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Posted Date: 26 September 2025

doi: 10.20944/preprints202509.2188.v1

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Article

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

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## Abstract

The oriental cockroach (*Blatta orientalis* L.) is a common synanthropic pest in livestock farms, acting as a potential mechanical vector of pathogens. This study evaluated the insecticidal efficacy of four commercially available food baits against *B. orientalis* collected from seven industrial pig farms in Bulgaria. A no-choice bait feeding test was applied under controlled laboratory conditions. 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 sufficient knockdown (<25%) but also resulted in complete mortality by the end of the test (168 h), although with delayed dynamics. The results demonstrate the high potential of food baits for integrated pest management in swine facilities, with product choice depending on desired speed of action and infestation intensity.

**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 (Nasirian, 2019; 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 (I.C.U.P., 2021). 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 (Wang et al., 2004).

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).

**Objective.** 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, *Blatta orientalis* (L.), collected from seven industrial pig farms in Bulgaria. Prior to bioassays, insects were acclimated under laboratory conditions for at least 3 days at 20–26 °C, 30–50% relative humidity, with a 9:15 h light:dark photoperiod. 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).

**Table 1.** Insecticidal food baits used in the study.

| Code name | Formulation            | Active ingredient                             | Insecticide class (IRAC MoA)                                |
|-----------|------------------------|---|---|
| AG        | Gel bait, 30 g syringe | 1) 0.6% Indoxacarb                            | 1) IRAC 22A: oxadiazines                                    |
| MG        | Gel bait, 40 g syringe | 1) 2.15% Imidacloprid<br>2) 0.5% S-methoprene | 1) IRAC 4A: neonicotinoids<br>2) IRAC 7A: growth regulators |
| Chl.D     | Solid bait, 5 g box    | 1) 50% Silicon dioxide<br>2) 1% Tetramethrin  | 1) UNM<br>2) IRAC 3A: pyrethroid                            |
| Chl.E     | Gel bait, 10 g syringe | 1) 50% Diatomite                              | 1) UNM  |

**Legend.** IRAC MoA, Insecticide Resistance Action Committee mode-of-action code; UNM, non-specific mechanical/physical disruptors (Inorganic desiccant).

### Test Method

A no-choice lethal feeding assay with insecticidal food baits was conducted following 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, sustained until the end of the monitoring period, were classified as dead. If control mortality exceeded 5%, observed mortality in treatments was corrected using Abbott's formula (Abbott, 1925).

### Assessment

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

### Statistical Analysis

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

## 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 problem insects and leave low toxic residues (Miller & McCoy, 2011; 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 (Öz et al., 2010; 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 (Lapied et al., 2001; McCann et al., 2001). Imidacloprid—a neonicotinoid—also targets the nervous system and is increasingly incorporated into bait formulations (Sibia et al., 2014). To potentiate neonicotinoid performance, juvenile hormone analogues such as S-methoprene are frequently added to commercial products (Marchal et al., 2014).

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 SiO<sub>2</sub>), is considered safe and recommended for eco-friendly pest management (Korunic, 1998). Desiccant particles damage the cuticle by absorbing cuticular hydrocarbons and by abrasion, increasing water loss and causing death by desiccation (Faulde et al., 2006).

In our laboratory no-choice lethal feeding assays with Oriental cockroaches from pig-production facilities, the tested baits showed excellent acceptance and high cumulative efficacy (Table 2). With the indoxacarb gel (AG) we recorded a strong knockdown: 80% of individuals 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. 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).

With 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 rose earlier and to 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.

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

| h   | AG (N=30)                          |                  | MG (N=30)                     |                                     | Chl.D (N=30)                  |                                 | Chl.E (N=30)                      |                                |
|-----|------------------------------------|------------------|-------------------------------|-------------------------------------|-------------------------------|---------------------------------|-----------------------------------|--------------------------------|
|     | KD (%)                             | Mort. (%)        | KD (%)                        | Mort. (%)                           | KD (%)                        | Mort. (%)                       | KD (%)                            | Mort. (%)                      |
|     | $\bar{x} \pm SD$                   | $\bar{x} \pm SD$ | $\bar{x} \pm SD$              | $\bar{x} \pm SD$                    | $\bar{x} \pm SD$              | $\bar{x} \pm SD$                | $\bar{x} \pm SD$                  | $\bar{x} \pm SD$               |
| 8   | 3.3±0.58 <sup>a</sup>              | 0                | 56.7±0.58 <sup>a</sup>        | 16.7±0.58 <sup>a</sup>              | 16.7±0.58 <sup>a</sup>        | 0.0±0.00                        | 10.0±0.00 <sup>a</sup>            | 0.0±0.00                       |
| 16  | 10.0±0.00 <sup>ab</sup>            | 0                | 60.0±0.00 <sup>b</sup>        | 20.0±0.00 <sup>b</sup>              | 20.0±0.00 <sup>b</sup>        | 0.0±0.00                        | 10.0±0.00 <sup>b</sup>            | 0.0±0.00                       |
| 24  | 16.7±0.58 <sup>abc</sup>           | 0                | 63.3±0.58 <sup>c</sup>        | 20.0±0.00 <sup>c</sup>              | 20.0±0.00 <sup>c</sup>        | 0.0±0.00                        | 10.0±0.00 <sup>c</sup>            | 0.0±0.00                       |
| 48  | 80.0±0.00 <sup>abcd</sup>          | 0                | <b>66.7±0.58<sup>d</sup></b>  | 20.0±0.00 <sup>d</sup>              | 20.0±0.00 <sup>d</sup>        | 20.0±3.46 <sup>d</sup>          | 10.0±0.00 <sup>d</sup>            | 0.0±0.00                       |
| 72  | 93.3±0.58 <sup>abcde</sup>         | 0                | 63.3±0.58 <sup>e</sup>        | 23.3±0.58 <sup>e</sup>              | <b>23.3±0.58<sup>ae</sup></b> | 76.7±0.58 <sup>de</sup>         | 10.0±0.00 <sup>e</sup>            | 0.0±0.00                       |
| 96  | <b>100.0±0.00<sup>abcdef</sup></b> | 0                | 46.7±1.16 <sup>bcdef</sup>    | 40.0±1.00 <sup>abcdef</sup>         | 23.3±0.58 <sup>af</sup>       | 76.7±0.58 <sup>df</sup>         | <b>20.0±1.00<sup>abcdef</sup></b> | 0.0±0.00                       |
| 120 | 100.0±0.00 <sup>abcdeg</sup>       | 0                | 46.7±1.16 <sup>bcdeg</sup>    | 46.7±1.53 <sup>abcdeg</sup>         | 16.7±0.58 <sup>efg</sup>      | 83.3±0.58 <sup>d</sup>          | 13.3±0.58 <sup>g</sup>            | 86.7±0.58 <sup>g</sup>         |
| 144 | 100.0±0.00 <sup>abcdeh</sup>       | 0                | 26.7±0.58 <sup>abcdefgh</sup> | 73.3±0.58 <sup>abcdefgh</sup>       | 10.0±0.00 <sup>bcdefgh</sup>  | 90.0±0.00 <sup>d</sup>          | 13.3±0.58 <sup>h</sup>            | 86.7±0.58 <sup>h</sup>         |
| 168 | 100.0±0.00 <sup>abcefg</sup>       | 0 <sup>#</sup>   | 3.3±0.58 <sup>abcdefgh</sup>  | <b>96.7±0.58<sup>abcdefgh</sup></b> | 0.0±0.00 <sup>abcdefgh</sup>  | <b>100.0±0.00<sup>def</sup></b> | 0.0±0.00 <sup>abcdefgh</sup>      | <b>100.0±0.00<sup>gh</sup></b> |
|     | R <sup>2</sup> = 0.995             | -                | R <sup>2</sup> = 0.918        | R <sup>2</sup> = 0.954              | R <sup>2</sup> = 0.833        | R <sup>2</sup> = 0.945          | R <sup>2</sup> = 0.662            | R <sup>2</sup> = 0.997         |
|     | Sig. (p) = 0.000                   | -                | Sig. (p) = 0.000              | Sig. (p) = 0.000                    | Sig. (p) = 0.000              | Sig. (p) = 0.000                | Sig. (p) = 0.004                  | Sig. (p) = 0.000               |

**Legend.** KD, knockdown; Mort., mortality;  $\bar{x}$ , mean; SD, standard deviation; N, number of individuals; R<sup>2</sup>, 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. **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—<sup>a-a</sup>: 8 h vs. all other time points; <sup>b-b</sup>: 16 h vs. all others; <sup>c-c</sup>: 24 h vs. all others; <sup>d-d</sup>: 48 h vs. all others; <sup>e-e</sup>: 72 h vs. all others; <sup>f-f</sup>: 96 h vs. all others; <sup>g-g</sup>: 120 h vs. all others; <sup>h-h</sup>: 144 h vs. all others.

The high efficacy of bait-based insect control—and its agreement with our findings—has been documented for nearly half a century (Rust & Reiersen, 1978) and by numerous contemporary studies (Holbrook et al., 2003; Wang & Bennett, 2008; Gondhalekar & Scharf, 2012; Kostina et al., 2020; Rahayu et al., 2021, and others). 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 remain effective against field populations (Fardisi et al., 2017). Collectively, these data support incorporating insecticidal food baits into integrated cockroach management programs for infested pig farms.

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