Original Article

Laboratory Evaluation of Commercial Insecticidal Baits Against Oriental Cockroaches (*Blatta orientalis* L.) From Pig Farms in Bulgaria

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ABSTRACT

Background: The oriental cockroach (*Blatta orientalis* L.) is a common pest in livestock farms, posing a risk as a mechanical vector for pathogens.

Objectives: This study aimed to evaluate the insecticidal efficacy of four commercially available food baits against *B. orientalis* collected from seven industrial pig farms in Bulgaria.

Methods: A no-choice bait feeding test was conducted under controlled laboratory conditions. Baits tested included indoxacarb gel, imidacloprid + S-methoprene gel, and two inorganic desiccant-based formulations.

Results: Indoxacarb gel exhibited a rapid knockdown effect, reaching 100% immobilization by 96 h. The imidacloprid + S-methoprene gel induced early knockdown (66.7% by 48 h) and progressive mortality, achieving 96.7% by 168 h. The inorganic desiccant-based baits did not induce pronounced knockdown (<25%) but also resulted in complete mortality by the end of the test (168 h), although with delayed dynamics.

Conclusion: The results highlight the practical value of insecticidal baits as an effective and safer component of integrated pest management programs in livestock production systems, adaptable to diverse conditions and infestation levels, with product selection depending on cockroach density and the desired speed of action.

Keywords: *Blatta orientalis*, Insecticidal baits, Indoxacarb, Imidacloprid, S-methoprene, Silicon dioxide, Diatomite, Pig farms, Pest control

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Introduction

Cockroaches are cosmopolitan insects that have undergone millennia of evolution, resulting in a high degree of adaptation to diverse environments (Gondhalekar et al., 2021). Their active habitats include settings with heavy microbial contamination—such as sewers, refuse dumps, and manure heaps—which implies direct contact with carcasses and feces (Vatandoost, 2023). Their lifestyle, feeding behavior, and reproductive biology make them important mechanical vectors of pathogenic microorganisms, including multidrug-resistant bacteria affecting humans and animals, via contaminated cuticle and mouthparts, as well as through regurgitation and fecal deposits (Turner et al., 2021; Vatandoost, 2023; Kakooza et al., 2025). In a large-scale synthesis, Donkor (2020) further summarized and confirmed the carriage and dissemination of numerous pathogens (bacterial, viral, fungal, and parasitic) by cockroaches.

To protect animal and human health, the implementation of integrated cockroach management is recommended (Abbasi, 2025). A key component is the use of baits, in which the insecticidal active ingredient is incorporated into a food matrix with high—often selective—attractiveness to cockroaches. Some bait formulations include denatonium benzoate (Bitrex), a highly bitter synthetic agent used as a deterrent for people and companion animals to prevent accidental ingestion. Baits are applied as gels for placement into cracks and crevices, and as dry, solid baits housed in plastic stations that reduce inadvertent contact or access by non-target animals (pets) and humans. These advantages make baits one of the preferred methods for insecticidal treatments (Hubbard et al., 2024).

Our recent survey documented widespread infestations of the oriental cockroach in industrial pig farms in Bulgaria, with several units (newborn units, sanitary filters, and weaning sections) exhibiting high population densities (Boneva et al., 2023).

The aim of the present study was to determine the efficacy of several commonly used insecticidal baits against the oriental cockroach, *Blatta orientalis* L., collected from pig farms in Bulgaria, in order to assess their suitability for pest-control applications.

Materials and Methods

Insects

Tests were performed with the oriental cockroach, *B. orientalis* (L.), collected from seven industrial pig farms in Bulgaria. The identification of *B. orientalis* adults and fifth-instar nymphs was confirmed based on external morphology (body coloration, pronotal pattern, wing pad development, and antennal segmentation) following the diagnostic characters described by Bell et al. (2007). Before bioassay, insects were acclimated for at least 3 days in laboratory conditions with a temperature of 20–26 °C, relative humidity of 30–50%, and a photoperiod of 9 h light: dark. From each population, experimental and control groups were formed, each comprising 10 randomly selected 5th-instar nymphs.

Food baits

The efficacy of four insecticidal bait formulations widely used in cockroach control was evaluated (Table 1). Each formulation was tested as received, without additional dilution or modification. All baits were stored in sealed containers at room temperature and used within their shelf-life period. For clarity, the commercial products were coded according to their trade names to avoid brand-related bias. The tested baits included a gel formulation containing 0.6% indoxacarb, a pro-insecticide disrupting sodium channel function after enzymatic activation (code AG), a combined gel containing 2.15% imidacloprid, a nicotinic acetylcholine receptor agonist, together with 0.5% S-methoprene, a juvenile hormone analogue disrupting normal development and reproduction (code MG), an inorganic desiccant gel with 50% diatomite (code Chl.E), and a solid bait combining 50% silicon dioxide, an inorganic desiccant, with 1% tetramethrin, a neurotoxic pyrethroid blocking sodium channels (Code Chl.D).

Test method

A no-choice lethal feeding assay with insecticidal food baits was conducted (Gondhalekar et al., 2011). For each population, treatment groups received 1 g of a test bait as the sole food source; control groups were maintained under identical conditions on the laboratory non-toxic diet. All groups had water ad libitum. Each test set-up was run in triplicate. Knockdown and mortality were recorded every 8 h during the first 24 h, and thereafter daily through day 7.

Knockdown was defined as stimulus-induced immobility rendering individuals unable to move freely, feed, or drink, while still exhibiting vital signs and partial reflex responses (e.g. trembling of legs/antennae) after gentle probing with forceps (Dong et al., 1998). Individuals in complete physiological immobilization with no response to stimuli and no limb movement, which persisted until the end of the monitoring period, were classified as dead. If the mortality of the control group exceeded 5%, the mortality observed in the treatments was corrected using Abbott's formula (Equation 1) (Abbott, 1925):

1. Corrected mortality (%)=[(Pt−Pc)×100]/(100−Pc)

Where, Pt is the observed mortality rate (%) in the treatment group and Pc is the mortality rate (%) in the control group.

Statistical analysis

Data were analyzed using UNIANOVA, with post hoc comparisons by Tamhane's T2 or Tukey's HSD test, depending on the outcome of Levene's test for homogeneity of variances. Analyses were conducted using SPSS software, version 26.0.

Assessment

Efficacy was interpreted according to OECD guidance (OECD, 2013): in a no-choice test, efficacy is generally considered sufficient when a mortality rate ≥95%, corrected according to Abbott, is achieved by the end of the assay.

Results

All baits showed excellent acceptance by *B. orientalis* (Table 2). Cumulative mortality across the MG, Chl.D, and Chl.E treatments exceeded 95% by the end of 168 hours, whereas AG produced 100% knockdown without recorded mortality (R^2=0.995). MG showed the highest knockdown effect (66.7%) at 48 hours and a mortality of 96.7% at 168 hours (R^2=0.918–0.954). Chl.D and Chl.E achieved 100% mortality at 168 hours with a slower dynamics of the knockdown effect (R^2=0.833–0.997).

Discussion

Insecticidal baits have emerged as the leading and preferred method for chemical control of cockroaches in infested premises, increasingly replacing contact sprays. They are targeted at the insects and leave low toxic residues (Rutgers NJAES, 2020; UF/IFAS Extension, 2022). High water content and optimized phagostimulants — especially in gels and pastes —enhance attractiveness and consumption (and thus uptake of active ingredients) relative to solid baits (Lucero et al., 2025).

Among the widely used active ingredients in modern cockroach baits are indoxacarb and imidacloprid, as well as inorganic desiccants, such as silicon dioxide and diatomite. Indoxacarb acts on the insect nervous system and belongs to the oxadiazine class, blocking voltage-gated sodium channels of the pyrazoline type (Rezende-Teixeira et al., 2022). Imidacloprid, a neonicotinoid, also targets the nervous system through the activation of postsynaptic nicotinic acetylcholine receptors and is increasingly incorporated into bait formulations (Naveen et al., 2022). To enhance the overall efficacy of neonicotinoid-based formulations, juvenile hormone analogues, such as S-methoprene are sometimes included to provide long-term population suppression by disrupting insect development and reproduction (Jindra & Bittova, 2020).

Desiccant actives are another common option for bait matrices. Natural diatomite (diatomaceous earth), a geological material composed of fossilized siliceous skeletons (diatoms and other algae containing amorphous silicon dioxide), is considered safe and recommended for eco-friendly pest management (Korunic, 1998). Desiccant particles damage the cuticle by absorbing cuticular hydrocarbons and abrasion, increasing water loss and causing death by desiccation (Faulde et al., 2006).

Table 1. Insecticidal food baits used in the study

Code	Formulation	Active Ingredient(s)	Insecticide Class (IRAC MoA)
AG	Gel bait, 30 g syringe	0.6% indoxacarb	IRAC 22A: oxadiazines
MG	Gel bait, 40 g syringe	2.15% imidacloprid 0.5% s-methoprene	IRAC 4A: neonicotinoids IRAC 7A: growth regulators
Chl.D	Solid bait, 5 g box	50% silicon dioxide 1% Tetramethrin	UNM IRAC 3A: pyrethroid
Chl.E	Gel bait, 10 g syringe	50% diatomite	UNM

IRAC MoA: Insecticide Resistance Action Committee mode-of-action code; UNM: Non-specific mechanical/physical disruptors (inorganic desiccant).

Table 2. Efficacy of insecticidal food baits in no-choice lethal feeding assays against the oriental cockroach, *B orientalis*, from pig farms in Bulgaria

Hour	AG (n=30)		MG (n=30)		Chl.D (n=30)		Chl.E (N=30)	
	KD (%)	Mort. (%)	KD (%)	Mort. (%)	KD (%)	Mort. (%)	KD (%)	Mort. (%)
8	3.3±0.58^{a}	0	56.7±0.58^{a}	16.7±0.58^{a}	16.7±0.58^{a}	0±0	10±0^{a}	0±0
16	10±0^{ab}	0	60±0^{b}	20±0^{b}	20±0^{b}	0±0	10±0^{b}	0±0
24	16.7±0.58 ^{bc}	0	63.3±0.58^{c}	20±0^{c}	20±0^{c}	0±0	10±0^{c}	0±0
48	80±0^{abcd}	0	66.7±0.58^{d}	20±0^{d}	20±0^{d}	20±3.46^{d}	10±0^{d}	0±0
72	93.3±0.58^{abcde}	0	63.3±0.58 ^{e}	23.3±0.58^{e}	23.3±0.58^{ae}	76.7±0.58^{de}	10±0^{e}	0±0
96	100±0^{abcdef}	0	46.7±1.16^{bcdef}	40.0±1^{abcdef}	23.3±0.58 ^{af}	76.7±0.58^{df}	20±1^{abcdef}	0±0
120	100±0^{abcdeg}	0	46.7±1.16^{bcdeg}	46.7±1.53^{abcdeg}	16.7±0.58^{efg}	83.3±0.58^{d}	13.3±0.58^{g}	86.7±0.58g
144	100±0^{abcdeh}	0	26.7±0.58^{abcdefgh}	73.3±0.58^{abcdefgh}	10±0^{bcdefgh}	90±0^{d}	13.3±0.58^{h}	86.7±0.58h
168	100±0^{abcefgh}	0#	3.3±0.58^{abcdefgh}	96.7±0.58^{abcdefgh}	0±0^{abcdefgh}	100±0^{def}	0±0^{abcdefgh}	100±0gh
R^2	0.995	-	0.918	0.954	0.833	0.945	0.662	0.997
P	0.000		0.000	0.000	0.000	0.000	0.004	0.000

Abbreviations: KD: Knockdown; Mort.: Mortality; N: Number of individuals; R^2: Coefficient of determination based on observed means.

[#]Presence of slight reflex movements despite complete physiological immobilization in an unnatural posture and inability to move, feed, or drink.

Note: Formulations: AG, 0.6% indoxacarb gel; MG, 2.15% imidacloprid + 0.5% S-methoprene gel; Chl.D, 50% silicon dioxide + 1% tetramethrin (solid bait); Chl.E, 50% diatomite gel. Post hoc (Tamhane/Tukey): Identical superscripts within a column denote significant differences in knockdown or mortality at $P<0.05$, as follows: a–a: 8 h vs all other time points; b–b: 16 h vs all other time points; c–c: 24 h vs all other time points; d–d: 48 h vs all other time points; e–e: 72 h vs all other time points; f–f: 96 h vs all other time points; g–g: 120 h vs all other time points; h–h: 144 h vs all other time points.

In our laboratory, in lethal no-choice feeding assays with oriental cockroaches from pig farms, the tested baits showed excellent acceptance and high cumulative efficacy (Table 2). Using the indoxacarb gel (AG), we recorded a strong knockdown: 80% of cases by 48 h and 100% by 96 h. Although no mortality was recorded by the end of the monitoring period (168 h), the complete immobilization (inability to move, feed, or drink) indicates high practical efficacy and a trajectory toward eventual lethality. Indoxacarb acts as a pro-insecticide that requires bioactivation by insect esterases and amidases to form the toxic N-decarbomethoxyllated metabolite (Wing et al., 2000). In cases where paralysis occurs rapidly, this enzymatic activation may be disrupted, preventing the full conversion to the active form and thus reducing or eliminating mortality. This mechanism could account for the 0% mortality observed in the AG group by the end of the experimental period. The very high coefficient of determination (R^2=0.995) supports a strong effect attributable to the active ingredient. High field performance of related products has been reported in apartments infested with German cockroaches, achieving 75.1% and 92.1% population reductions at two and four weeks, respectively (Wang & Bennett, 2008).

For the combination gel (MG; imidacloprid + S-methoprene), knockdown was more moderate (66.7%) at 48 h, while mortality increased over time—reaching 73.3% at 144 h and approaching a maximum (~96–97%) by the end of the observation period. High coefficients of determination (R^2=0.918; 0.954) again indicate a strong causal link between the measured outcomes and the applied insecticide(s).

Using the two inorganic desiccant products (Chl.D and Chl.E), knockdown remained weak (<25%) with negligible, statistically non-significant differences between products. Nevertheless, both achieved complete (100%) mortality by 168 h. Mortality occurred earlier and reached satisfactory levels with the pyrethroid-fortified Chl.D (76.7% at 72 h), whereas the diatomite-only Chl.E reached an effective mortality of 86.7% at 120 h. Coefficients of determination ranged from moderate for knockdown (R^2=0.662; 0.833) to high for mortality (R^2=0.945; 0.997).

From a practical standpoint, the temporal dynamics of knockdown and mortality should guide product choice. Under heavy infestations, products delivering rapid knockdown and/or faster mortality are preferable to curb migration and the spread of pathogens.

The high efficacy of bait-based insect control, confirmed by our findings, has been documented for nearly half a century (Rust & Reierson, 1978) and by numerous contemporary studies (Wang & Bennett, 2008; Kostina et al., 2020; Rahayu et al., 2021). Field applications have produced substantial population reductions, typically 80–96.4% within four weeks, across different settings (Appel & Benson, 1995; Ree et al., 2006), and most baits have remained effective against field populations (Fardisi et al., 2017). Taken together, these data support incorporating insecticidal food baits into integrated cockroach management programs for infested pig farms.

Conclusion

Insecticidal food baits are an effective method for controlling cockroaches in livestock facilities. All the products tested met the European Chemicals Agency (ECHA) criteria for effectiveness against *B. orientalis*. Given their high consumption rates, selectivity, and practical benefits, these baits should be an essential part of an integrated approach to managing cockroaches.

Limitations

The main limitation of this study is the laboratory-based design, which may not fully reflect real farm environments. Future field studies are required to confirm the observed efficacy under practical conditions.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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