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Indoor Air Quality and Pest Control Efficacy: A Case Study of Imidacloprid vs. Green Insecticides in Food Outlets Attached to Malaysian Shopping Malls

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ABSTRACT---- ***This study compares the performance of imidacloprid, a low-toxicity synthetic insecticide, with green insecticides in managing Blattella germanica (L.) infestations and their impact on indoor air quality in food retail outlets located in shopping malls. Indoor air parameters (temperature, relative humidity, air velocity, CO_2, and TVOC) and cockroach counts were measured before and after treatment, and results were compared against DOSH (2010) guidelines. Imidacloprid concentrations remained below 0.1000 mg/m³, indicating no significant contribution to indoor air contamination. In contrast, green insecticides were associated with a potential long-term increase in cockroach infestations. Outlet A, located in a Green Building Index (GBI)-certified mall, demonstrated better ventilation compared to Outlet B. Findings suggest that while green insecticides align with sustainability goals, imidacloprid showed superior efficacy in suppressing cockroach populations without compromising indoor air quality.***

Keywords: Indoor air quality; German cockroach; imidacloprid; green insecticides; food retail; ventilation; Blattela germanica

1. INTRODUCTION

Indoor air quality (IAQ) is increasingly recognized as a critical factor in public health, particularly in enclosed and high-traffic environments such as shopping malls. Studies have consistently identified chemical contaminants, including pesticides, as major contributors to indoor air pollution (Asha Gaikwad & Niharika Shivhare, 2019). According to the U.S. Environmental Protection Agency (US EPA), indoor air can contain pollutant concentrations two to five times higher than outdoor air, a significant concern given that people spend about 90% of their time indoors. The problem is especially pronounced in commercial food outlets, where high human traffic, food preparation, and routine chemical treatments converge.

The persistence of indoor pollutants is often linked to inadequate ventilation. Previous research (Moya et al., 2004; Etzel, 2001; Meklin et al., 2005) has shown that contaminants accumulate in poorly ventilated spaces, leading to exposure risks ranging from mild symptoms, such as nasal irritation and headaches, to more serious conditions including respiratory and cardiovascular diseases. Shopping malls, particularly those with poorly maintained mechanical ventilation and air-conditioning (MVAC) systems, are especially vulnerable due to the concentration of enclosed retail and food operations.

Among these pollutants, pesticide residues from routine pest control activities have drawn increasing attention. Although necessary for maintaining hygiene and safety in food premises, the frequent use of insecticides introduces potential health hazards through indoor air contamination. Integrated Pest Management (IPM) strategies have been developed to reduce such risks. For example, Changlu et al. (2019) demonstrated that combining non-aerosol baiting with improved sanitation could cut insecticide residues by up to 90% within a year.

Imidacloprid, a systemic chloronicotinyl insecticide, is often promoted as a low-toxicity option for indoor pest control because of its selective action on insect nervous systems and low volatility (Matthew Fossen, 2006). Nonetheless, concerns remain about its cumulative presence in poorly ventilated environments. Green insecticides, typically formulated from essential oils and biodegradable ingredients, are increasingly adopted in green-certified buildings as alternatives. These products are marketed as environmentally friendly and non-hazardous, but robust field data on their long-term effectiveness against resilient pests such as *Blattella germanica* remain limited.

The German cockroach (*Blattella germanica*) is one of the most persistent pests in food-handling areas, hospitals, and commercial outlets. Its close association with human activity and its role as a carrier of foodborne pathogens make it a significant public health concern (Bonnefoy et al., 2008; Rueger et al., 1969). Exposure to cockroach droppings and secretions has been linked to allergic reactions, food contamination, and transmission of disease-causing microorganisms. Severe infestations may even contribute to psychological stress (Valles, 2020), underscoring the need for reliable pest control strategies.

While pesticides are widely recognized for their benefits in food safety and pest management (Barr & Deedham, 2002; Casida & Quistad, 2000; Cooper & Dobson, 2007), their extensive use has also raised environmental and health concerns (Damalas & Eleftherophorinos, 2011). Indoor exposure can occur through inhalation, ingestion, or dermal contact (Nigg et al., 1990; Bila & Dezotti, 2003; Hernandez et al., 2013). In green buildings, where indoor environmental quality is a key evaluation criterion, it is critical to assess whether plant-based insecticides can provide effective pest suppression while reducing chemical exposure. Malaysia's Green Building Index (GBI) emphasizes IAQ and energy efficiency, but provides little guidance on the use of chemical agents in operational food outlets.

This study seeks to address this gap by comparing IAQ outcomes and pest suppression efficacy in two food retail outlets: Outlet A, located in a GBI-certified mall using imidacloprid, and Outlet B, in a non-certified mall using plant-based insecticides. IAQ parameters (CO_2, TVOC, temperature, humidity, and air velocity) were measured alongside *Blattella germanica* infestation levels. Baseline data were collected two months prior to treatment, followed by post-intervention monitoring after four months of consistent applications.

A key limitation of this study is the absence of an untreated control group. Without a control, it is not possible to fully distinguish the effects of the insecticide treatments from natural fluctuations in cockroach populations or environmental variations such as changes in mall occupancy, sanitation practices, or seasonal climate. This constraint reduces the strength of causal inferences that can be drawn from the findings. Nonetheless, in real-world food retail outlets, it is operationally and ethically impractical to suspend pest control entirely, which explains why a control group could not be implemented in this study.

The findings aim to inform pest management professionals, building designers, and public health regulators about the trade-offs involved in transitioning to greener pest control in commercial food settings. Specifically, this study evaluates whether (i) imidacloprid and green insecticides affect IAQ during application, (ii) both treatments differ in their ability to suppress *Blattella germanica*, and (iii) green-certified buildings provide ventilation advantages that mitigate IAQ risks.

Ultimately, this research aspires to guide integrated pest management practices that balance efficacy, sustainability, and indoor air quality goals, aligning with broader public health and sustainable development objectives.

2. METHODOLOGY

3.1. Project Site

The study was conducted in two food retail outlets located within shopping malls. Outlet A was situated in a mall certified with Green Building status, while Outlet B was located in a non-certified mall. Both outlets were part of the same food chain, with similar size, layout, and design. Each outlet comprised a kitchen for food preparation, a dining area, and a service counter (Figure 1)

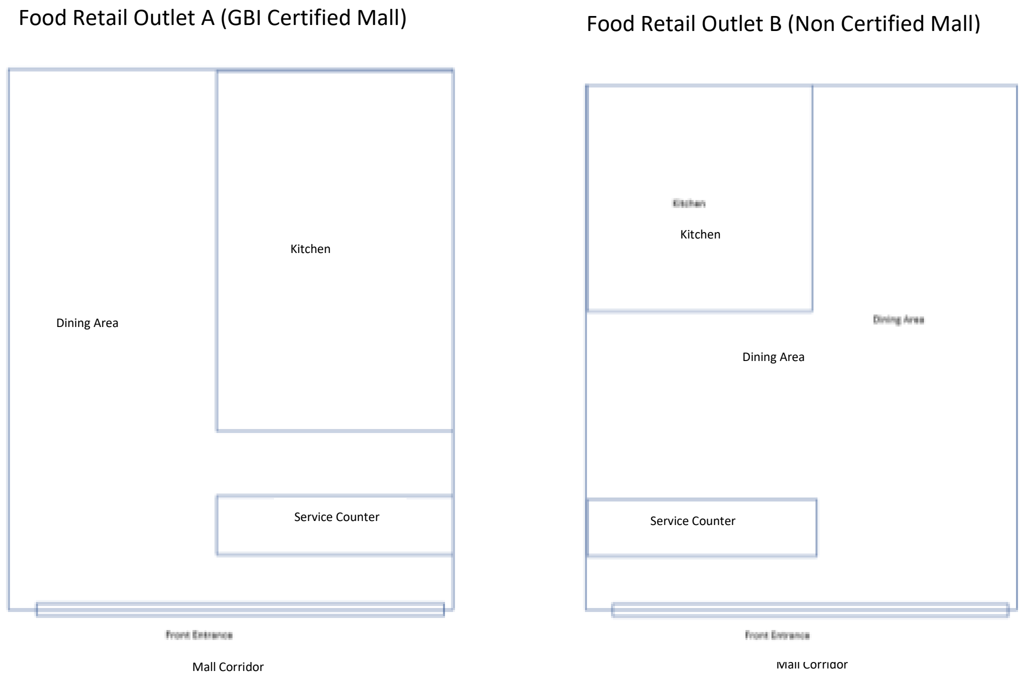

Figure **Error! No text of specified style in document.**: Layout of the two food retail outlets

3.2. Air Samplings

Two sampling points were established in each outlet: one in the dining area and one in the kitchen (Figure 2).

Figure 2: Sampling point locations in the food retail outlets

Air samples were collected 12 hours after residual spray application along the outlet perimeters. Sampling was conducted using Amberlite XAD-2 cartridges connected to air samplers positioned at a height of 1.65 m and operated at a flow rate of 2 L/min. The flow rate was maintained at 2 L/min for 25 minutes, yielding a total sampled air volume of 50 L (Hafeez et al., 2015). Following collection, cartridges were stored in capped glass tubes in the dark at –20 °C until analysis.

3.3. Imidacloprid Analysis

Samples were prepared by transferring specific quantities of the formulated products into 25 mL volumetric flasks, each containing 0.01 g of active ingredient (imidacloprid). A diluent of acetonitrile and water (70:30) was used to dissolve the samples. The mixtures were sonicated to ensure complete solubilization of the active ingredient, then brought to volume with diluent. Before analysis, all samples were filtered through 0.45 µm Milipore membranes. High-performance liquid chromatography (HPLC) was employed for quantification (Hafeez et al., 2016).

3.4. Cockroach Count

Twenty cockroach traps were placed in each outlet, covering the dining area, service counter, and kitchen. Captured cockroaches were categorized into four groups: males, females, gravid females, and nymphs. This classification allowed detailed observation of reproductive growth, particularly among females and gravid individuals, over the course of the experiment.

3. RESULTS AND DISCUSSION

Air Sampling Results of Imidacloprid

Table 1: Imidacloprid concentrations at Outlet A and Outlet B

Outlet	Area	Before experiment (mg/m³)	After experiment (mg/m³)
A	Dining	<0.1000	<0.1000
	Kitchen	<0.1000	<0.1000
B	Dining	<0.1000	<0.1000
	Kitchen	<0.1000	<0.1000

As shown in Table 1, imidacloprid concentrations at both outlets were consistently below 0.1 mg/m³, both before and after the four-month experiment.

Imidacloprid is a systemic chloronicotinyl insecticide that kills target pests through ingestion or direct contact. Its mode of action involves disrupting nicotinic acetylcholine receptors in the insect central nervous system. Because of its very low vapor pressure (1.0×10^{-7} mmHg), imidacloprid is essentially non-volatile. It also has a low soil adsorption coefficient, meaning it is unlikely to disperse widely through airborne soil particles. Furthermore, its low Henry's law constant (6.5×10^{-11} atm·m³/mol) indicates minimal volatility from water. Collectively, these physical characteristics suggest that imidacloprid is unlikely to be present in indoor air in detectable amounts following application (Matthew Fossen, 2006). This explains why imidacloprid concentrations remained <0.1000 mg/m³ in Outlet A throughout the study.

Green insecticides, in contrast, are derived from organic sources and are generally considered more environmentally friendly. They are believed to pose less risk to human and animal health and ecosystems while still controlling unwanted pests. Such products are sometimes referred to as ecological insecticides or biopesticides (Nollet & Rathore, 2019).

At Outlet B, a green insecticide formulated with a proprietary blend of plant-based essential oils, octadecennoic acid potassium salt, lecithin, and purified water was applied over the four-month experimental period. Its mode of action involves dehydrating insects by disrupting their waxy cuticle, leading to fluid loss and death within minutes of contact. Since imidacloprid was not used in Outlet B, the air sampling results also showed no detectable concentrations of imidacloprid, which was consistent with expectations.

3.1. Indoor Air Quality Parameters

In addition to imidacloprid analysis, other IAQ parameters were measured, including CO_2, relative humidity, air temperature, air velocity, and TVOC. Data were collected during outlet operating hours (10:00–22:00). Measurements were taken using an IAQ meter (TSI 8762) for temperature, humidity, and CO_2, a DustTrak TSI 8520 for particulates, and a VelociCalc TSI 9555 for air velocity.

Real-time monitoring was conducted across four time slots daily (10:00–13:00, 13:00–16:00, 16:00–19:00, and 19:00–22:00). At each point, readings were allowed to stabilize before recording, with three replicates taken per location.

According to the *Industry Code of Practice on Indoor Air Quality* (DOSH, 2010), physical parameters such as air temperature, relative humidity, and air movement are key IAQ indicators, while CO_2 serves as a measure of ventilation performance. TVOC concentrations are used as indicators of chemical contaminants in indoor environments. All data collected were analyzed using SPSS version 29.0.0.0 (241) and compared against the DOSH (2010) guidelines to determine whether IAQ parameters were within acceptable limits (Table 2).

Table 1: Indoor air quality parameters at Outlet A and Outlet

Parameter	Outlet A	Median	Range	Outlet B	Median	Range
Temperature (°C)	4	23.6	23.1–24.0	4	25	24.9–26.0
Relative humidity (%)	4	59.95	57.7–61.3	4	73.7	71.7–76.0
Air velocity (m/s)	4	0.075	0.070–0.080	4	0.09	0.080–0.120
CO_2 (ppm)	4	872	722–991	4	913	737–995
TVOC (ppm)	4	0.507	0.485–0.716	4	0.441	0.405–0.697

3.2. Temperature and Relative Humidity

Malaysia's tropical climate is characterized by relatively uniform temperatures, high humidity, and abundant rainfall, with generally light winds. The mean annual temperature ranges from 22–32 °C, while relative humidity varies between 10–90% (MED, 2022).

Figures 3 and 4 show the temperature and relative humidity recorded in the two food retail outlets located within shopping malls. Both parameters were lower in Outlet A compared to Outlet B. The temperature at Outlet A ranged between 23.1–24.0 °C, while Outlet B recorded higher values of 24.9–26.0 °C. Similarly, relative humidity at Outlet A ranged from 57.7–61.3%, whereas Outlet B showed higher values between 71.7–76.0%.

According to DOSH (2010) requirements, acceptable ranges for indoor environments are 23–26 °C for temperature and 40–70% for relative humidity. While both outlets met the temperature requirement, Outlet B exceeded the recommended upper limit for relative humidity.

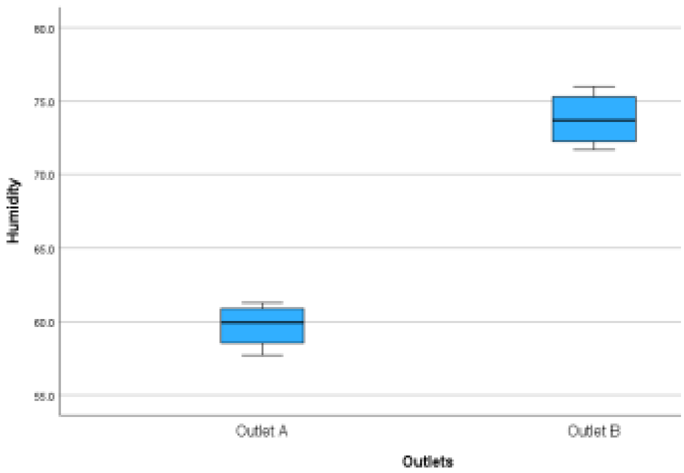

Figure 3: Relative humidity in food retail outlets attached to malls

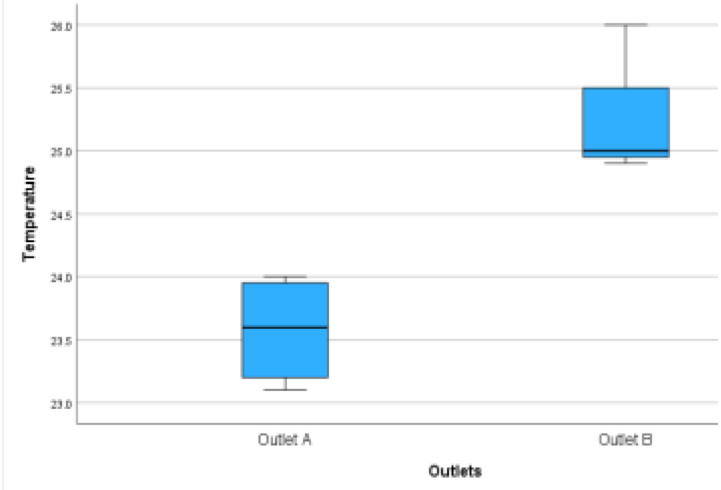

Figure **Error! No text of specified style in document.**: Temperature in food retail outlets attached to malls

3.3. Air Velocity

Air velocity plays an important role in both indoor air quality and the health of building occupants. Airflow influences the distribution of contaminants and pathogens in the environment by moving air from areas of higher pressure to areas of lower pressure (IAQ Consultants, 2022).

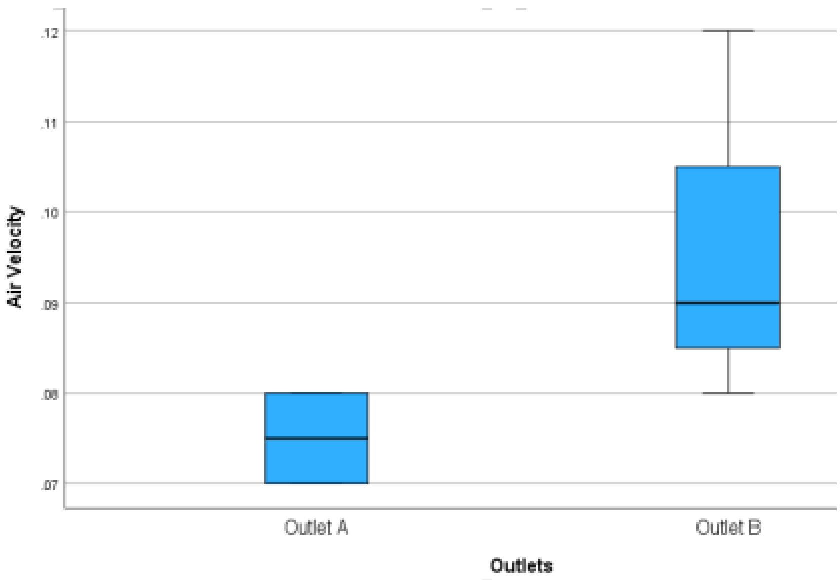

Figure 5: Air velocity in food retail outlets attached to malls

As shown in Figure 5, the air velocity at Outlet A ranged between 0.070–0.080 m/s, while Outlet B recorded slightly higher values of 0.080–0.120 m/s. According to DOSH (2010) guidelines, the acceptable range for indoor air movement is 0.15–0.50 m/s. The recorded values at both outlets were below this recommended range.

This discrepancy may be attributed to the location of the outlets within the shopping mall. Ventilation systems are typically designed to regulate airflow across the entire mall space rather than individual retail units, which could explain the lower velocities observed in these outlets.

3.4. Carbon Dioxide

Carbon dioxide (CO_2) is widely used as an indicator of ventilation performance in indoor environments. Shopping malls provide an interesting case study because they are public spaces where people spend significant amounts of time for leisure and dining. The overall activity within the mall, including fluctuations in occupancy, can directly influence CO_2 levels measured inside individual food retail outlets.

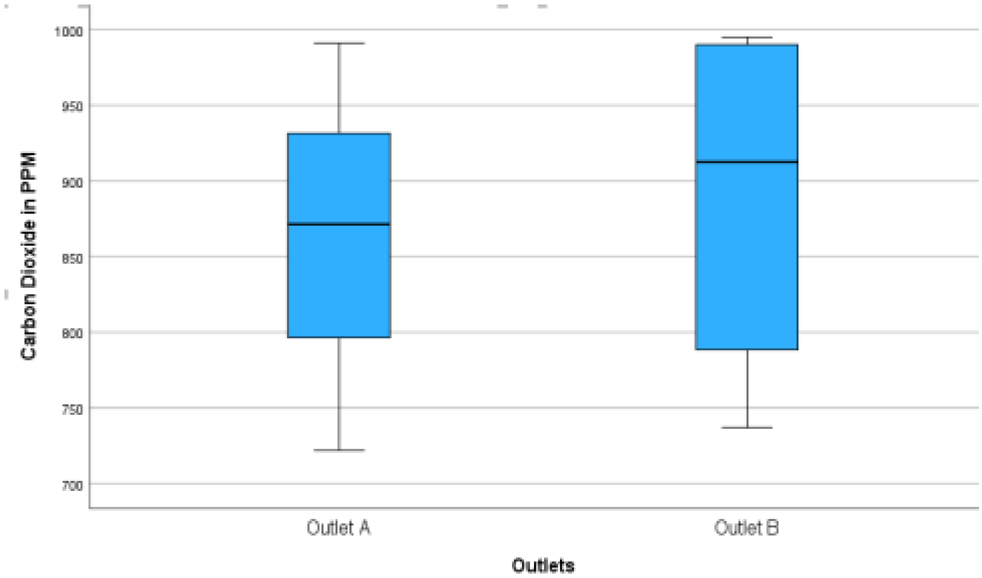

Figure 6: Carbon dioxide concentrations in food retail outlets attached to malls

In this study, CO_2 levels were recorded during weekends, when visitor numbers are typically higher. Previous research has shown that indoor pollutant concentrations, including particulate matter, are often higher on weekends compared to weekdays due to increased occupancy (Carolyn Payus & Carmen Chai, 2017).
According to DOSH (2010) guidelines, acceptable indoor CO_2 concentrations should remain below 1000 ppm. In Outlet A, CO_2 ranged from 722–991 ppm, while Outlet B recorded values between 737–995 ppm. These results indicate that ventilation in both outlets remained within acceptable limits, although levels at Outlet B approached the upper threshold during peak activity (Figure 6).

3.5. Total Volatile Organic Compounds (TVOC)

Potential sources of total volatile organic compounds (TVOCs) in food retail outlets include aerosol sprays, cleaning and disinfecting agents, air fresheners, pesticides, and other common household products. Exposure to TVOCs can cause both short- and long-term health effects. In poorly ventilated buildings, indoor concentrations of VOCs are often much higher—up to ten times—than outdoor levels (US EPA).

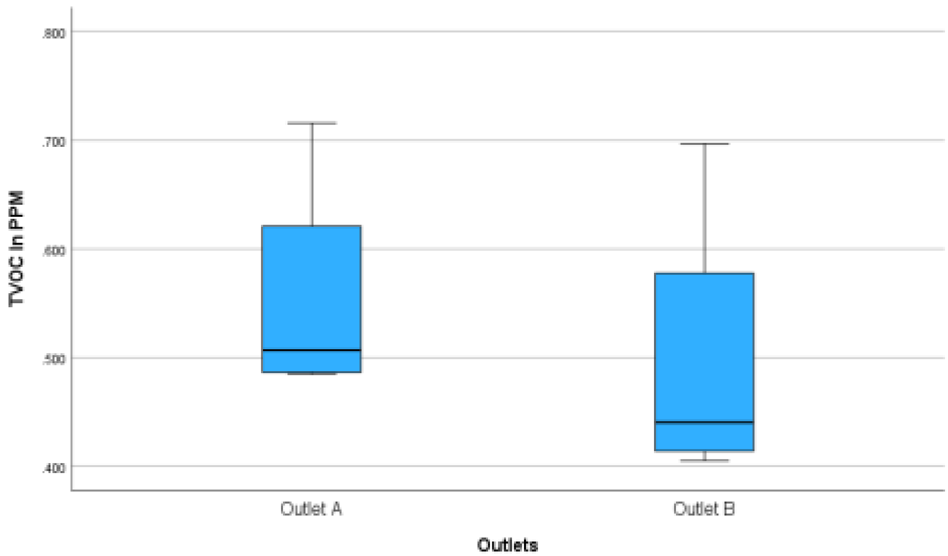

Figure 7: VOC concentrations in food retail outlets attached to malls

According to DOSH (2010) guidelines, acceptable TVOC concentrations in indoor environments should not exceed 3 ppm. As shown in Figure 7, TVOC levels in both outlets were consistently below 1 ppm. These low concentrations were likely due to effective ventilation systems within the food retail spaces. Elevated TVOC levels can cause health issues such as eye, nose, and throat irritation, headaches, nausea, and loss of coordination. Prolonged exposure may also damage the liver, kidneys, or central nervous system. Some organic compounds are known or suspected carcinogens in humans.

Table 2: Cockroach count by caste before experiments

Outlet	Area	Male	Female	Gravid	Nymphs	Total
A	Dining	18	9	6	169	202
	Kitchen	15	8	7	158	188
B	Dining	17	6	3	148	174
	Kitchen	17	8	8	171	204

Table **Error! No text of specified style in document.**: Cockroach count by caste after experiments

Outlet	Area	Male	Female	Gravid	Nymphs	Total
A	Dining	17	7	3	165	192
	Kitchen	13	8	8	163	192
B	Dining	22	10	3	170	205
	Kitchen	20	15	9	183	227

A total of 20 sticky traps were deployed in each outlet, with 12 placed in dining areas and 8 in kitchens (Urban Pest Control Operators, 2004). Results before and after the four-month experiment are summarized in Tables 3 and 4.

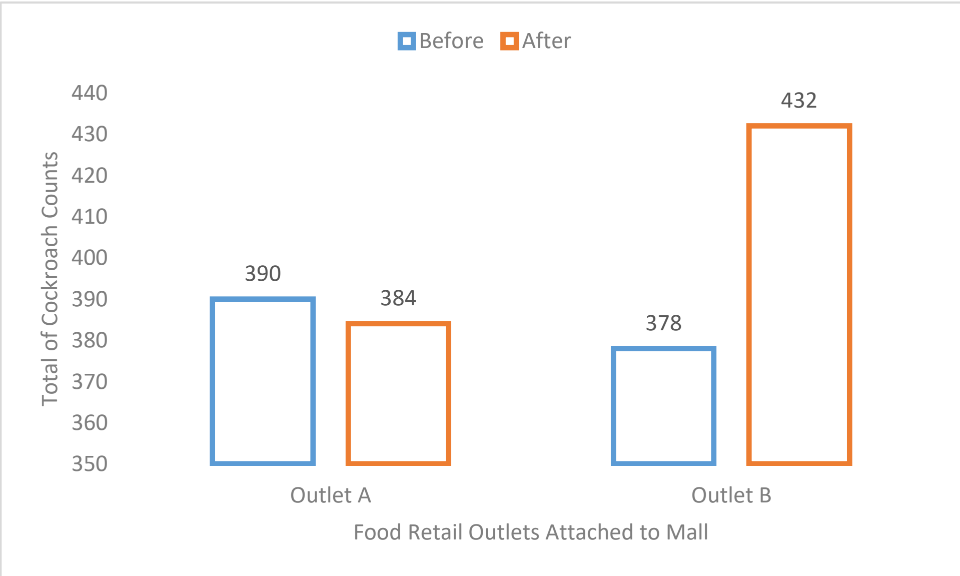

Figure 8: Comparison of total cockroach counts between Outlet A and Outlet B

At Outlet A (imidacloprid treatment), the total cockroach population decreased slightly by 1.5%. In contrast, Outlet B (treated with a green insecticide) recorded an increase of 14.3% after four months (Figure 8).

3.6. Population Dynamics of *Blattella germanica*

Blattella germanica cannot survive in environments without human activity, as food, water, and harborage are essential for its growth (S. Valles, 2021). Food retail outlets therefore provide ideal conditions for infestation.

Population dynamics are strongly driven by the reproductive caste (females and gravid females). A single gravid female carries an ootheca containing 30–40 eggs, which she retains until just before hatching. The ootheca protrudes from the posterior of the gravid female, making this caste critical for understanding population growth.

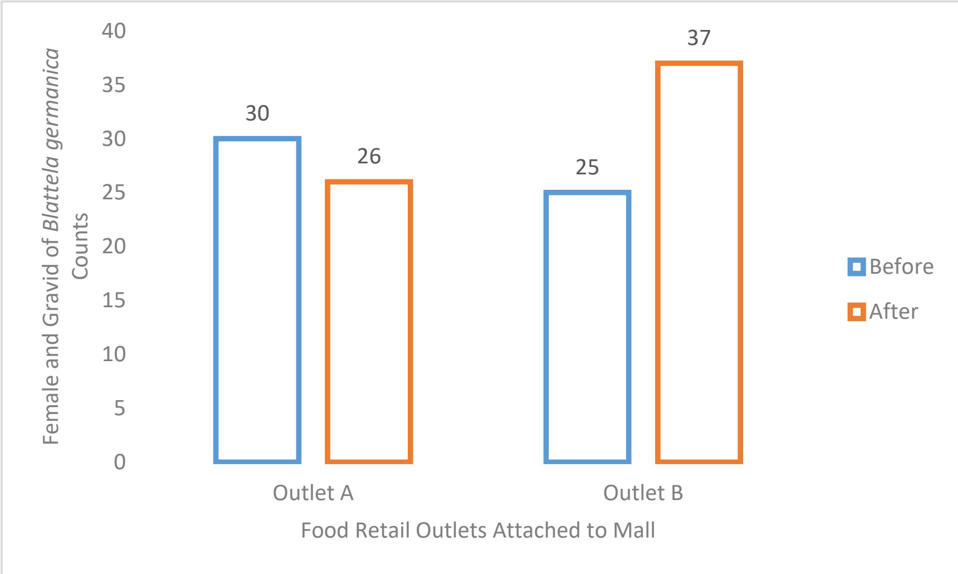

Figure 9. Comparison of female and gravid cockroach counts between Outlet A and Outlet B

As shown in Figure 9, Outlet A recorded a 13.3% decrease in the reproductive caste after imidacloprid treatment. In contrast, Outlet B experienced a 48% increase after the application of green insecticides. Under ideal conditions, *B. germanica* populations expand exponentially, with nymphs making up about 80% of the population and adults 20%. The full life cycle is typically completed within 100 days (S. Valles, 2021).
This exponential growth presents serious public health risks, as cockroaches are vectors of disease-causing microorganisms including bacteria, protozoa, fungi, helminths, and viruses. These can lead to diseases such as gastroenteritis, typhoid, and diarrheal syndromes (Feleke Moges et al., 2016).

3.7. Implications for Indoor Air Quality and Pest Management

This study confirms that low-toxicity insecticides such as imidacloprid do not contribute to indoor air pollution when used routinely in food retail outlets. Supporting IAQ parameters—including CO_2, temperature, relative humidity, air velocity, and TVOC—remained within DOSH guidelines, indicating adequate ventilation.
Outlet B, treated with a green insecticide, also showed no air pollution; however, its poor efficacy against *B. germanica* raises concerns. While often marketed as "eco-friendly" or "non-toxic," organic pesticides still contain active toxic ingredients. For example, pyrethrins, derived from chrysanthemum flowers, are considered natural but still pose toxicity risks and may contain impurities (Bond et al., 2014). The US EPA also cautions that terms such as "non-toxic" can be misleading, since all pesticides must be toxic to pests to be effective (NPIC).
Thus, for a pest management strategy to be sustainable in green buildings, effectiveness must be prioritized alongside IAQ. Relying solely on green insecticides may allow pest populations to expand, increasing the risk of disease transmission. Integrated Pest Management (IPM), which combines chemical and non-chemical methods, remains the most appropriate strategy for minimizing pesticide use while ensuring effective control.

4. CONCLUSION

This study demonstrated that imidacloprid was more effective than green insecticides in suppressing *Blattella germanica* infestations. In terms of indoor air quality, imidacloprid did not contribute to chemical pollution, as concentrations at both sampling points remained consistently below 0.1 mg/m³ before and after the four-month experiment.
The choice of insecticide is critical in pest management. An effective product should not only control cockroach populations but also reduce the risk of exponential growth over the long term. Monitoring cockroach counts by caste provides valuable insight, particularly into the reproductive groups (females and gravid females), which drive population expansion. As shown in Figure 9, the reproductive caste increased by 48% at Outlet B after treatment with green insecticides, even over a relatively short period of four months. This trend signals the potential for rapid infestation growth if ineffective control methods are used.
Future research should expand the scope beyond cockroaches to include other common pests in food retail outlets such as

rats, ants, and mosquitoes. Comparative studies involving different insecticide categories, including volatile and synthetic formulations, would provide a broader understanding of pest management options. A multi-site design involving a larger number of outlets would also enhance statistical robustness and generalizability.

To strengthen validity, future studies should ideally include a third group receiving no treatment, serving as a true control. Extending the monitoring period to at least 12 months would enable observation of long-term trends in IAQ and pest population dynamics, including the potential development of insecticide resistance. Seasonal variation and differences in building design should also be considered to better capture environmental influences on treatment outcomes.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] A. Hafeez, S. Iqbal, I. A. Tawab, A. Bhutto, R. Uddin and F. Anwar, "Liquid chromatographic separation and quantification of imidacloprid in different modes of formulations," *American-Eurasian J. Agric. & Environ. Sci.*, vol. 15, pp. 2381, 2015.

[2] A. Hafeez and I. A. Tawab, "Development and validation of an HPLC method for the simultaneous determination of fipronil, chlorfenapyr, and pyriproxyfen in insecticide formulations," *Journal of AOAC*, 2016.

[3] A. J. Dobbs and N. Williams, "Indoor air pollution from pesticides used in wood remedial treatments," *Environmental Pollution (Series B)*, vol. 6, pp. 271, 1983.

[4] A. Cincinelli and T. Martellini, "Indoor air quality & health," *Int. J. Environ. Res. Public Health*, vol. 14, pp. 1286, 2017.

[5] A. Gaikward and N. Shivhare, "Indoor air pollution: A threat," *Int. J. Sci. Res. Rev.*, vol. 7, pp. 1463, 2019.

[6] C. Bond, K. Buhl and D. Stone, "Pyrethrins general fact sheet," *National Pesticide Information Center, Oregon State University Extension Services*, 2014.

[7] C. Payus and C. Chai, "Indoor air quality at shopping mall in Kota Kinabalu, Sabah (particulate matter and ozone)," *Annals of Tropical Medicine and Public Health*, 2017.

[8] C. Wang, A. Eiden, R. Cooper, C. Zha, D. Wang and E. Reilly, "Changes in indoor insecticide residue levels after adopting an integrated pest management program to control German cockroach infestations in an apartment building," *Insects*, vol. 10, pp. 304, 2019.

[9] G. M. Daraban, R.-M. Hlihor and D. Suteu, "Pesticides vs. biopesticides: From pest management to toxicity and impacts on the environment and human health," *Sustainability*, vol. 11, pp. 983, 2023.

[10] E. Czajka, K. Pancer, M. Kochman et al., "Characteristics of bacteria isolated from body surface of German cockroaches caught in hospitals," *Przeglas Epidemiologiczny*, 2003.

[11] F. Moges, S. Eshetie, M. Endris, K. Huruy, D. Muluye, T. Feleke, F. G/Silassie, G. Ayalew and R. Nagappan, "Cockroaches as a source of high bacterial pathogens with multidrug resistant strains in Gondar Town, Ethiopia," *BioMed Res. Int.*, vol. 2016, pp. 2825056, 2016.

[12] H.-H. Pai, W.-C. Chen and C.-F. Peng, "Isolation of bacteria with antibiotic resistance from household cockroaches (*Periplaneta americana* and *Blattella germanica*)," *Acta Tropica*, 2005.

[13] IAQ Consultants, "Indoor air quality resources," available at: www.iaqsg.com, accessed 2022.

[14] L. A. Nnamonu and A. Onekutu, "Green pesticides in Nigeria: An overview," *J. Biol. Agric. Healthcare*, vol. 5, pp. 48, 2015.

[15] L. M. L. Nollet and H. S. Rathore, *Green Pesticides Handbook*, CRC Press, USA, 2019.

[16] Malaysian Meteorological Department (MMD), "Climate data of Malaysia," *Ministry of Science, Technology and Innovation (MOSTI)*, available at: www.met.gov.my, accessed 2022.

[17] M. Fossen, "Environmental fate of imidacloprid," *Department of Pesticide Regulation*, 2006.

[18] M. E. Rueger and T. A. Olson, "Cockroaches (Blattaria) as vectors of food poisoning and food infection organisms," *J. Med. Entomol.*, 1969.

[19] M. F. Cotton, E. Wasserman, C. H. Pieper et al., "Invasive disease due to extended spectrum beta-lactamase-producing *Klebsiella pneumoniae* in a neonatal unit: the possible role of cockroaches," *J. Hosp. Infect.*, 2000.

[20] H. Müller-Mohnssen, "Chronic sequelae and irreversible injuries following acute pyrethroid intoxification," *Toxicol. Lett.*, vol. 107, pp. 161, 1999.

[21] National Pesticide Information Center, "Green pesticide myths," available at: http://npic.orst.edu/capro/greenmyths.html, accessed 2022.

[22] V. M. Pathak, V. K. Verma, B. S. Rawat et al., "Current status of pesticide effects on environment, human health and its eco-friendly management as bioremediation," *Sustainability*, vol. 13, pp. 962691, 2022.

[23] Raj et al., "Present status of insecticide impacts and eco-friendly approaches for remediation," *Sci. Total Environ.*, vol. 240, pp. 117432, 2024.

[24] S. Gawande, R. R. Tiwati, P. Narayanan and A. Bhadri, "Indoor air quality and sick building syndrome: Are green

buildings better than conventional buildings?" *Indian J. Occup. Environ. Med.*, vol. 24, pp. 30, 2020.

[25] S. Valles, "German cockroach, *Blattella germanica* (Linnaeus) (Insecta: Blattodea: Blattellidae)," *University of Florida Extension Publication*, 2021. Available at: https://edis.ifas.ufl.edu/publication/IN128.

[26] X. Valles, H. Kampen and K. Sweeney, "Public health significance of urban pests," *World Health Organization*, Geneva, Switzerland, 2008.

[27] Y.-H. Lee, H.-H. Kim, J.-I. Lee, J.-H. Lee, H. Kang and J.-Y. Lee, "Indoor contamination from pesticides used for outdoor insect control," *Sci. Total Environ.*, vol. 625, pp. 994, 2018.

[28] Y. M. Tatfenga, M. U. Usuanlele, A. Orukpe, A. K. Digban, M. Okodua, F. Oviasogie and A. A. Turay, "Mechanical transmission of pathogenic organisms," 2005.