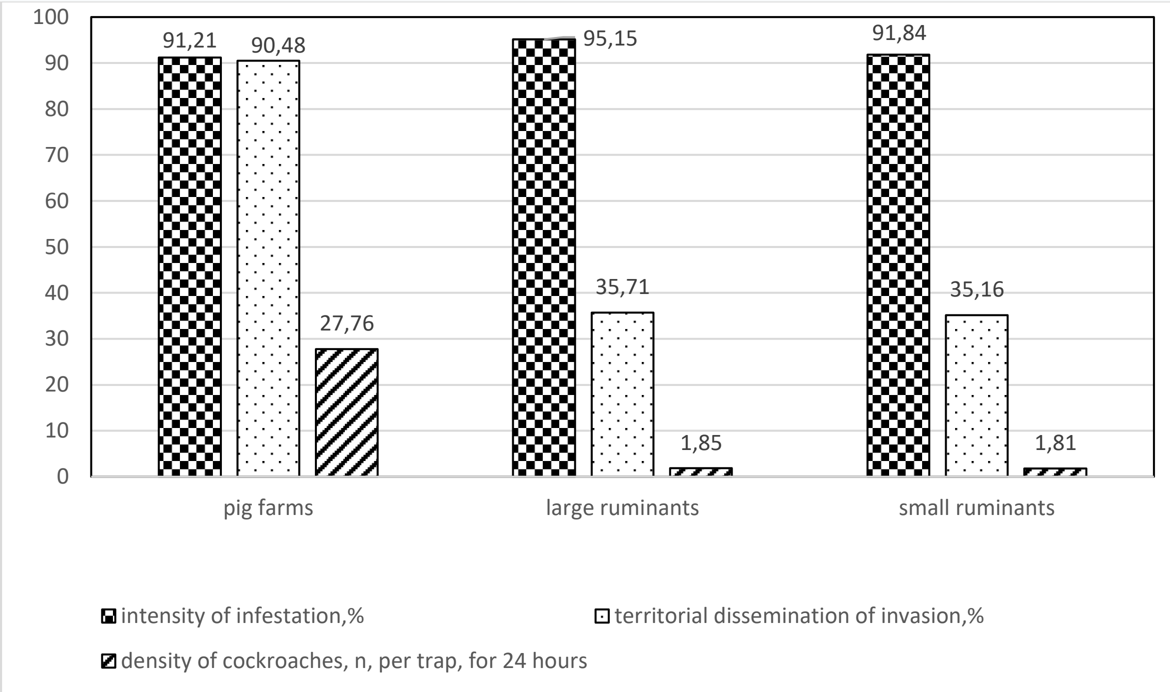

Figure 3. Quantitative indicators of the invasion in the infested sites

The lowest indicators of the presence of cockroaches were found in FPPs and this is not surprising. High hygiene standards have been introduced in these facilities as well as mandatory contracts with authorized pest control companies which perform constant monitoring and corrective actions. In addition, cockroaches like a warm, moist environment with abundant food; moist and decaying places are their natural habitat (4, 29). This fact also contributes to the explanation of the observed differences between AF and FPPs. According to Kutrup (30) and Agrawal & Tilak (31) most often cockroaches can be found in places with higher humidity and temperatures as well as in those where food resources are freely available to cockroaches, as respectively with the increase in size and the values of these parameters, the density of the cockroach population also increases. These statements also explain the absence of cockroaches in FPPs and AF for raising animals other than pigs, due to the different microclimatic parameters inside the technological premises.

Considerable differences were also found between the different units in the invased sites. For example, an uneven spread of the infestation was found in the surveyed pig farms – **Figure 4.** As a recurring rule, the rooms for newborn piglets, weaned piglets and pregnant sows, as well as the sanitary filters, are the most frequently and highly invased units.

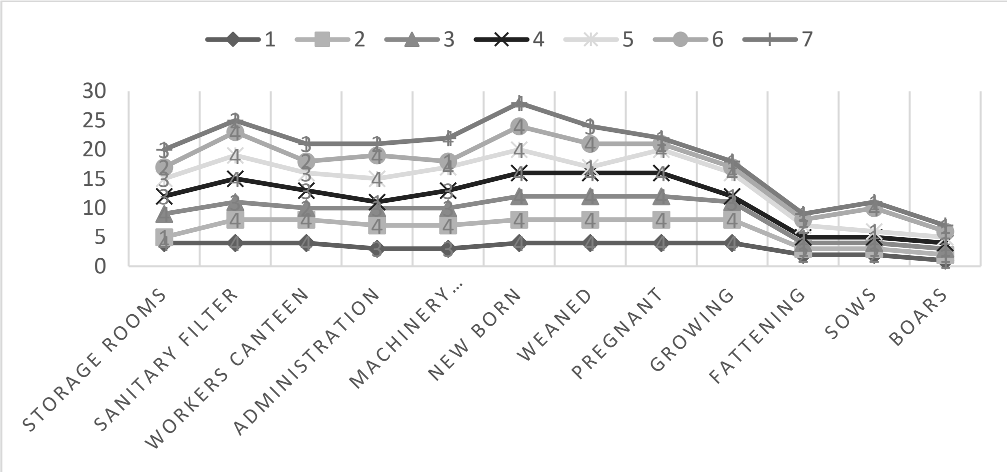

Figure 4. Intensity of invasion dynamic of cockroaches in different units of pig farms (n=7)

All specimens caught in our survey were identified as *B.orientalis*. It is known that Oriental cockroaches tend to stay close to preferred roosting sites. According to various studies, the majority (85%) of re-observed cockroaches remain in areas on one side of a building. Only 2% of observed cockroaches move between buildings. The lack of movement between buildings may be due to the lack of structural features and pheromone trails for the oriental cockroaches to follow (32). Some researchers have shown that cockroaches move between buildings in a variety of ways, which determines the extensiveness of the infestation and its territorial spread. But others have pointed that cockroaches live in groups and are attracted to moisture, warmth and darkness, which explains their uneven density in different areas (33).

In addition, the cockroaches and their biological cycle are closely related to environmental parameters. Oriental cockroaches (*Blatta orientalis* L.) take refuge mainly in low, moist and dark rooms with the presence of organic substrate, such as basements (34), garbage collection areas (35), garbage dumps (36), sewage (37, 38) or under debris and litter near buildings (39). Several features of the swine production system are conducive to the growth of pest populations. However, some of these characteristics are integral components of cultural and production practices that are key to efficient pig growth and farm biosecurity. For example, piglets require a warm and dry environment of about 35°C. In many places, the breeding technology includes water cooling of the animals, which is a prerequisite for maintaining optimal humidity for the development of cockroaches, and the presence of water cushions in order to eliminate liquid fertilizer fractions, enables continuous access to water, which is of vital importance for the oriental cockroach as a limiting factor. The pig's diet includes a sufficient amount of protein supplements and attractants, which are an excellent food resource for the oriental cockroach. Agricultural buildings, depending on cultivation technology, provide an excellent refuge for pests. These conditions are optimal for the growth and breeding of cockroaches and cockroach infestations are particularly prevalent in the farrowing sector (newborn) (40). Our results also showed a higher density of cockroach populations in these rooms and technology groups. In our opinion, the probable reason for the unsuccessful capture of live cockroaches in the remaining livestock sites, despite the anamnestic data of their presence, is an indication of their accidental penetration and low population size. This is probably due to the different technological breeding model, the sub-optimal microclimatic conditions (lower temperature and humidity), as well as the poorer of protein and attractant feed.

CONCLUSION

The dominant synanthropic species of cockroaches in AF in Bulgaria is *Blatta orientalis*. The industrial pig farms are the most frequently and highly infested sites. An uneven spread of the infestation was found in the infested sites, with the most affected being the premises for rearing the newborn piglets. The presence of cockroach infestation in livestock facilities, as well as their high epidemic role as pathogen spreaders, requires the implementation of targeted efforts on the monitoring and control of infestations. This will increase the level of biosecurity and minimize risks to the health of animals and staff.

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