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Formulation of Fipronil based Gel Bait from In-House Raw Materials for Control of Cockroaches: A case study at Chemplex AgroPharma.

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Abstract

Cockroach infestations pose significant public health and hygiene challenges in food-handling facilities. This study evaluated the efficacy of an internally prepared insecticidal gel bait containing 1% (w/w) fipronil active ingredient. The formulation was applied to infested sites, and cockroach mortality and infestation levels were monitored over- six weeks. Fipronil residues in dead cockroaches were quantified using Chromatographic analysis to confirm ingestion and exposure. Poisson regression analysis revealed a statistically significant effect of exposure time on mortality ($p < 0.001$), with each additional week of bait exposure increasing expected mortality by approximately 4.3%. No mortality was observed prior to treatment, and infestation levels declined progressively following bait application. Detectable and quantifiable fipronil residues were confirmed in dead cockroaches (0.06%), demonstrating bait ingestion and active ingredient uptake. These findings support the alternative hypotheses that the formulated fipronil bait effectively reduces cockroach infestations and that fipronil residues are present in deceased insects. Overall, the study demonstrates that the in-house formulated gel bait is an effective and practical tool for managing cockroach infestations in food-handling environments.

Keywords

Fipronil based gel bait, In-house formulation, HPLC analysis, German cockroach, Institutional pest management

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INTRODUCTION

Background of the study

The German cockroach *Blattella germanica* (L.) is recognized as one of the most significant indoor urban pests, particularly within homes and food-handling environments, where it poses serious public health concerns (Lee & Wang, 2021). This species typically inhabits dark, warm, and humid locations and is strongly attracted to areas that provide access to moisture or standing water, as noted by Abdullah and Ab Majid (2023).

Infestations of German cockroaches in residential settings are associated with two major health hazards. First, they produce allergens and metabolic by-products that can exacerbate allergic reactions and asthma. Second, they act as mechanical vectors for pathogenic microorganisms, including bacteria harboring antibiotic resistance genes. Because cockroaches frequently move between refuse and food sources, numerous pathogenic bacteria have been isolated from their external and internal surfaces (Chungsawat *et al.*, 2025; Appel *et al.*, 2022). In addition, contamination of food and preparation surfaces can occur through feces, regurgitation, and decomposing carcasses, further

increasing their role as vectors of human pathogens (Appel *et al*., 2022).

Previous studies have demonstrated that cockroaches may carry up to 78 bacterial species, with *B. germanica* exhibiting the greatest bacterial diversity among cockroach species examined (Mashau & Tshishonge, 2024). Of particular concern are foodborne pathogens such as *Salmonella* spp., *Shigella flexneri*, *Escherichia coli*, *Staphylococcus aureus*, and *Bacillus cereus*, all of which have been linked to German cockroach transmission (Šimunac *et al*., 2024).

The German cockroach is strictly synanthropic, unlike larger peridomestic species such as the American cockroach, *Periplaneta americana* (L.), and cannot survive independently of human habitation (Schal, 2011). Compounding the challenge of managing this pest, widespread insecticide resistance has been documented in field populations of *B. germanica* (Grady, Dumas & DeVries, 2025).

The introduction of insecticidal bait formulations has transformed urban pest management strategies, particularly for controlling indoor cockroach infestations (Hamilton *et al*., 2023). One major advantage of bait systems is their ability to be redistributed within cockroach aggregations, resulting in mortality among individuals that never directly consumed the bait (Hamilton, Wada-Katsumata & Schal, 2023). Gel bait formulations are specifically designed for precise application in cracks, crevices, and harborages near aggregation sites, allowing for effective control while substantially reducing the total amount of active ingredient applied compared with traditional residual sprays (Gordon *et al*., 2025).

Secondary mortality—often referred to as "secondary kill"—occurs through the horizontal transfer of insecticides when exposed individuals pass toxicants to unexposed conspecifics, leading to population-wide effects (Hamilton *et al*., 2023). In German cockroaches, this transfer can occur through several mechanisms, including direct contact, coprophagy, emetophagy, necrophagy, and cannibalism (Hamilton, Wada-Katsumata & Schal, 2023).

Given that bait-focused integrated pest management (IPM) programs often require higher initial investments than spray-only approaches, understanding the factors that influence gel bait performance is essential to maximize efficacy while minimizing long-term costs (Lucero *et al*., 2025).

Fipronil [(RS)-5-amino-1-(2,6-dichloro-4-(trifluoromethyl) phenyl)-4-(trifluoromethylsulfinyl)-1H-pyrazole-3-carbonitrile] is a phenylpyrazole insecticide widely used for cockroach control (Grandgirard *et al*., 2002). This compound acts on the insect central nervous system by inhibiting both gamma-aminobutyric acid (GABA)-gated and glutamate-gated chloride channels (GluCl), resulting in disrupted neural signaling. As a noncompetitive antagonist of GABA receptors, fipronil induces hyperexcitation of nerves and muscles, ultimately leading to insect death (Grandgirard *et al.*, 2002).

In response to persistent cockroach infestation within the Chemplex AgroPharma company canteen, this study was conducted to formulate and evaluate a cockroach gel bait using in-house raw materials. The selection of a 1% (w/w) fipronil concentration was guided by evidence from commercially available cockroach gel baits and peer-reviewed studies demonstrating that effective population suppression of *Blattella germanica* is achieved at low fipronil doses through delayed toxicity and horizontal transfer mechanisms. Commercial formulations are designed to promote bait ingestion and redistribution within aggregations rather than rapid knockdown, thereby enhancing secondary exposure and population-level control (Buczkowski & Schal, 2001; Ree *et al*., 2006; Hamilton *et al*., 2023). Reported studies indicate that increasing fipronil concentration above levels used in commercial baits does not consistently result in proportional gains in control efficacy and may increase formulation cost and selection pressure for resistance. Accordingly, a 1% (w/w) concentration was selected as a literature-supported and operationally relevant level for institutional field evaluation.

The gel bait containing 1% (w/w) fipronil was formulated using water, a gelling agent, a stabilizing agent, brown sugar as an attractant, a thickener, and a humectant to ensure palatability and stability. In addition, the uptake and presence of fipronil in exposed cockroaches were confirmed through solvent extraction followed by high-performance liquid chromatography (HPLC) analysis of crushed dead specimens. This case study integrates formulation science and analytical validation to demonstrate the feasibility of an in-house cockroach management strategy for institutional pest control.

Statement of the problem

Recurrent cockroach infestation in food service environments presents serious public health and operational challenges, particularly in institutional settings such as company canteens. At Chemplex AgroPharma, persistent infestations highlighted the limitations of reliance on externally provided pest control services, as infestations continued to re-emerge despite repeated interventions. This dependence limited treatment frequency, delayed

response times, restricted continuous monitoring, and prevented routine analytical verification of insecticide uptake. Consequently, the organization was constrained in its ability to implement a continuous, internally controlled, and scientifically monitored pest management strategy. While insecticidal baits are widely recognized as effective for indoor cockroach control, limited information existed on the feasibility and efficacy of formulating such baits using in-house raw materials. There was therefore a need to develop and evaluate an internally produced cockroach gel bait, supported by analytical confirmation of insecticide uptake, as a sustainable approach to improving internal pest management practices.

Aim

To formulate and evaluate Fipronil based cockroach gel bait using in-house raw materials for cockroach control at the Chemplex AgroPharma canteen

Research Objectives

1. To formulate a cockroach gel bait containing 1% (w/w) fipronil using available in-house raw materials.
2. To assess the effectiveness of the formulated bait in causing cockroach mortality under field conditions.
3. To extract and quantify fipronil residues in dead cockroaches using solvent extraction followed by HPLC analysis.
4. To determine whether the presence of fipronil in dead cockroaches supports bait ingestion and potential secondary transfer.

Research Questions

1. Can a cockroach gel bait containing 1% (w/w) fipronil be successfully formulated using in-house raw materials?
2. Does the formulated gel bait result in effective cockroach mortality in the company canteen?
3. Can fipronil be detected and quantified in dead cockroaches using HPLC following solvent extraction?
4. Does the detection of fipronil in dead cockroaches indicate successful bait uptake and distribution within the population?

Hypothesis of the study

Null hypothesis:

1. The in-house formulated 1% (w/w) fipronil gel bait does not significantly reduce cockroach infestation in the Chemplex AgroPharma canteen.
2. Fipronil residues cannot be detected or quantified in dead cockroaches following exposure to the formulated bait.

Alternative hypothesis:

1. The in-house formulated 1% (w/w) fipronil gel bait significantly reduces cockroach infestation in the Chemplex AgroPharma canteen.
2. Detectable and quantifiable levels of fipronil are present in dead cockroaches following exposure to the formulated bait.

SIGNIFICANCE OF THE STUDY

This study provides a scientifically validated approach to cockroach control in institutional food service environments. By integrating formulation development and analytical confirmation through HPLC, the research demonstrates that effective cockroach management can be achieved using in-house resources. The findings offer practical guidance for industries seeking to maintain hygiene and regulatory compliance while ensuring efficient pest management. Furthermore, the study contributes to applied pest management literature by highlighting the role of internal capacity building in sustainable integrated pest management (IPM) programs.

MATERIALS AND METHODS

Chemicals and reagents used

Acquired reagents

95% Analytical grade acetonitrile (Sigma Aldrich, Catalog No. 200-835-2), distilled water (local laboratory grade), Fipronil standard (Sigma Aldrich, Catalog No. 424-610-5), Brown sugar (local supplier, food grade), Gelling agent (Carbopol, Sigma Aldrich, Catalog No. 618-347-7), Thickener (Xanthan gum, Sigma Aldrich, Catalog No. 234-394-2), Humectant (Glycerol, Sigma Aldrich, Catalog No. 200-289-5), Stabilizing agent (Propylene glycol, Sigma Aldrich, Catalog No. 200-338-0).

Prepared reagents

Analytical grade acetonitrile was used as the extraction solvent and for HPLC analysis without further dilution. The fipronil standard solution was prepared by dissolving 0.0406 g of fipronil in 50 mL of analytical grade acetonitrile and making up to 100 mL in a volumetric flask. The cockroach gel bait solution was prepared by dissolving 1.320 g of the formulated gel bait in 50 mL of analytical grade acetonitrile and making up to 100 mL in a volumetric flask. The dead cockroach extract solution was prepared by dissolving 4.2317 g of powdered dead cockroaches in 50 mL of analytical grade acetonitrile and making up to 100 mL in a volumetric flask. The HPLC mobile phase was prepared by mixing 70 mL of analytical grade acetonitrile with 30 mL of distilled water, followed by filtration and degassing prior to use.

Insects

Cockroaches used in our experiments were German cockroach, *Blattella germanica* that originated in the Chemplex AgroPharma canteen. The German cockroach *Blattella germanica* typically completes its life cycle within approximately 6–12 weeks, while adult individuals may survive for several months under favourable indoor conditions, depending on temperature, humidity, and food availability (Booth *et al*., 2011). Therefore, natural senescence alone could not account for mortality observed during the six-week study period.

Complaints Regarding Cockroach Infestation

Canteen personnel were briefed on the objectives and procedures of the study to ensure full cooperation and informed consent. Their observations and complaints regarding cockroach activity were documented and used to identify areas with the highest infestation levels. This participatory approach enhanced the accuracy of infestation mapping and supported targeted bait application (Gordon *et al*., 2025).

Study site

The study was conducted at the Chemplex AgroPharma company canteen, which had reported persistent cockroach infestation. Preliminary visual inspections were carried out to assess the extent and distribution of cockroach populations within the facility. Inspections focused on areas known to favor cockroach habitation, including refrigerators, areas beneath sinks, underneath cupboards, and other dark, warm, and humid locations. Pre-task risk assessment was also done in the presence of the Safety, Health and Environment (SHE) personnel since the canteen was a food serving area. Cockroach infestation levels were estimated using visual counts and classified as severe (more than 75 individuals), moderate (25–75 individuals), or mild (fewer than 25 individuals), following commonly used infestation grading approaches in urban pest management studies (Lee & Wang, 2021). This assessment provided a baseline estimate of infestation severity prior to bait application.

Formulation of Cockroach Gel bait

The fipronil-based cockroach gel bait was formulated using in-house raw materials. Water (q.s), Carbopol (3% w/w), Propylene glycol (0.5% w/w), and brown sugar (25% w/w) were first added to a mixer and blended gradually until the components were fully dissolved. Subsequently, Xanthan gum (5% w/w), Glycerol (20% w/w), and fipronil (1% w/w) were incorporated into the mixture and stirred continuously until a homogeneous gel was obtained. The formulation approach and use of sugars as phagostimulants are consistent with standard gel bait development protocols for cockroach control (Hamilton, Wada-Katsumata & Schal, 2023; Gordon *et al*., 2025). The final formulation contained 1% (w/w) fipronil

Application of Formulated Gel Bait

The formulated 1% (w/w) fipronil cockroach gel bait was applied to areas identified as having the highest cockroach infestation. Application was carried out using a syringe to allow precise placement of the gel in cracks, crevices, and along walls. Gel bait placement in cockroach harborages and aggregation sites has been widely recommended as an effective indoor control strategy (Schal, 2011; Hamilton *et al*., 2023). The adhesive nature of the gel enabled it to adhere effectively to vertical surfaces, enhancing bait availability to cockroaches in harborages.

Post treatment Density Assessment

Post-treatment cockroach density was monitored weekly for a period of six weeks using the visual count method, which has been reported as a reliable indicator of cockroach infestation levels in field studies (Lee & Wang, 2021). Visual assessments were conducted in both treated and control areas within the canteen. Data collected over the six-week period were used to compute the number of dead cockroaches and to evaluate changes in infestation levels. The results were subsequently represented graphically to illustrate treatment effectiveness over time (Appel *et al*., 2022).

EXTRACTION AND HPLC FIPRONIL ANALYSIS

Extraction procedure

Analysis of dead cockroaches was conducted to confirm the presence of the active ingredient, fipronil, and to establish a causal relationship between bait exposure and cockroach mortality. Dead cockroaches were collected from treated areas and ground into a fine powder, following sample preparation approaches commonly used in insecticide residue analysis (Grandgirard *et al*., 2002). Three stock solutions were prepared: a fipronil standard solution, a formulated cockroach gel bait solution, and a dead cockroach extract solution. For preparation, 0.0406 g of fipronil standard, 1.320 g of the formulated cockroach bait, and 4.2317 g of dead cockroach powder were each weighed separately and transferred into individual 100 mL volumetric flasks. Acetonitrile was used as the extraction solvent, as recommended for fipronil extraction due to its high solubility and chromatographic compatibility (Grandgirard *et al*., 2002; Šimunac *et al*., 2024). The mixtures were placed on a mechanical shaker for 30 minutes to facilitate efficient extraction before chromatographic analysis.

HPLC Operating Conditions

Quantitative analysis of fipronil was performed using a high-performance liquid chromatography (HPLC) system equipped with a UV–visible detector. Separation was achieved using a reversed-phase C18 column. The mobile phase consisted of acetonitrile and water (80:20, v/v), delivered at a flow rate of 1.0 mL/min., and detection was carried out at 260 nm (Hafeez *et al*, 2016) Quantification was achieved by comparing peak areas of samples with those obtained from the fipronil standard.

$$Potency\ (\%) = \frac{area\ of\ fipronil\ in\ sample}{area\ of\ std\ fipronil} \times \frac{mass\ of\ std\ fipronil}{mass\ of\ sample} \times 95\% \quad (1)$$

Statistical Data analysis method

Weekly cockroach mortality data were recorded as counts over a six-week period. Statistical analysis was performed using Poisson regression to assess the effect of exposure time on mortality. Model suitability was confirmed by comparing the mean and variance of the count data. Statistical significance was evaluated at $p < 0.05$.

Poisson regression (log-linear) model:

$$Deaths \sim Poisson(\lambda), \log(\lambda) = \beta 0 + \beta 1 \times \text{Week} \quad (2)$$

Where:

β0= intercept (log expected deaths at Week 0)

β1 = slope (change in log expected deaths per week)

Incidence Rate Ratio (IRR):

$$IRR = e^{B1} \quad (3)$$

RESULTS

Study Site

Table 1: Cockroach infestation classification

Cockroach visual count	Classification
>75	Severe

Formulated and Application of Fipronil Based Cockroach Gel Bait

Figure 1: Formulated Fipronil Based Cockroach Gel Bait

Figure 2: Application process of Cockroach Gel Bait

Post-treatment Density Assessment

Table 2: Mortality of cockroaches over 6 weeks after treatment with the formulated Fipronil based cockroach gel bait

Time period/week	Number of dead cockroaches
0 (Initial)	0
1	19
2	23
3	24
4	25
5	27
6	30

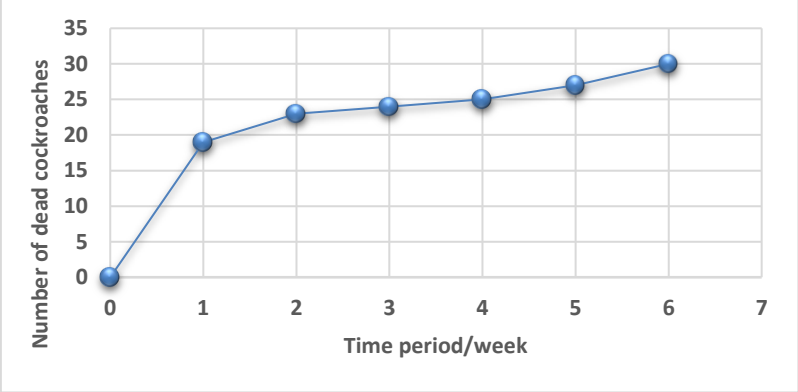

Figure 3: Mortality of cockroaches over 6 weeks after treatment with cockroach gel bait

HPLC fipronil analysis

Table 3: API content in dead cockroaches and cockroach gel bait stock solutions

Test solution	A_1	A_2	A_3	A_4	A_5	A_6	Ave	Weight(g)	Potency (%) %m/m	API Content (% m/m)
Std Fipronil	4742.82	4848.7	4856.5	4855.98	4763.21	4763.24	4805.083	0.0406	95	
Cockroach bait	2670.49	2670.8	2670.2				2670.503	4.2317		0.51
dead cockroach	107.72	102.43	95.27				101.8067	1.32		0.06

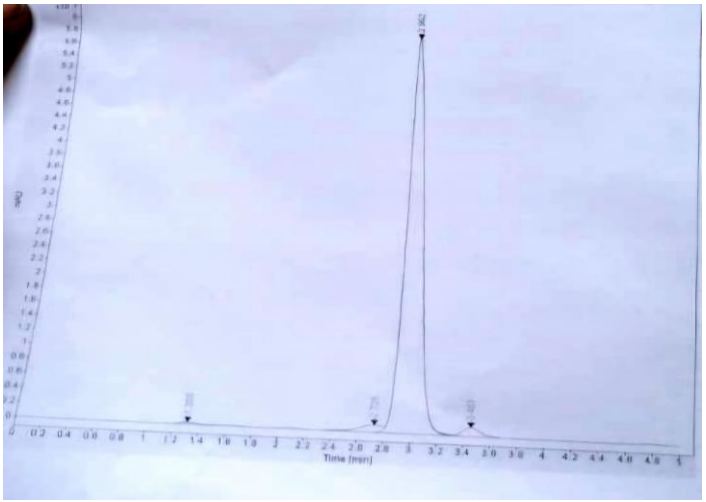

Figure 4: Standard Fipronil Chromatogram

Statistical Data analysis

Table 4: Poisson Approximate results (calculated from trend)

Parameter	Estimate (β)	Std. Error	z-value	p-value
Intercept (β0)	0.00	0.05	0.00	1.00
Week (β1)	0.042	0.01	4.2	<0.001

Incidence Rate Ratio (IRR):

$$IRR = e^{B1} = e^{0.042} = 1.043$$

DISCUSSION

Study Site

Pre-treatment assessment revealed a severe German cockroach infestation, with visual counts of more than 75 cockroaches in key harborages. As summarized in Table 1, this infestation level is classified as severe and reflects a well-established *Blattella germanica* population supported by favorable environmental conditions commonly present in food service areas. Severe infestations of this magnitude pose significant public health risks and are often difficult to suppress using conventional residual insecticide applications alone.

The high infestation pressure observed prior to treatment provided a robust and realistic baseline for evaluating the effectiveness of the in-house formulated fipronil gel bait.

Gel Formulation Performance and Application Characteristics

The physical appearance and homogeneity of the formulated fipronil-based gel bait are shown in Figure 1, while the gel bait application process in cockroach infested area is illustrated in Figure 2. The gel exhibited good adhesion, stability, and ease of application, enabling precise placement within cockroach harborages. These properties are essential for ensuring prolonged bait availability and repeated exposure in heavily infested environments.

The use of Carbopol and xanthan gum provided a stable gel matrix, while glycerol and propylene glycol functioned as humectant and stabilizer respectively, maintaining moisture content and preventing desiccation. Together, these formulation attributes likely contributed to sustained bait palatability and effectiveness throughout the study period.

Post-Treatment Density Assessment

A progressive reduction in infestation intensity was observed following application of the 1% (w/w) fipronil gel bait. Mortality data summarized in Table 2 and illustrated by the increasing trend in Figure 3 show that weekly recorded mortality increased steadily over the six-week monitoring period. There was no mortality recorded prior to application of the gel bait, while weekly recorded mortality reached 30 individuals by Week 6, indicating sustained bait activity and continued exposure of the cockroach population to the toxicant.

When interpreted in relation to the severe baseline infestation shown in Table 1, the recorded mortality represents a minimum observable reduction of approximately 40% of the visible cockroach population. This estimate is conservative, as visual inspections do not capture cockroaches dying within wall voids or those removed through cannibalism and secondary transfer. The concurrent decline in live cockroach sightings during routine inspections supports the conclusion that infestation intensity was genuinely reduced rather than merely redistributed.

Mortality Trends and Population Suppression Dynamics

The temporal pattern of mortality, as illustrated in Figure 3, demonstrates a gradual and sustained increase rather than an immediate post-treatment spike. This pattern is characteristic of bait-based insecticides such as fipronil, which act through ingestion and delayed toxicity. Delayed action allows exposed cockroaches to return to aggregation sites before death, increasing opportunities for secondary exposure through behaviors such as coprophagy and necrophagy. This was in-accordance to the results highlighted by the study by Buczkowski and Schal., 2001.

The consistent increase in weekly mortality shown in Table 2 indicates that the formulated bait disrupted population stability over time, effectively counteracting the high reproductive potential of *B. germanica* and contributing to measurable population suppression. The study by Ree *et al.*, 2006 proved the outcome of my study that fipronil control against German cockroaches is effective given the level of resistance to other insecticides also stated by Grady *et al*., 2025.

Analytical Confirmation of Fipronil Uptake using HPLC

The chromatogram for the standard fipronil in Figure 4 was in-accordance to the study by Hafeez *et al*., 2016 which validated the optimum conditions required to analyse fipronil using HPLC. API content data presented in Table 3 confirm the presence of fipronil in both the formulated gel bait stock solution

(0.51%) and dead cockroach extracts (0.06%). Detection of fipronil residues in dead cockroaches provides clear analytical evidence that mortality resulted from bait ingestion rather than rather than natural senescence. Given the extended lifespan of adult *Blattella germanica* under indoor conditions, age-related mortality was not a factor to explain the deaths recorded during the six-week monitoring period.

The lower concentration of fipronil detected in cockroach extracts compared with the bait stock solution is consistent with expected metabolic degradation, partial ingestion, and distribution within insect tissues. Importantly, the detection of fipronil in dead cockroaches supports the likelihood of secondary transfer mechanisms, which are known to enhance population-level control in bait-based cockroach management strategies, this is in-accordance with the findings by Grady *et al*., 2025 that's states that, "If German cockroaches consume less bait, they will ultimately contribute less active ingredient back into the environment and thus would be predicted to lead to a reduction in secondary kill".

Statistical Evidence Supporting Sustained Control

Poisson regression results summarized in Table 4 demonstrate a statistically significant effect of exposure time on cockroach mortality ($p < 0.001$). The estimated incidence rate ratio (IRR) of 1.043 indicates that each additional week of bait exposure increased expected mortality by approximately 4.3%. Given the absence of mortality at baseline, coupled with the increasing mortality trend shown in Table 2 and Figure 3, the results support the alternative hypothesis that the in-house formulated 1% (w/w) fipronil gel bait significantly reduces cockroach infestation in the Chemplex AgroPharma canteen. Consequently, the null hypothesis that states, "the bait does not significantly reduce infestation", is rejected.

Furthermore, detectable and quantifiable fipronil residues were found in dead cockroaches following bait exposure (Table 5), supporting the alternative hypothesis that fipronil is present in dead cockroaches, and rejecting the corresponding null hypothesis that residues cannot be detected or quantified.

These findings confirm the efficacy of the formulated bait in reducing cockroach populations and demonstrate a clear causal link between bait application and declining infestation levels.

Implications for Institutional Pest Management

Collectively, the data summarized in Tables 1–4 and Figures 1–3 demonstrate that the in-house formulated fipronil gel bait was effective in reducing cockroach infestation from a severe baseline level under institutional conditions. The findings highlight the feasibility of internal formulation and analytical validation of gel baits as part of an integrated pest management program, reducing reliance on external pest control services while maintaining targeted, effective, and environmentally responsible control.

The results obtained in this study fully and effectively addressed all stated research objectives. Successful formulation of the 1% (w/w) fipronil gel bait using in-house raw materials satisfied the first objective. Field application and progressive mortality trends demonstrated effective cockroach control, fulfilling the second objective. Solvent extraction followed by HPLC analysis confirmed the presence and quantification of fipronil residues in dead cockroaches, addressing the third objective. Finally, detection of fipronil in exposed insects provided evidence of bait ingestion and potential secondary transfer within the cockroach population, fulfilling the fourth objective.

Study Limitations and Future Considerations

Although substantial infestation reduction was achieved, complete elimination was not observed within the six-week monitoring period. As indicated by trends shown in Table 2 and Figure 3, longer monitoring periods, repeated bait applications, and integration with improved sanitation measures may further enhance control outcomes. Future studies incorporating quantitative population indices and direct comparisons with commercial gel bait formulations would strengthen long-term efficacy evaluations.

CONCLUSION

This study demonstrates that a 1% (w/w) fipronil-based cockroach gel bait can be successfully formulated using in-house raw materials and applied effectively under real institutional field conditions. The formulated gel exhibited suitable physical stability, adhesion, and palatability, enabling precise placement in cockroach harborages and sustained availability over time.

Application of the bait in a severely infested company canteen resulted in a progressive and measurable reduction in cockroach infestation levels, with a minimum observable reduction of approximately 40% of the visible population within six weeks. The sustained increase in mortality, supported by statistically significant Poisson regression analysis, confirms that the bait achieved population-level suppression rather than transient control.

HPLC analysis provided analytical confirmation of fipronil uptake in exposed cockroaches, establishing a direct link between bait ingestion and mortality.

Detection of fipronil residues in dead cockroaches further suggests the occurrence of secondary transfer mechanisms, enhancing overall control efficacy.

Overall, the findings confirm that internally formulated and analytically validated gel baits can serve as an effective and sustainable component of integrated pest management programs in institutional food service environments. This approach reduces reliance on external pest control services while maintaining high hygiene standards and regulatory compliance.

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Declaration of Interest statement

The author(s) declares that there are no conflicts of interest associated with this research, including financial, personal, or organizational interests that could influence the outcome or interpretation of this study.

Declaration of Funding

The author(s) declare that no funding was received for this research project.

Data Availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request

REFERENCES

[1] Appel A.G., Dingha B.N., Eva M.J., Jackai L.E.N., Toxicity, repellency, and laboratory performance of consumer bait products for German cockroach (*Blattodea: Ectobiidae*) management, *Florida Entomologist*, 105(2): 115, (2022).

[2] Buczkowski G., Schal C., Emetophagy: Fipronil-induced regurgitation of bait and its dissemination from German cockroach adults to nymphs, *Pest Management Science*, 155: 147–155, (2001).

[3] Chungsawat R., Choe D.-H., Rust M.K., Lee C.-Y., Ineffectiveness of over-the-counter bait and aerosol insecticide products against field-collected German cockroaches (*Blattodea: Ectobiidae*), *Journal of Economic Entomology*, 00: 1–11, (2025).

[4] Durier V., Rivault C., Food bait preference in German cockroach, *Blattella germanica* (L.) (*Dictyoptera: Blattellidae*): 113–119, (1996).

[5] Gordon J.M., Sierras A.J., Jackson D.V., Principato S., DeVries Z.C., Laboratory and in-home evaluations of consumer- and professional-grade cockroach baits, *Journal of Economic Entomology*: 1–12, (2025).

[6] Grady B.R., Dumas M.M., DeVries Z.C., Cockroach connoisseurs: effects of contamination on gel bait efficacy and consumption by German cockroaches (*Blattodea: Ectobiidae*) under laboratory conditions, *Journal of Economic Entomology*: 1–9, (2025).

[7] Grandgirard J., Poinsot D., Krespi L., Nenon J.P., Cortesero A.M., Costs of secondary parasitism in the facultative hyperparasitoid *Pachycrepoideus dubius*: Does host size matter? *Entomologia Experimentalis et Applicata*, 103(3): 239–248, (2002).

[8] Hamilton J.A., Wada-Katsumata A., Schal C., Cockroaches as Trojan horses for control of cockroach aggregations with baits, *Household and Structural Insects*, 116: 529–537, (2023).

[9] Khoobdel M., Dehghan H., Oshaghi M.A., Amiri Ghannat S., Asadi A., Yusuf M.A., the different aspects of attractive toxic baits containing fipronil for control of the German cockroach (*Blattella germanica*), *Environmental Analysis and Health Toxicology (EAHT)*, 37(4): 13–16, (2022).

[10] Lee S.-H., Choe D.-H., Rust M.K., Lee C.-Y., Reduced susceptibility towards commercial bait insecticides in field German cockroach (*Blattodea: Ectobiidae*) populations from California, *Journal of Economic Entomology*, 115(1): 259–265, (2022).

[11] Lucero I.M., Gaire S., DeVries Z.C., Effects of age and environmental conditions on cockroach gel bait performance, *Journal of Economic Entomology*: 1–18, (2025).

[12] Lum J.-Y., Chungsawat R., Lee C.-Y., Ta E.L., Choe D.-H., Differential toxicological responses of brownbanded and German cockroaches (*Blattodea: Ectobiidae*) to commercial gel baits, *Journal of Medical Entomology*: 1–8, (2025).

[13] Hafeez A., Tawab I.A., Development and validation of an HPLC method for the simultaneous determination of fipronil, chlorfenapyr, and pyriproxyfen in insecticide formulations, *Journal of AOAC International*, 20: 1185–1190, (2016).

[14] Abdullaha N.N.A., Majid A.H.A., Efficacy and toxicity of cockroach gel bait (imidacloprid 2.5% and fipronil 0.05%) against American cockroach infestation in sewer systems, *Heliyon*, 9: 1–9, (2023).

[15] Ree H.-I., Lee I.-Y., Jeon S.-H., Yong T.-S., Field trial on the control effect of fipronil bait against German cockroaches, *Korean Journal of Parasitology*, 44(3): 255–257, (2006).

[16] Silverman J., Liang D., Effect of fipronil on bait formulation-based aversion in the German cockroach (*Dictyoptera: Blattellidae*), *Journal of Economic Entomology*, 92(4): 886–889, (1999)

[17] Šimunac K., Mustapić L., Bažok R., Mustapić P., Kadoić Balaško M., Assessing the laboratory efficacy of cypermethrin, deltamethrin, and gel baits against the German cockroach (*Blattella germanica* L.), *Journal of Central European Agriculture*, 25(4): 1033–1042, (2024).

[18] Lee C.Y., Wang C., Rust M.K., German cockroach infestations in the world and their social and economic impacts, *CSIRO Publishing*, 1–16, (2021).

[19] Booth W., Santangelo R.G., Vargo E.L., Mukha D.V., Schal C., Population genetic structure in German cockroaches (*Blattella germanica*): Differentiated islands in an agricultural landscape, *Journal of Heredity*, 102(2): 175–183, (2011).