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EVALUATION OF ESSENTIAL OILS OF LEMON (*Citrus limon*), LAVENDER (*Lavandula angustifolia*), AND PEPPERMINT (*Mentha piperita*) FOR THE CONTROL OF GERMAN COCKROACH, *Blattella germanica* IN LABORATORY BIOASSAY

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Abstract

The German cockroach, *Blattella germanica*, is a globally distributed household pest of medical importance. Control has traditionally relied on synthetic insecticides, but concerns over environmental safety, human health, and insecticide resistance have increased interest in botanical alternatives. This study evaluated the insecticidal efficacy of baking soda combined with sugar and essential oils from *Mentha piperita* (peppermint), *Citrus limon* (lemon), and *Lavandula angustifolia* (lavender) against adult *B. germanica* under laboratory conditions. Mortality and knockdown effects were recorded over 96 hours, and data were analyzed using SPSS version 27 at $P < 0.05$. Results showed that *M. piperita* oil was the most effective treatment, producing 100% mortality at 5 ml after 72 hours (LC_{50} = 3.273 ml). *L. angustifolia* and baking soda plus sugar each recorded 60% mortality at 10 ml after 96 hours (LC_{50} = 14.396 ml and 25.660 ml, respectively). Knockdown analysis indicated the fastest action for *M. piperita* (KT_{50} = 37 hours), while *L. angustifolia* and baking soda plus sugar recorded 96 hours. *Citrus limon* showed no mortality. Overall, *M. piperita* demonstrated the highest toxicity, suggesting strong potential for use in eco-friendly German cockroach management within integrated pest management systems.

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INTRODUCTION

The German cockroach, *Blattella germanica* Linnaeus (Order: Dictyoptera; Family: Blattellidae), is among the most widespread and economically important household pests worldwide (Yeom et al., 2018). Its close association with human habitations has made it a significant public health concern. Numerous studies have shown that cockroaches can harbor and mechanically transmit a wide range of pathogenic microorganisms, including bacteria, fungi, viruses, and parasitic organisms that may affect human health (Nasirian, 2017). As a result, infestations of German cockroaches pose serious sanitary and health challenges in residential, commercial, and institutional environments.

Apart from their role in disease transmission, German cockroaches are known to contribute to various allergic conditions. Their body fragments, cast skins, saliva, and fecal materials contain allergens capable of inducing allergic reactions in susceptible individuals. Exposure to these allergens has been associated with skin irritation, dermatitis, itching, swelling, and respiratory disorders, particularly asthma (Czajka et al., 2003). Previous studies have reported that cockroach allergens are important triggers of asthma attacks and other allergic diseases, especially among individuals living in heavily infested environments (Nalyanya et al., 2000). Furthermore, the frequent movement of cockroaches between contaminated sites and food preparation areas increases their potential to disseminate pathogenic organisms and contaminate food and household surfaces (Brenner et al., 2003; Donkor, 2020).

Blattella germanica is a small, light-brown cockroach measuring approximately 10–15 mm in length. The species is characterized by a high reproductive capacity, rapid development, and short generation time, which contribute to its success as a household pest. Female German cockroaches typically carry their egg cases until shortly before hatching, enhancing offspring survival. These biological characteristics enable populations to increase rapidly, making infestations difficult to manage effectively.

Control of German cockroaches has traditionally relied on the application of synthetic insecticides through sprays, baits, dusts, and other formulations. Although these products can provide effective control, their prolonged and indiscriminate use has raised concerns regarding environmental contamination, insecticide resistance, and potential adverse effects on humans and non-target organisms. Consequently, there is increasing interest in the development of safer and environmentally sustainable alternatives for cockroach management.

Botanical pesticides have emerged as promising alternatives to conventional chemical insecticides. Many plant species contain naturally occurring bioactive compounds that possess insecticidal, repellent, antifeedant, and growth-regulating properties (Hikal et al., 2017). These compounds can be obtained from different plant parts, including leaves, seeds, roots, flowers, fruits, stems, and bark, and formulated into products for pest control (Ahmad et al., 2017). Plant-derived pesticides are generally considered environmentally friendly because they are biodegradable and often exhibit lower toxicity to humans and other non-target organisms. The extraction and formulation of these bioactive compounds have attracted considerable attention in integrated pest management programmes worldwide (Joseph and Sujatha, 2012).

In view of the increasing need for eco-friendly pest control strategies, this study evaluated the insecticidal efficacy of selected botanical products and household materials, namely peppermint oil (*Mentha piperita*), lavender oil (*Lavandula angustifolia*), citrus extract (*Citrus limon*), and baking soda, against adult German cockroaches under laboratory conditions.

The specific objectives of the study were to identify, collect, culture, and maintain a laboratory population of *Blattella germanica* for experimental purposes. Evaluate the insecticidal activity of peppermint oil, lavender oil, citrus extract, and baking soda against adult German cockroaches and determine the most effective treatment and concentration for the control of *Blattella germanica* under laboratory conditions.

MATERIALS AND METHOD

Experimental study area

The laboratory evaluation study was conducted in the Entomology Unit laboratory (Botanical and Zoological Garden) of the Zoology Department, University of Lagos, Nigeria, with coordinates 6031´0´´N 3023´10´´E / 6.516670N 3.386110 E. The experimental set up was carried out under ambient temperature of 27 ± 2^{o}C and 70 ± 5% relative humidity.

Test chemicals

Essential oils of peppermint (*Mentha piperita* L.), citrus (*Citrus limon* L.), lavender (*Lavandula angustifolia* Mill.) and mixture of baking soda and sugar were purchased from Bariga market, Lagos state, Nigeria. These natural products were identified and deposited at the Department of Zoology (Entomology Unit), University of Lagos. The choice of diluents was distilled water in order to achieve stock solution of the test chemicals. These natural products were tested via toxicity and repellent (activity) bioassays.

Test insects

Adults of the German cockroach were collected from students' cupboards in various Male and Female Halls of Residence, within the University, Akoka campus to set up a mass culture. *B. germanica* colonies were kept in plastic containers, covered by a fine mesh (muslin) cloth for ventilation and stripped with rubber band to keep the insects in place. The plastic containers were further smeared with petroleum jelly to prevent the cockroach from moving out of the container. The containers were regularly cleaned and insect frass and faeces removed. The petroleum jelly at the edge of the container was also renewed to prevent escape of the roaches upon opening. Cleaning was done using wet foam rubbed round the containers and the dirt's packed out with a piece of serviette paper.

Culture of the *B. germanica* colonies was maintained in the laboratory at the Botanical and Zoological Garden, University of Lagos, where all bioassays were also carried out. While the culture lasted, the roaches were fed thrice a week with crumbs of bread and/or biscuits placed in the plastic container and also provided with water fitted with cotton stoppers. The plastic container was provided with paper egg cartons as shelter. The adult cockroaches (*B. germanica* colonies) were maintained in a growth chamber and tested for all bioassays at 27 ± 2°C, 60 – 70% RH (relative humidity). For the laboratory bioassays, adult's male and female were used, since males and females of *B. germanica* showed different susceptibility ratio.

Experimental procedures on contact toxicity bioassay

Contact toxicity test were used to evaluate insecticidal activity. The choice of diluents was 1ml of distilled water and 5ml of methylated spirit, respectively in order to achieve stock solution of the test chemical concentrations. To evaluate the contact toxicity effects of the natural products against adult males of *B. germanica*, the products were directly applied on filter papers (8.5×7.5 cm) at equal concentration for the different EOs (peppermint oil, citrus oil, lavender oil) and baking soda + sugar mixture. The filter papers were treated with various concentrations – 0.5, 10, and 15 mL/cm^{3}of the natural products. For control, the filter paper was treated with solvent alone without EOs (test chemicals) addition. The filter papers were air dried for an hour in order to evaporate the solvent completely and then were introduced with a picker inside petri dish. Five (5) German cockroaches were added each into the petri dish samples and covered with a fine mesh cloth for ventilation. Insect mortality and response was determined after 24 h, 48 h, 72 h and 96 h exposure (treatment) to test chemicals. All experiments were repeated and performed in triplicate. Each test was replicated 3 times and five (5) adult German cockroaches were used for each replicate.

In quantal response, mortality was defined as inability to move when placed on the dorsal side and inability to respond to prodding. Mortality readings were taken for cockroaches when no part of the body or limb movement was observed upon pricking with a camel hair brush and waiting for ten minutes for any movement to occur. When no legs and abdominal movements were observed, insects were considered dead. Number of dead *B. germanica* was counted and recorded. Responses of the cockroaches to the various experimental set up were written down and the parameters used in taking records are the knock down time and the rate of mortality per hours.

Statistical analysis

All analyses were performed using SPSS v27 statistical software package. The percentage of mortality was determined and transformed to arcsine square-root values for analysis of variance (ANOVA). Data were analyzed using the general linear models procedure, and mean comparisons were made using the least significant difference (LSD) test ($P \leq 0.01$) (SAS Institute Inc., 1989). Concentration-mortality data, corrected according to Abbott's formula (Abbott 1925), were recorded after 24 h, 48 h, 72 h and 96 h exposure (treatment) to test chemicals, and were then subjected to standard probit analysis using POLO-PC statistics software (LeOra 1987) to estimate LC_{50} and KT_{50}, and the slope of the regression line for each treatment were obtained using probit analysis. The knockdown and mortality data were statistically analyzed using one-way ANOVA and the data means were compared by Duncan's multiple range test. Statistical significance was set at $p<0.05$. Lethal Concentration 50% (LC_{50}) and 95% confidence intervals were estimated. The LC values were considered significantly different if their 95% confidence intervals did not overlap.

RESULTS

Mortality of *Blattella germanica* After 96 Hours of Exposure

The mortality of *Blattella germanica* varied among the treatments after 96 hours of exposure. *Mentha piperita* (peppermint oil) was the most effective treatment, causing 100% mortality. *Lavandula angustifolia* (lavender oil) and baking soda plus sugar each recorded 60% mortality, whereas *Citrus limon* produced no mortality throughout the experimental period.

Based on the toxicity index values obtained, the treatments were ranked in the following order of effectiveness:

Mentha piperita (3.273) > *Lavandula angustifolia* (14.396) > Baking soda + sugar (25.660).

The differences among treatments were statistically significant ($P < 0.05$) (Table 4).

Knockdown Effect on *Blattella germanica*

The knockdown response of *B. germanica* differed among the treatments. *Mentha piperita* exhibited the fastest knockdown effect, with a KT_{50} value of 37 hours (Figure 1). In contrast, *Lavandula angustifolia* and baking soda plus sugar showed slower knockdown activity, each recording a KT_{50} value of 96 hours (Figures 2 and 3).

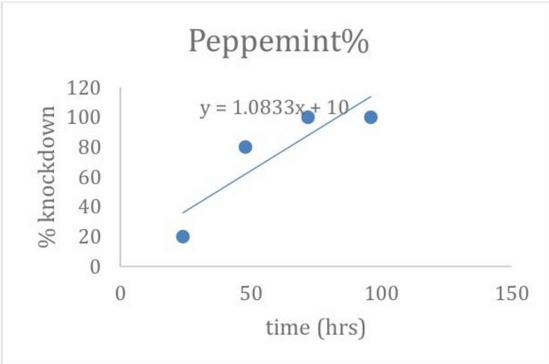

Figure 1: KT_{50} = Knockdown time = 37 hrs

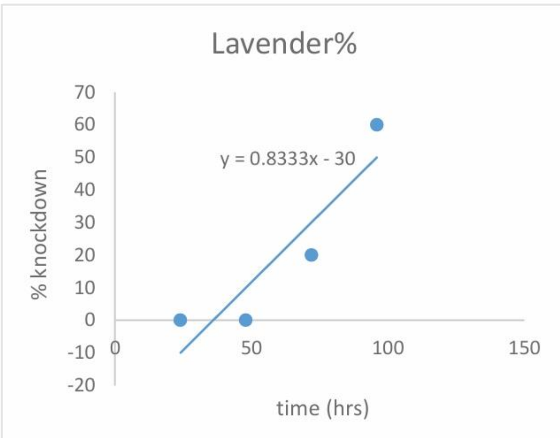

Figure 2: KT_{50} = Knockdown time = 96 hrs

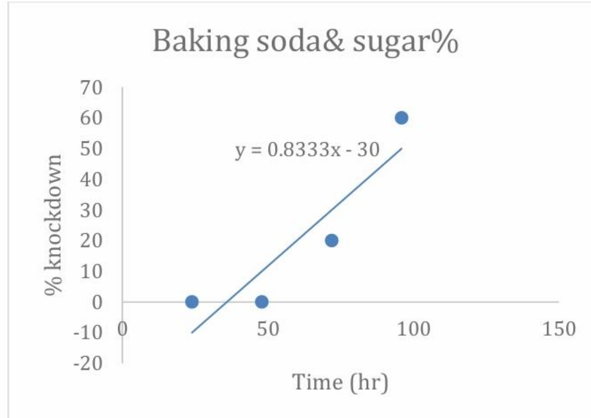

Figure 3: KT_{50} = Knockdown time = 96 hr

Table 1: Relative toxicity of Lavender, Peppermint and Baking soda + sugar on *B. germanica* after 96 hours

Treatment	LC_{50} (95% C.L) ml/L	LC95 (95% C.L) ml/L	Slope ± SE	DF	Probit line of equation	TF	Toxicity ranking
Lavender oil	14.396 (12.573 - 17.475)	19.592 (16.614 - 48.867)	12.289 ± 4.558	1	y = 12.289 x - 14.233	1.78	2
Peppermint oil	3.273 (2.532 - 6.152)	7.292 (6.168 - 25.906)	4.727 ± 3.049	1	y = 4.727 x - 2.434	7.84	1
Baking soda + sugar	25.660 (13.496 - 1813.676)	97.575 (23.705 - 97973226.84)	2.836 ± 1.700	1	y = 2.836 x - 3.996	1	3

LT_{50} = 50% lethal time are significantly different ($P<0.05$) (one-way ANOVA and Duncan's multiple range test). *LC = Lethal concentration *CL = Confidence limit *TF = Toxicity factor

$$TF = \frac{LC50\ Value\ of\ bakind\ soda}{LC50(\ value\ of\ lavender),\ \ (peppermint\ )after\ 96hrs)}$$

DISCUSSION

The results of this study demonstrated that both the plant extracts and commercially available botanical products exhibited varying levels of insecticidal activity against the German cockroach, Blattella germanica. Mortality increased with increasing concentration and exposure period, indicating a dose-dependent and time-dependent effect of the tested botanicals. Among all the treatments evaluated, Mentha piperita (peppermint oil) showed the highest efficacy, achieving 100% mortality at a concentration of 5 ml after 72 hours of exposure. In contrast, Lavandula angustifolia and baking soda produced moderate effects, each recording 60% mortality at 10 ml after 96 hours. No mortality was observed in the treatment involving Citrus limon, suggesting that under the conditions of this study, it had little or no toxic effect on *B. germanica.*

The high mortality recorded for *M. piperita* is consistent with findings from previous studies that have reported the insecticidal potential of peppermint essential oil against various insect pests. Phillips and Appel (2010) reported that menthone, a major constituent of peppermint oil, exhibited significant toxicity against German cockroach nymphs through fumigation. Similarly, topical application studies demonstrated that menthone was highly toxic to adult male and female German cockroaches. These findings support the effectiveness of peppermint oil observed in the present study.

Other researchers have also documented the insecticidal properties of *M. piperita* against a wide range of insect species. Sinthusiri and Soonwera (2013) reported rapid knockdown and high mortality rates of peppermint oil against adult houseflies (*Musca domestica*). Likewise, Hanan (2013) found that peppermint essential oil was highly toxic to housefly larvae, while Manimaran et al. (2012) observed strong knockdown effects against mosquito species including *Culex quinquefasciatus*, Aedes aegypti, and *Anopheles stephensi*. The agreement between these studies and the present findings suggests that peppermint oil possesses broad-spectrum insecticidal activity.

The observed toxicity of *M. piperita* may be attributed to its rich phytochemical composition. Peppermint oil contains biologically active compounds such as menthol, menthone, isomenthone, and limonene, which have been reported to possess antimicrobial, antifungal, and insecticidal properties. These compounds may interfere with the nervous system of insects, resulting in paralysis, reduced mobility, feeding inhibition, and eventual death.

The increasing interest in plant-derived insecticides is largely due to concerns associated with the continuous use of synthetic pesticides, including environmental contamination, pest resistance, and potential risks to human health. Unlike many conventional insecticides that rely on a single active ingredient, botanical pesticides often contain multiple bioactive compounds that can affect insects through different modes of action. This characteristic may reduce the likelihood of resistance development while providing effective pest control.

German cockroaches are important public health pests because they contaminate food, household materials, and living environments. Through their feeding and movement, they can mechanically transmit disease-causing microorganisms and trigger allergic reactions in sensitive individuals. Therefore, the development of environmentally friendly and effective control measures such as botanical insecticides could contribute significantly to improved urban pest management.

CONCLUSION

The findings of this study demonstrate that botanical products can serve as effective alternatives to conventional insecticides for the management of German cockroaches. Among the tested treatments, Mentha piperita exhibited the highest insecticidal activity, producing complete mortality within the exposure period evaluated. The effectiveness of peppermint oil may be linked to its bioactive constituents, which are known to possess insecticidal properties.

The results highlight the potential of plant-based products as environmentally friendly pest management tools due to their biodegradability, diverse modes of action, and relatively low toxicity to humans and non-target organisms. Further studies should focus on the isolation, characterization, and formulation of the active compounds responsible for the observed insecticidal activity. Such investigations could facilitate the development of safe, effective, and commercially viable botanical insecticides for the control of German cockroaches and other household pests.

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