



Formulation and Evaluation of the Repellent Activity of an Herbal Gel Bait against the German Cockroach (*Blattella germanica* L.) in Pune, Maharashtra”

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Abstract: The formulation developed incorporating bioactive ingredient eugenol (10%, 15%, and 18%), Caffeine (5%, 7.5 %, and 10%) and naphthalene as a standard, was evaluated for repellent activity against the German cockroach *Blattella germanica* (L.) which is the most common kitchen nocturnal pest insect. The repellent activity of gel formulation was tasted under laboratory conditions. Three formulations of gel bait F1, F2 and F3 developed containing various proportions of eugenol and caffeine. In this formulation of gel complimentary additives that enhance its efficacy used were Carbopol 940, starch, HPMC, propylene glycol, glycerine, sucrose, and gelatine etc. The formulation F3 containing highest concentration of eugenol showed the best repellence than F1 and F2 formulation and naphthalene. F1 Formulation is less effective than F2 and F3 Formulation as it shows low mortality rate for increased exposure of time. Similar F2 Formulation is more effective than F1 Formulation but less effective than F3 formulation when the mortality rate of cockroach was compared. The F3 gel formulation exhibited repellence (92%) against *B. germanica*, and F3 formulation was further used for tasting the repellent activity in laboratory and residential areas in Pune district of Maharashtra state for *B. germanica*. The gel performance is examined by placing the cockroach in the favourable environment and also tracking the duration required for the deterrence. After examined the gel performance, it indicates that the gel gives the significant results as repellent. F3 formulation in laboratory and local residential area was found to be promising. Further improvements in efficacy and residual activity of F3 formulation may be realized with appropriate formulations.

Keywords: formulation, development, household cockroach, *Blattella germanica*, herbal gel, repellent activity, eugenol, caffeine

Introduction

Of the 4000 species of cockroach known to exist, approximately 30 species co-exist in human habitat and approximately 16 species are associated with human health problems [1]. Since cockroaches are important pests of households, granaries, godowns, eating houses etc. and they are widely distributed throughout the world, it is most necessary to control them. The most useful method of their control is by use of insecticide. The insecticides which can be used to control roaches may be either contact powder or liquids or they may be in the gaseous form.

These are some of the species those are found in human habitat; their saliva and faeces are significant source of allergens and pathogens of diarrhoea, typhoid fever, mental distress and various other health related problems those are particularly observed among children and old people.



To kill them by using synthetic insecticides will be harmful to nature and poisonous to man and pet animals. The insecticidal properties of number of plants have been discovered long ago. Botanical plant extracts are environmentally less harmful than synthetic pesticides to control pests. They possess one or more useful properties such as biodegradability, broad spectrum of activity & ability to reduce insect resistance. Synergistic effect due to mixing of different plant species plays a key role to control pests. High cost of chemical insecticide leads to search alternative source for pest management.

Synthetically prepared insecticides, pesticides remain the primary method of cockroach control; but due to cockroach resistant nature to this it has become the serious challenge for pest management strategies. Gels have been a preferred alternative demonstrating better efficacy where synthetic insecticides and pesticides have failed. The effectiveness of this gel depend on multiple factor including active ingredients that is used to attract and kill the cockroach , various excipients to make the gel stable and formulation design.

In the recent years, plant based herbal repellents have gain attention as they are promising substitute to synthetic insecticides and pesticides. Herbal repellent are considered as eco friendly products with minimum side effects on human, animal, environment as compared to synthetic products [2]. These have unpleasant odour or can cause adverse effect such as skin irritation, allergies, asthma problem, etc. natural repellent offers a safer mode of pest deterrence. Eugenol has been proven to control roaches by blocking the octopamine receptor binding sites, breaking down waxy coatings, and fast absorption. It also has antimicrobial and antioxidant activities, making it a powerful insecticide. Eugenol, isoeugenol, and methyleugenol showed similar contact toxicity to *Sitophilus zeamais* (LD 50 values approximately 30 µg/mg insect) [3-4].

The toxic and repellent properties of nine major constituents of essential oils, comprising benzene derivatives and terpenes, were evaluated against *Periplaneta americana* (L.) [5].

The toxicity of 12 essential oil components [carvacrol, 1,8-cineole, trans-cinnamaldehyde, citronellic acid, eugenol, geraniol, S-(-)-limonene, (-)-linalool, (-)-menthone, (+)-alpha-pinene, (-)-beta-pinene, and thymol] to adult male; adult female; gravid female; and large, medium, and small nymphs of the German cockroach [6].

Neupane, et al., (2020) studied the repellancy and contact toxicity of clove bud oil and its constituents against German cockroaches, *Blattella germanica* [7-9]

Therefore, objective of this study is to control cockroaches by using biorational control methods. Hence laboratory assays were carried out to evaluate the repellent property of plant extracts of four indigenous native botanicals namely eugenol, caffeine, and carbopol against cockroach. The natural ant repellent plays an important role in earth's natural ecosystem. Therefore objective of present work is:

- To eliminate toxic effects occurring due to repeated use of synthetic chemical insecticides.
- Use of natural herbal plant extracts for control of cockroaches.
- To develop new rationale & eco-friendly process to control the cockroaches by using herbal plant extracts.

The present study was initiated to study the repellent activity of formulated herbal gel F1, F2 and F3 containing eugenol and caffeine, against German cockroach which is predominant in kitchens and grocery under laboratory conditions. The most promising F3 formulation was then further evaluated for repellency against cockroaches in the field. This study aims to evaluate the attractiveness and repellent efficacy of herbal based formulation against cockroach species. The formulation three experimental F1, F2 & F3 gel consists of the following ingredients (Fig.1):-

1. Caffeine :-

In cockroach it affects on the nervous system; it causes overstimulation of nerve cell that can disrupt normal behaviour that leads to hyperactivity and eventually paralysis or death at higher dose. Caffeine disrupts the normal movement and feeding behaviour. It acts as a toxicant or irritant.

2. Eugenol :-

The name is derived from *Eugenia caryophyllata*, the former Linnean nomenclature term for cloves. The currently accepted name is *Syzygium aromaticum*. It also targets the cockroach nervous system, disrupts the octopamine receptor, increases cell membrane permeability and inhibits key enzymes, that leads to paralysis and digestive failure which leads to death.



Fig.1. Ingredients of herbal bait gel.

3. Carbopol 940 :-

It helps to extend repellence duration against cockroach by prolonging bioavailability. Utilized in pharmaceutical products as rheology modifiers, tablet binders, suspension stabilizers, extended release polymers, muco-adhesive aids, and bioavailability enhancers, Carbopol helps in suppressing survival and oviposition in adult cockroach and also suppresses the egg hatch rate.

4. Sucrose:-

It acts as phagostimulant that helps in attractiveness and helps in making the gel palatable to cockroach. It helps to promote feeding activity and acceptance of gel by cockroach.

5. Starch

It is used as a recipient, widely used in pharmaceutical industries due to its ability to absorb water and swell and further helps in forming gel like consistency.

Material & Methods:-

Identification and Collection of the Species

The German cockroach (*Blattella germanica* [Linnaeus]) was identified based on its characteristic morphological features. Adult cockroaches are typically light brown to tan in colour, with two distinct, parallel dark stripes on the pronotum behind the head. Adults generally measure approximately $\frac{1}{2}$ – $\frac{5}{8}$ inch (13–16 mm) in length and possess an oval, dorsoventrally flattened body. Both males and females have well-developed wings that extend over most or all of the abdomen, although they rarely fly and primarily move by running. They also possess long, thread-like antennae, which are characteristic of cockroaches. These morphological characteristics were used as reference criteria for species identification before collection and subsequent evaluation of the repellent gel bait [10-12].

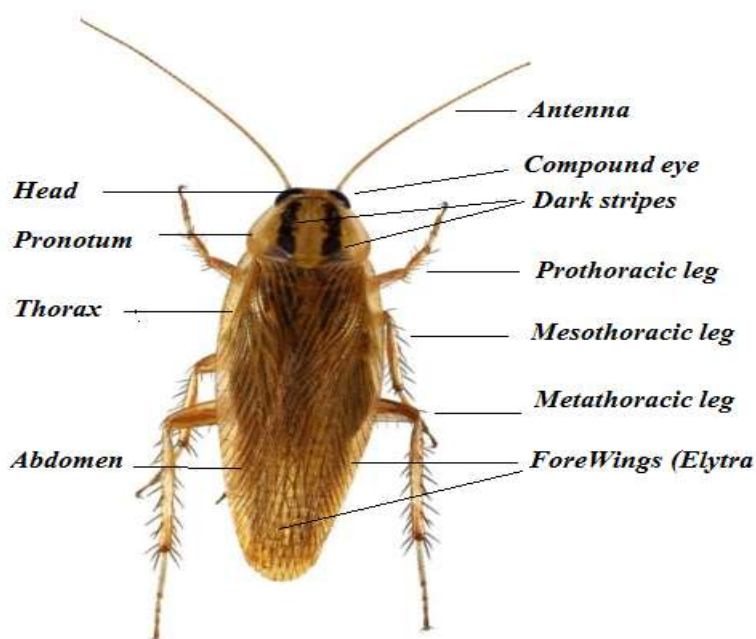


Fig.2. German cockroach (*Blattella germanica* L.)

Maintenance of Cockroaches

Cockroaches were collected from plagued locations, especially from drainage chambers and dark, humid areas where cockroach activity was notable. The collected cockroaches were instantly reassigned into a clean, ventilated plastic box of 1lit. capacity. Four containers were used for storage.

Thin layer of petroleum jelly was applied on the inner top lining of boxes and securely closed with perforated lid for ventilation and avoid chance of evasion. The control units were properly maintained at room temperature with appropriate aeration and cleanliness without gel bait. Cockroaches were habituated to this environment preceding experimental procedures.

The cockroaches were kept in the plastic box at a room temperature and relative humidity to 40 % - 50%. They were reared by feeding them with sucrose and starch. The adult male and female cockroaches selected for repellent test were healthy [13-15].

2. Preparation of Herbal Cockroach Repellent Gel (Formulation F3)

The weighed quantity of Carbopol 940 was taken first and then dissolved properly in a small portion of water with continuous stirring. Water was added in a systematic manner to confirm complete swelling of Carbopol and also prevents the lump formation. Synchronously, another mixture was formulated by solubilising sucrose, caffeine and starch in warm water upon warming with continuous stirring. Further gelatine was incorporated into a warm solution and mixed uniformly to get an identical solution. Both the Carbopol base and gelatine based phases, were combined with uniform mixing to form undifferentiated gel base. Simultaneously, eugenol was poured slowly into the gel matrix to ensure homogeneous distribution into the formulation (Fig.3).

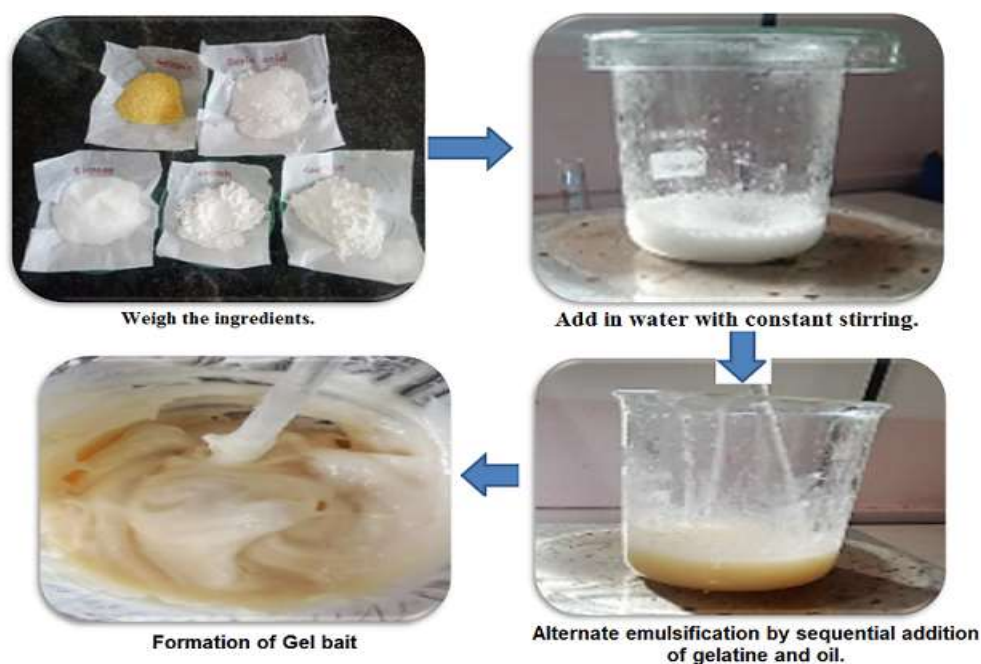


Fig.3. Diagrammatic presentation of preparation of herbal gel.

Thereafter, glycerine and propylene glycol were added as humectants and preservative, respectively, and the mixture was agitated to obtain homogeneous gel. At the end, the viscosity and stability of the gel was improved by adding the remaining portion of starch under continuous stirring[16-18]. The formulated gel was set aside to cool at room temperature and then assessed for its physical characteristics. Three F1, F2 and F3 gel were formulated with various ingredients in different proportion as shown in table no. 1.

Table1. Formulation and ingredients in repellent gel (Fig.6 and Fig. 7)

Sr. No.	Ingredients	F1 formulation		F2 Formulation		F3 Formulation	
		Amount	%w/w	Amount	%w/w	Amount	%w/w
1	Eugenol	2ml	10.00%	3ml	15.00%	3.6ml	18.00%
2	Caffeine	1gm	5.00%	1.5 gm	7.50%	2gm	10%

3	Sucrose	1.5gm	7.50%	1.5gm	7.50%	1.5gm	7.50%
4	Gelatin	1.5gm	7.50%	1.5gm	7.50%	1.5gm	7.50%
5	HPMC	0.45gm	2.25%	0.45gm	2.25%	0.45gm	2.25%
6	Starch	1.5gm	7.50%	2gm	10.00%	2gm	10.00%
7	Glycerine	1ml	5.00%	1ml	5.00%	1ml	5.00%
8	Propylene glycol	0.00ml	0.00%	2ml	10.00%	0.6ml	3.00%
9	Carbopol 940	1gm	5.00%	2gm	10.00%	1.65gm	8.25%
10	Water	15ml	75.00%	15ml	75.00%	15ml	75.00%

3. Application and Evaluation of Repellent Gel

Plywood, wooden chamber, six boxes of size 45x45x45cm were constructed as shown in figure4, the top with wire screen and front side with 10cm hole having cotton sleeve were made available from local carpenter. These boxes were used for repellent tests, standard and control tests. All four side walls of the boxes were smeared with Vaseline to avoid the escape of cockroaches. In experimental boxes the herbal gel bait was applied by placing spots of approximately 0.5cm size at the five places, four corners and one spot in the center at the bottom of five boxes. Same size box were used for control where water and food were placed in a container at the floor in box. For standard tests Napthalene pieces of 1gm each were placed on the floor of box at five places one in centre and four on the corners. In each set of box food like bread pieces and water in small container for the cockroaches were placed. 10 males and 10 female adult cockroaches those were anesthetised with CO₂ were released in experimental, standard and control test boxes. The cockroaches released in experimental, standard and control set of boxes were carefully observed for any behavioural changes like locomotion, lay down on dorsal side and death. First effectiveness of F₁, F₂, and F₃ formulation were tested. After observing the effectiveness of the F₃ formulation, the latter were selected for repellent activity. The effectiveness of gel was analyzed for a period of every 3 hours after post application. The cockroaches dead were counted at every 3, 6, 12 hours, and there after record was maintained at every 12 hours. The experiment was replicated five times, each replica consisting of 20 (ten male and ten female) cockroaches [19-21].



Fig.4. Wooden chamber 45 x 45 x 45 cm size used for testing the repellent activity.



Fig.5. Application & study of repellent activity & mortality.

Results and Discussions:

Preliminary phytochemical screening

The preliminary phytochemical screening of clove oil and caffeine was performed to identify the presence or absence of selected phytochemical constituents. As presented in Table 2, both clove oil and caffeine showed positive results for alkaloids. Tannins were detected in clove oil but were absent in caffeine. However, both ingredients showed negative results for flavonoids, saponins, carbohydrates, and proteins. These findings indicate that alkaloids were detected in both ingredients, whereas tannins were detected only in clove oil under the test conditions. The results provide preliminary information regarding the chemical characteristics of the active ingredients selected for the formulation of the repellent gel bait.

Table2. Phytochemical properties of repellent gel ingredients.

Sr. No.	Phytochemical Tests	Clove oil	Caffeine
1	Flavonoids	-	-
2	Saponins	-	-
3	Alkaloids	+	+
4	Carbohydrates	-	-
5	Proteins	-	-
6	Tannins	+	-

The formulated repellent gel bait (F3) was evaluated for its physical appearance and selected physicochemical properties. As shown in Table 3, the optimized formulation exhibited a cream colour, smooth appearance, and characteristic spicy, clove-like odour. The viscosity was found to be 682.5 centipoises (cP), indicating the semisolid consistency of the gel formulation. The formulation showed no phase separation, suggesting acceptable physical homogeneity during the evaluation. The reported pH range was 5.5–7.5, which represents the specified range; however, the actual measured pH should be reported if a single experimental value was obtained. The formulation was also reported to be non-irritant under the conditions of the irritation test. Overall, the observed physical and physicochemical characteristics indicate that formulation F3 possessed satisfactory preliminary properties for further investigation of its repellent efficacy against German cockroaches (*Blattella germanica*).

Table3. Evaluation properties of ingredients of repellent bait

Evaluation Parameter (F3)	Result
Colour	Cream colour
Appearance	Smooth
Odour	Spicy & clove like odour
Viscosity	682.5 centipoises
Consistency	No phase separation
pH	5.5-7.5
Irritability	Non-irritant

Evaluation of Repellent Activity

The repellent activity of the three formulations (F1, F2, and F3) was evaluated against German cockroaches (*Blattella germanica*) at different observation intervals, ranging from 3 to 48 hours, with a control and standard included for comparison. As presented in Table 3, the control group showed zero repellent activity throughout the observation period. Among the tested formulations, F3 exhibited the highest initial repellent activity, with a recorded value of 98 at 3 hours, followed by 92 at 6 hours, 84 at 9 hours, 74 at 12 hours, 46 at 24 hours, 36 at 36 hours, and 20 at 48 hours. Formulation F2 showed values of 80, 74, 62, 50, 36, 30, and 14 at the corresponding observation intervals, whereas F1 showed values of 70, 64, 48, 40, 30, 18, and 10, respectively. These results indicate a gradual decline in repellent activity over time for all three formulations, with F3 maintaining the highest activity among the tested formulations throughout the observation period. The standard showed values of 92, 87, 80, 64, 50, 30, and 18 at the corresponding intervals. Thus, F3 demonstrated the most promising and sustained repellent performance among the formulated gel baits, with an initial response comparable to or higher than the standard. All tested formulations were reported to exhibit lethal activity; however, the mortality results should be quantified separately to distinguish repellency from insecticidal effects.

Table 3. Evaluation of Repellent activity in three formulations.

Parameter	Control	Test			Standard
Number of cockroaches	100	100	100	100	100
Observation time (hrs)		F1	F2	F3	
3	0	70	80	98	92
6	0	64	74	92	87
9	0	48	62	84	80

12	0	40	50	74	64
24	0	30	36	46	50
36	0	18	30	36	30
48	0	10	14	20	18
Lethal Activity	No	Yes	Yes	Yes	Yes

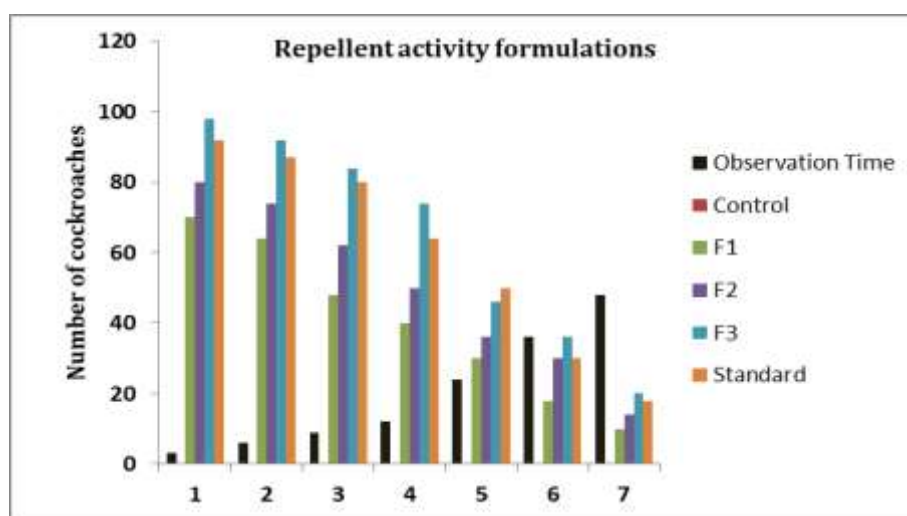


Fig. 6 Repellent activity in three formulations

The F3 formulation was further used for tasting the repellent activity in laboratory for *B. germanica*.

Statistical Evaluation of Cockroach Repellent Activity under Laboratory Conditions

The repellent activity of the optimized F3 gel formulation was evaluated under laboratory conditions using five experimental boxes at different observation intervals ranging from 3 to 48 hours. As shown in Table 4, the mean percentage repellency was 91.8% at 3 hours, indicating a strong initial repellent effect. The mean repellency subsequently decreased to 86.2% at 6 hours, 70.8% at 9 hours, and 60.0% at 12 hours. At 24 hours, the average repellency was 53.2%, which further decreased to 47.0% at 36 hours and 42.4% at 48 hours. These findings indicate a time-dependent decline in the repellent activity of the F3 formulation. Despite this reduction, the formulation maintained measurable repellent activity throughout the 48-hour observation period. The differences observed among the five experimental boxes may reflect variability in experimental conditions or cockroach responses. Overall, the laboratory results suggest that the F3 gel formulation exhibited promising initial repellency and retained activity over the observation period.

Table 4. Evaluation of Cockroach Repellent Activity under Laboratory Conditions

Time in hours	Box 1	Box 2	Box 3	Box 4	Box 5	Average % repellence
3	95	93	90	89	92	91.8
6	88	90	85	82	86	86.2

9	73	71	70	68	72	70.8
12	60	59	61	58	62	60.0
24	55	53	51	49	58	53.2
36	50	48	45	45	47	47
48	45	42	40	42	43	42.4

Evaluation of Cockroach Repellent Activity in Residential Environments

The repellent activity of the F3 gel formulation was further evaluated in five residential locations: Wagholi, Lonikand, Kharadi, Thergaon, and Viman Nagar. As presented in Table 5, the average percentage repellency was 89.4% at 3 hours and 84.6% at 6 hours. The mean repellency decreased to 70.8% at 9 hours and 60.0% at 12 hours. At 24 hours, the average repellency was 51.8%, followed by 44.6% at 36 hours and 40.6% at 48 hours. These results demonstrate a progressive decline in repellent activity with increasing observation time under residential conditions. The reduction may be associated with the gradual loss or dissipation of volatile repellent constituents, although this mechanism would require further investigation. Variations among the five locations may also be attributable to differences in environmental conditions, infestation levels, and application circumstances. Overall, the F3 formulation demonstrated promising initial repellency in residential environments, with measurable activity persisting up to 48 hours. The similarity between the laboratory and residential findings supports further investigation of the formulation under practical household conditions. It was observed in five different locations that as the duration of exposure time in respect to weeks increased the %mortality rate was found to be decreased.

Table 5. Repellent activity of bait in residential environment in hours.

Time in hours	Wagholi	Lonikand	Kharadi	Thergaon	Viman nagar	Average % repellence
3	92	85	92	90	88	89.4
6	85	87	89	82	80	84.6
9	73	71	70	68	72	70.8
12	64	62	59	55	60	60.0
24	53	55	51	49	51	51.8
36	49	45	40	42	47	44.6
48	45	42	35	38	43	40.6

Discussion:

It was observed that F1 Formulation is less effective than F2 and F3 Formulation as it shows low mortality rate for increased exposure of time. Similar F2 Formulation is more effective than F1 Formulation but less effective than F3 formulation when the mortality rate of cockroach was compared. F3 Formulation is more effective than both the F1 and F2 Formulation as the concentration of eugenol is more here in formulation leading to paralysis



of cockroach and results in death Fig.5. Here mortality decreases with decrease in exposure time Anu Jagajith A (2026) formulated spray which has successfully repelled cockroaches, with higher concentrations of essential oils demonstrating greater efficacy. The toxic and repellent properties of nine major constituents of essential oils, comprising benzene derivatives and terpenes, were evaluated by Ngoh et.al., (1998) against *Periplaneta americana* (L.). They reported decreasing order of knockdown activity via contact was methyl-eugenol>isosafole=eugenol>safrole. The killing effect via contact was in the order eugenol=methyl-eugenol=isosafole>safrole. Fumigant toxicity was only observed for safrole and isosafole, with safrole being the more potent. Isoeugenol and the tested terpenes had neither contact nor fumigant toxic effect. The decreasing order of repellency to nymphs was safrole>isosafole>methyl-eugenol=α-pinene>eugenol>isoeugenol. Philips et.al., 2010 tested the toxicity of 12 essential oil components [carvacrol, 1,8-cineole, trans-cinnamaldehyde, citronellic acid, eugenol, geraniol, S-(-)-limonene, (-)-linalool, (-)-menthone, (+)-alpha-pinene, (-)-beta-pinene, and thymol] on nymphs, adult male, female and gravid female German cockroach, *Blattella germanica* (L.) They found that Thymol was the most toxic essential oil component to adult males, gravid females, and medium nymphs, with LD50 values of 0.07, 0.12, and 0.06 mg per cockroach, respectively, trans-Cinnamaldehyde was the most toxic essential oil component to adult females, large nymphs, and small nymphs, with LD50 values of 0.19, 0.12, and 0.04 mg per cockroach, respectively. (+)-alpha-Pinene was the least toxic essential oil component to all stages of the German cockroach. Neupane et al, 2020 under laboratory conditions study on German cockroach indicated that when the clove bud powder applied at 30 mg/cm² killed 92% at 6 hours after treatment (HAT). Similarly, clove bud oil, eugenol and eugenol acetate applied at 4.00 ml/cm² provided 95%, 85%, and 87% German cockroach mortality at 24, 6, and 24 HAT, respectively. When applied at 2.0 ml/cm², clove bud oil repelled 80% of German cockroaches within 30 min. In contrast, eugenol and eugenol acetate repelled 85% at 1.0 ml/cm² and 2.5 ml/cm², respectively, at 0.5 HAT. Our results also indicate and support to the findings of Nupane et al., (2020) that eugenol when applied in gel format in higher concentration, F3 formulation in laboratory and environmental conditions showed highest repellent activity and mortality. Both vary according to duration and concentration of eugenol and caffeine. The average repellence activity reported for first three hours was found to be highest, it was 91.8 % and 89.4% for laboratory conditions and in residential environment, respectively. Future research should focus on isolating and characterizing its active compound on multiple cockroach species to promise its effectiveness further.

Conclusion :

From the result evoked in this project it can be concluded that, the mortality rate and repellent activity of F3 formulation was highest. The conducted study effectively formulated and evaluated herbal repellent gel for roaches, which were added with plant based active constituent with identify repellent activity. F3 formulation was effective due to synergistic effect of both caffeine and eugenol.

The F3 formulation was suggested that it represent optimistic, nature friendly alternative to standard chemically derived insecticides. Further study involving long term stability, toxicity profiling to ensure its commercial use. The prepared formulation being herbal is cheap, eco-friendly, odourless, Hassel free and kitchen safe.

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