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Lipid Accumulation Staining

Eco-Friendly Pest Balls from Waste Cooking Oil and Herbal Plant Residues as a Substitute for Naphthalene

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ABSTRACT

Naphthalene, a polycyclic aromatic hydrocarbon used extensively in mothballs, poses well-documented risks to human health and the environment due to its toxicity, persistence, and capacity for bioaccumulation. Concurrently, increasing volumes of household waste, particularly used cooking oil and discarded herbal plant residues which contribute to escalating environmental burdens. This study integrates waste valorisation and green chemistry principles to develop biodegradable pest-repellent balls as an eco-friendly alternative to naphthalene products. Waste cooking oil underwent pretreatment, and herbal residues were processed into fine powders for incorporation into pest ball formulations. The optimal base composition was determined to be a mixing with glycerin-to-sodium hydroxide ratio of 2:1. One-way ANOVA revealed significant differences ($p < 0.05$) in percentage repellency (%RI), with performance ranked as cinnamon > clove > lemongrass > lemon > orange. Monthly longevity followed the order orange > clove > lemon > lemongrass > cinnamon, suggesting greater biodegradability for cinnamon-based formulations. Although the initial cost of the alternative pest ball may be slightly higher than the of commercial mothballs, the potential of converting household waste into effective, biodegradable pest control solutions makes it a more cost-effective and sustainable solution, offering greater value for health, safety, and the environment. These findings simultaneously address toxic chemical exposure and waste management challenges.

INTRODUCTION

Naphthalene is naturally occurring in crude oil and coal tar and was first discovered by Alexander Garden, a Scottish scientist [1, 2]. It is also referred to as tar camphor, naphthalin, moth flakes, and mothballs. It is an aromatic, lipophilic hydrocarbon, and the primary ingredient in mothballs. It is a polycyclic aromatic hydrocarbon (PAH). The white sphere, a solid form of mothballs, is generally placed in closets, drawers, and storage containers to repel moths and in the toilet as a deodoriser [3, 4]. The mothballs also have a general insect/ pest repellent function and were documented as a pesticide in the United States (US) since 1948 [1]. Risk assessments of naphthalene have been ongoing since the 1980s [5], reflecting its classification as both a volatile organic compound (VOC) and an emerging pollutant due to its persistence, bioaccumulative potential, and toxicological profile [6,7]. It is chemically stable and resistant to degradation [8, 9]. In 2018 alone, more than a thousand cases of mothball poisoning were reported in the US, with exposure pathways including ingestion, inhalation, and dermal contact [10].

Acute effects of naphthalene exposure include skin and eye irritation, nausea, and headaches, while prolonged inhalation may lead to hemolytic anemia through the destruction of red blood cells [11]. An accidental prenatal exposure to naphthalene resulted in both the mother and her preterm infant presenting with haemolytic anaemia and methemoglobinemia [12]. Methemoglobinemia is a condition where a form of haemoglobin that cannot bind oxygen efficiently builds up in the blood, leading to symptoms such as cyanosis and hypoxia [13]. In addition, as manufacturers have altered mothball appearance through bright colours and varied shapes to improve consumer appeal, they have inadvertently heightened the risk of accidental ingestion or intentional misuse. Accidental ingestion, particularly among children, inhalation exposure, and intentional misuse contribute to its public health burden. Parallel to the naphthalene challenge, improper disposal of waste cooking oil is an ongoing environmental issue. Discarded oil can contaminate waterways, block plumbing systems, and, when repeatedly reused, may form carcinogenic compounds [14]. This represents an underutilised waste stream that, if valorised, could support the production of sustainable pest control products.

In response to these risks, attention has shifted toward safer, plant-based alternatives. Kitchen herbs and plant waste such as clove (*Syzygium aromaticum*) [15], cinnamon (*Cinnamomum verum*) [16], lemongrass (*Cymbopogon citratus*) [17], and citrus peels from oranges (*Citrus reticulata*) and lemons (*Citrus limon*) [18] are recognised for their insect-repelling properties. These materials, used in fresh, dried, or essential oil form, provide effective repellence without the toxicological burden associated with synthetic chemicals.

This study proposes an integrated solution that addresses both toxic chemical use and household waste generation. The products aim to match or exceed the efficacy of conventional mothballs while eliminating naphthalene-related hazards and reducing landfill-bound waste. Beyond repellency, these pest balls may also function as natural deodorisers, offering multi-functional benefits. By coupling environmental protection with waste-to-resource strategies, this research aligns with the principles of the circular economy and advances the Sustainable Development Goals (SDGs) on responsible consumption and production, health, and environmental sustainability.

MATERIALS AND METHODS

The three main phases of this study were pretreatment of used cooking oil and preparation of powdered natural ingredients, production of pest ball, and efficiency testing. The experimental process involved is summarised in **Fig. 1**. In the initial stage, waste materials and natural ingredients were prepared through the pretreatment of waste cooking oil and grinding the natural ingredients into a fine powder. The source of waste cooking oil was collected from a small business specialising in local delicacies. The plant wastes, including lemongrass, lemon, and orange peel, were sourced from household kitchen scraps. The kitchen spices, such as cinnamon and clove, were obtained from readily available household supplies and supplemented with purchases from grocery stores.

Pretreatment

Direct use of the oil in its original state was unsuitable due to its strong odour and dark colour, which could compromise the end-product appeal. Fine activated carbon was used to decolourise and improve the clarity of the waste cooking oil. The oil was directly subjected to 24 h decolourisation, repeated twice, and followed by fine filtration to eliminate residual carbon and impurities. The plant materials (orange peels, lemongrass waste, lemon peels, and kitchen spices) were oven-dried at 109 °C for 30 min, ground into fine powder, and stored separately in sealed containers at room temperature.

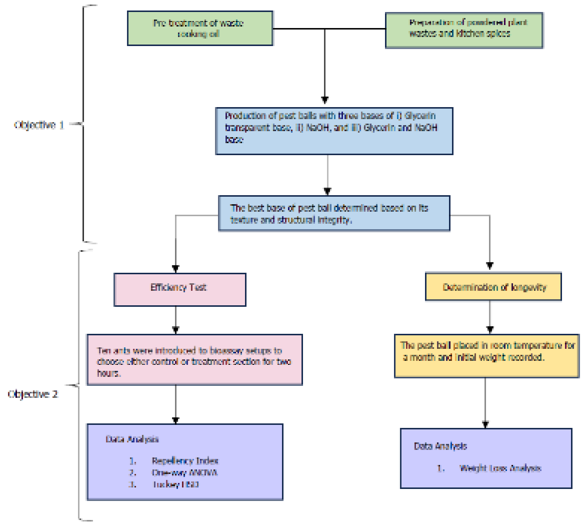

Fig. 1. Overall research methodology flowchart.

Production of Pest Ball

This experiment involves three types of bases, which are 1) glycerine transparent base, 2) NaOH and 3) NaOH and glycerine, was determine for the best base. The total weight of each pest ball was standardized to 16 g to fit the capacity of the silicon mould. Each base was then evaluated on its performance as the best in terms of texture, durability, and repellent effectiveness.

Glycerin Transparent Base

Based on the method by [19]. The glycerine base was cut into small pieces, placed in the stainless-steel bowl for the double boiling method until it completely melted. The treated waste cooking oil was added to the melted glycerin along with the powdered plant/ kitchen herbs in a ratio of 1:2:1 (Oil: Glycerin: Plant/Herbs). The mixture was then stirred continuously until the desired thickness formed. It was poured into a mould and allowed to set for 24 hours at room temperature. Then, it was removed from the moulds and stored at room temperature. The same steps were repeated, except that the powdered plant/kitchen herbs were not added for the negative control.

NaOH Base

The quantities of Sodium Hydroxide (NaOH) used in the study were determined following the method by [20]. The lye solution was prepared by dissolving the NaOH flakes in the water. The lye solution is then mixed with the treated waste cooking oil and the plant/kitchen herbs at a ratio of 1:2:1 (Lye: Oil: Plant/herbs). The mixture was stirred continuously until a thick consistency was achieved, then poured into moulds and allowed to cure for 24 h. Solidified pest balls were removed from the moulds and stored at room temperature. A negative control was produced using the same procedure without the addition of plant/kitchen spice powder.

Mixture of NaOH and Glycerin Base

The experiment used to make the mixture base of NaOH and glycerin was according to the method of [21]. The mixture base was prepared by melting 0.90g of NaOH in 2.70g of water and adding 1.40g of melted glycerin. Then a consistent amount of waste cooking oil, set at 7.00g for all groups, was also added to the mixture. The ratio of the mixture base to the plant/kitchen herbs was 1:2.

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Efficiency Test and Weight Loss of the Pest Ball

Efficiency tests were conducted to evaluate the repellency of the pest ball formulations against household ants, following the general approach of offering insects a choice between treated and untreated surfaces [22]. Repellence indices were calculated to quantify the degree of avoidance, and percentage repellency (%RI) was determined to measure the effectiveness of each formulation in deterring insect presence. Negative control was included in all assays to validate the repellency effect of the active formulations. Only ant species commonly encountered in domestic environments were selected to ensure the practical relevance of the findings.

Repellency was evaluated against household ants using a modified petri dish assay [23]. A ventilated plastic container was lined with white paper, divided into equal treatment (Pest ball) and control (No pest ball) zones. Ten worker ants were introduced at the central line for each replicate. Three independent replicates were conducted per treatment using freshly collected ants. The ant positions were recorded at 20-minute intervals up to 120 minutes. The exposure was prolonged as suggested by the Organization for Economic Cooperation and Development [24]. Repellency index (RI) based on the number of insects repelled by the control and treatment group surface [25]. The percentage repellency (% RI) was calculated to quantify avoidance [22]. When the % RI is high, it indicates a stronger repellent activity.

It is calculated using the following formula:

$$Percentage\ Repellency\ (\%RI) = \left(\frac{C - T}{C}\right) \times 100$$

Where:
C: The mean number of insects on the control (untreated) surface
T: The number of insects on the treated surface.

Only the best pest ball underwent weight loss analysis. The longevity of the pest balls in terms of percentage of weight loss was determined over a month at room temperature [26]. The percentage of weight loss was calculated using the following formula:

$$Weight\ loss\ \ (WL)\ = Cw - Sw$$

Where:
Sw: Starting weight (g)
Cw: Current weight (g)

Statistical Analysis

All experiments were performed in triplicate, and the average for each was calculated. Statistical analysis was conducted using one-way analysis of variance (ANOVA) in IBM SPSS Statistics Version 22, with data presented as mean ± standard error of mean (S.E.M) (n=3). A significance level of $p < 0.05$ was used for statistical comparisons.

RESULTS AND DISCUSSION

The Best Base for the Pest ball

The combination of glycerin and NaOH in a 1:2 ratio yields a pest ball formulation with markedly improved physical and functional characteristics compared to formulations using glycerin or NaOH alone.

This optimized base results in a structure that is neither excessively soft nor overly rigid and maintains its integrity well while still exhibiting gradual deformation and degradation over time. The NaOH in the base reduces oiliness by interacting with residual fats, improving overall texture. Glycerine, with its hygroscopic nature, makes the pest ball able to attract and retain moisture from the air, which contributes to the softened texture and accelerated breakdown of the pest balls. The combination of glycerine–NaOH base at a 1:2 ratio mitigates the strong odours typically associated with treated waste cooking oil. It allows for a gentler, sustained release of aroma rather than abrupt volatilization. This makes the pest ball not just functional but more eco-friendly, underpinning its designation as the optimal base for pest ball formulation [21, 27, 26].

Repellent Efficiency of the Pest Ball

A repellent is simply, by definition, something that makes insects move in a directional manner away from its source; in fact, insect repellents work by creating a vapor barrier, which should not be linked with toxicity [28]. The repellent efficiency was determined based on its percentage of Repellency index, longevity, and durability of the repellents.

Percentage of Repellency Index (%RI)

Ants began to exhibit avoidance behaviour within 20 minutes of exposure, which corresponds with a study by [29]. This is aligned with the study by [30], ant behaviors such as trophallaxis, grooming, and antennation ca interfere with the repellent effects. Our results demonstrated no mortality during the critical 2-hour observation window, indicating that the observed avoidance responses were not influenced by toxic or lethal effects, but were instead genuine behavioral repellence.

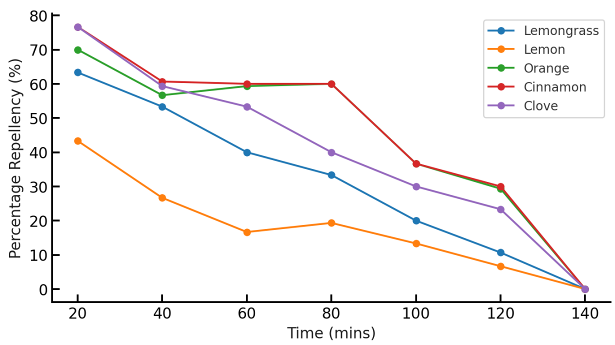

Fig. 2. Percentage Repellency (PR) of the pest ball with different plant/ kitchen herbs.

All pest balls showed more than 40% repellency after 20 minutes of exposure. Pest balls mixed with Cinnamon and Clove maintained a high % repellency for more than 1 hour. Cinnamon emerged as the most effective repellent, with an average of %RI of 76.67% at 20 minutes, stabilized for 80 minutes at 60% repellency before decreasing gradually to 0 % repellency at 140 minutes. Cinnamon is a good repellent for insects, especially for ants. This is supported by [31] and [32]. Eugenol and cinnamaldehyde are two bioactive ingredients in cinnamon that are widely recognized as the primary agents for its strong repellency [33]. In addition, tannin and calcium oxalate contribute to pest control by inhibiting insect growth, providing a dual mode of action that strengthens cinnamon's overall effectiveness as a natural repellent [33].

Clove followed as the second most effective repellent, with a mean %RI of 70% at 20 minutes. From 40 to 60 minutes of observation, the repellency decreased slightly from 56.67% to 53.33%. The repellency dropped to 23.33% after two hours. Cloves also contain eugenols, which are most responsible for their strong aroma and cause the high %RI [34]. Similar results were also achieved by [15,35] and [36], who also found that clove is effective against various insect species.

Lemongrass showed moderate repellence, with a mean of 63.33% at 20 minutes, decreasing to 53.33% at 40 minutes. The %RI decreases sharply from 30% to 16.67% in 100 minutes. Lemongrass notably contains citronella with high volatility, which can target multiple sites in insects, potentially creating a synergistic effect that enhances insecticidal properties [37]. However, because of this characteristic, the pest ball with lemongrass results in a short repellent effect [38] of the pest ball with lemongrass compared to the pest ball with cinnamon and clove. The usage of waste part of the lemongrass in this study which contained less citronella, could influence its performances as repellent as well.

Lemon exhibited a similar moderate repellency but at a slightly lower rate compared to lemongrass, with an average repellency index of 60% at 20 minutes, dropping to 36.67% at 40 minutes, and gradually decreasing to an hour. Orange, as the least effective repellent, had a starting repellency of 43.33% at 10 minutes, decreasing to 26.67% at 20 minutes. At 30 minutes of observation, it shows similar repellency to lemon at 16.67% and both decrease to 3.33% after two hours. Citrus fruits can be used to create pest balls since they have most waste components like peels and seeds, and a minor percentage of edible portion [39]. Therefore, they are suitable for the production of pest balls. However, lemon and orange are the least effective repellents because citrus fruits contain limonene that contributes to the sweet aroma [40]. Furthermore, insects, particularly ants, react positively towards sweet taste stimuli and negatively towards bitter ones [41]. In this study, ants attracted more to orange pest ball instead of moving away at 20 to 60 minutes but the %RI start to increase a bit at 80 to 100 minutes compared to lemon. This is due to compounds in orange remain stable and continue to exert its repellent effects [42].

Longevity of Percentage of Repellency

The one-way ANOVA result for pest ball %RI towards ants shows significant differences from 20 to 80 minutes with $p<0.05$ compared to the control. The %RI was fading after 80 minutes, and there were no significant differences between the control and exposed ant at 100 to 120 minutes. The high volatility of the bioactive in the pest ball contributes to poor longevity as a repellent [43]. Tukey HSD analysis of the different plant/herb types revealed that cinnamon had the longest-lasting repellency compared to the other repellents, which remained stable at 60% RI for 80 minutes. This is followed by clove > lemongrass > lemon > orange. In this study, plant wastes such as lemongrass, lemon, and orange were used in powdered form rather than essential oils. Essential oils contain more concentrated, long-lasting aromatic compounds and slower evaporation [44]. This may explain why repellency from these ingredients began to show a noticeable decrease after 60 to 120 minutes of observation, as the aromatic compounds lost their effectiveness.

Table 1. One-way ANOVA for pest ball %RI across time observations.

Time (mins)	Source Variation	of SS	df	MS	F	P-value	F crit
20 mins	Between	16.93	4	4.23	5.29	0.015	3.48
	Within	8	10	0.8			
	Total	24.93	14				
40 mins	Between	40.93	4	10.23	7.31	0.005	3.48
	Within	14	10	1.40			
	Total	54.93	14				
60 mins	Between	48.93	4	12.23	5.56	0.013	3.48
	Within	22	10	2.2			
	Total	70.93	14				
80 mins	Between	25.73	4	6.43	3.57	0.047	3.48
	Within	18	10	1.8			
	Total	43.73	14				
100 min	Between	16.93	4	4.23	3.02	0.071	3.48
	Within	14	10	1.4			
	Total	30.93	14				
120 mins	Between	6.93	4	1.73	2.89	0.079	3.48
	Within	6	10	0.6			
	Total	12.93	14				

As a result, the insignificant difference at 100 and 120 minutes might have resulted from the weakening of the odor that makes the repellency less effective compared to active ingredients with stronger and longer-lasting odors, such as essential oils [45]. Although the lemongrass waste used in this study was derived from leaves, which contain citral, a key compound responsible for its repellent properties [46], the drying and grinding process significantly reduces its volatile content, leading to a weaker aroma release [47].

Similarly, lemon and orange peels, which represent 50% and 65% of the total weight, are also rich in bioactive compounds like flavonoids [48]. In addition to it, flavonoids are a moderate repellent that can be used to manage pest insects without killing beneficial insects [49]. However, converting these peels into powder through drying diminishes the volatile component content, making the repellent effect less pronounced over time [50]. Eco-friendly repellents also have shorter lives which require specific storage conditions to maintain their efficacy [27].

Durability of the repellents.

All the pest balls experienced a gradual decrease of weight loss over a month (**Table 2**). A high weight loss potentially indicates a fast biodegradation due to evaporation of the pest ball components when exposed to air [26].

Table 2. Weight loss for each pest ball group after a month.

Pest Ball Groups	Initial weight (g)	Final weight (g)	Weight Loss (g)
Lemongrass	16	9	7
Lemon	16	10	6
Orange	16	11	5
Cinnamon	16	8	8
Clove	16	11	5

Since the biodegradable pest balls consist of natural products, they will naturally deteriorate over time upon exposure to water or heat conditions at room temperature [51]. The weight loss was also influenced by the base chosen from the earlier stage, which contained glycerine and NaOH.

As a hygroscopic substance, glycerine attracts and retains moisture, leading to faster degradation [52, 53]. The volatile compounds in the pest ball in the form of powder also degrade faster [50]. NaOH hardens the texture and promotes drying, accelerating the pest ball's physical breakdown [54].

Cost of the Pest ball

The cost analysis incorporates expenses paid for only successful pest balls throughout the process. **Table 3** shows the cost of production per pest ball of kitchen spices with cinnamon and clove. Each pest ball of cinnamon or clove (**Fig. 2**) costs only RM0.44.

Table 3. Cost Production per Pest Ball with cinnamon or clove.

Item	Cost Per Item	Quantity Used per Pest Ball	Total
Cinnamon / Clove	30 g / RM 2.60	4.00 g	RM 0.35
NaOH	600 g / RM 17.00	1.00 g	RM 0.03
Glycerin Transparent base	1 kg / RM 24.00	2.00 g	RM 0.05
Activated Carbon	1 kg / RM 6.80	0.35 g	RM 0.01
		Total	RM 0.44

Although the price is slightly higher than conventional naphthalene mothballs, which range from RM 1.50 to RM 3 per 396 g/box or RM 0.15 – RM 0.30 per mothball [55, 56], the pest balls provide long-term economic benefits by avoiding the healthcare costs linked to hazardous chemicals and accidental ingestion [57]. The process is economical and sustainable, generating no waste, requiring little energy for saponification, and producing a fully biodegradable product [56].

(I) (II)

Fig. 2. Pest ball with cinnamon (I) and clove (II).

CONCLUSION

The goal of this study was to develop a sustainable and environmentally safe substitute for conventional toxic insect repellents, and this goal was achieved. The mixture of NaOH and glycerine with a ratio of 1:2 is the optimal base as a binding agent of pest ball formulation regarding texture, odor release, and its degradation over time. The effectiveness of the natural repellent from plant wastes and kitchen spices, as observed over two hours, is cinnamon > clove > lemongrass > lemon > orange. The repellency towards ants is still significant for 20 to 60 minutes, but drops drastically after 80 to 120 minutes. The durability of pest balls, as determined by weight loss analysis, shows a pattern of cinnamon > lemongrass > lemon > clove > orange. This is driven by the evaporation of water in the pest ball, and the active compound in the natural ingredients itself helps in determining the degradation of the pest ball over time.

RECOMMENDATION

The use of activated carbon in the pretreatment of waste cooking oil can be replaced by using onion peels, which provides a more straightforward and waste-minimizing approach. Furthermore, KOH can also be considered as the base of pest ball as it provides a softer texture than NaOH. The application of essential oils derived from natural substances, such as lemongrass, citrus peels, cinnamon, and clove, should be further investigated in future research. Essential oils might provide more concentrated and powerful insect-repelling qualities. Lastly, further study can vary repellence tests to other household pests. The observation can also be on a longer period to observe their mortality dose along with the aroma release.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Herbst MC. Fact sheet on naphthalene [Internet]. 2015 [cited 2024 Jul 8]. Available from: https://www.researchgate.net/publication/280097942_Fact_Sheet_on_Naphthalene
2. Makar S, Saha T, Singh SK. Naphthalene, a versatile platform in medicinal chemistry: Sky-high perspective. Eur J Med Chem. 2019;161:252-76.
3. Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological profile for naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene [Internet]. Atlanta (GA): US Department of Health and Human Services, Public Health Service; 2005 [cited 2024 Jun 14]. Available from: https://www.epa.gov/sites/default/files/201403/documents/naphthalene_toxicology_profile_tp67_3v.pdf
4. Batterman S, Chin J, Jia C, Godwin C, Parker E, Robins T, Max P, Lewis T. Sources, concentrations, and risks of naphthalene in indoor and outdoor air. Indoor Air. 2012;22(4):266-78.
5. Price PS, Jayjock MA. Available data on naphthalene exposures: strengths and limitations. Regul Toxicol Pharmacol. 2008;51(2 Suppl):S15-21.
6. Jia C, Batterman S. A critical review of naphthalene sources and exposures relevant to indoor and outdoor air. Int J Environ Res Public Health. 2010;7(7):2903-39.
7. Lei M, Zhang L, Lei J, Zong L, Li J, Wu Z, Wang Z. Overview of emerging contaminants and associated human health effects. Biomed Res Int. 2015;2015:404796.
8. Wolf D, Gan J. Influence of rhamnolipid biosurfactant and Brij-35 synthetic surfactant on 14C-pyrene mineralization in soil. Environ Pollut. 2018;243:1846-53.
9. Lahiri D, Nag M, Dey A, Sarkar T, Joshi S, Pandit S, Das AP, Pati S, Pattanaik S, Tilak VK, Ray RR. Biofilm mediated degradation of petroleum products. Geomicrobiol J. 2022;39(3-5):389-98.
10. Kuwada G, Murakami A, Glaser DW, Ingraham SE, Purohit PJ. Mothball ingestion in the setting of G6PD deficiency causing severe hemolytic anemia, methemoglobinemia, and multiple organ failure in a toddler. Hawaii J Health Soc Welf. 2022;81(1):14-7.
11. Li J, Lu H, Fan X, Chen Y. Human health risk constrained naphthalene contaminated groundwater remediation management through an improved credibility method. Environ Sci Pollut Res Int. 2017;24(19):16120-36.
12. Molloy EJ, Doctor BA, Reed MD, Walsh MC. Perinatal toxicity of domestic naphthalene exposure. J Perinatol. 2004;24(12):792-3.
13. Ahmad R, Amir SH, Khan SA. Naphthalene mothballs poisoning leading to intravascular hemolysis: a case report. J Emerg Med. 2020;58(1):e1-3.
14. Ganesan K, Sukalingam K, Xu B. Impact of consumption of repeatedly heated cooking oils on the incidence of various cancers: a critical review. Food Sci Nutr. 2017;59(3):488-505.
15. Daud D, Nursalim DZ, Ibrahim M, Mansor M, Rahim MA, Mohd Zaki F, et al. Anti-feedant and molluscicidal activities of selected spices against Achatina fulica (Gastropoda: Achatinidae). J Sci Math Lett. 2023;11(2):66-73.
16. Sanga AG, Mazigo HD, Manjurano A, Morona D, Thomas A, Kweka EJ. Measuring repellence and mortality effects of clove and cinnamon essential oils impregnated nets against Anopheles

https://doi.org/10.54987/jobimb.v13i1.1080

gambiae sensu stricto using tunnel test. J Nat Pestic Res. 2023;5:100046.
17. Zibaee I, Khorram PB. Synergistic effect of some essential oils on toxicity and knockdown effects against mosquitoes, cockroaches and housefly. Arthropods. 2015;4(4):107-15.
18. Rodhi MNM, Saifuddin PNS, Veny H. Characterisation of used cooking oil and orange peels as the medium of insect repellent. Malays J Chem Eng Technol. 2020;3(2):31-6.
19. Goukonde NR, Rajput NJ, Bansod NB, Sanap NG. Formulation and evaluation of herbal scrub soap. World J Biol Pharm Health Sci. 2024;18(3):354-70.
20. Pauhesti P, Yulia PS, Widiyatni H, Sutadiwiria Y, Jane G, Yanti W. Soap bar making from waste cooking oil for residents of 07 Area, Duri Pulo Subdistrict, Jakarta. Int J Community Serv. 2024;4(2):145-8.
21. Susilo A, Pranowo D, Cahyati M, Nurjannah N, Prihanto AA, Masyithoh D, Pangesti IF, Ihwanudin AY. Physicochemical quality of transparent solid soap with the addition of forest honey (Apis dorsata) as an environmentally friendly sanitizer. BIO Web Conf. 2024;88:00011.
22. Morimoto Y, Kawada H, Kuramoto K, Mitsuhashi T, Saitoh T, Minakawa N. New mosquito repellency efficiency for evaluation of repellents and pyrethroids using an attractive blood-feeding device. Parasit Vectors. 2021;14(1):156.
23. Wang C, Lü L, Zhang A, Liu C. Repellency of selected chemicals against the bed bug (Hemiptera: Cimicidae). J Econ Entomol. 2013;106(6):2522-9.
24. Organisation for Economic Cooperation and Development (OECD). Guidance document on laboratory and simulated-use testing: the efficacy of baits and repellents against tropical ants for indoor use [Internet]. Paris: OECD; 2020 [cited 2025 Feb 8]. Available from: https://www.oecd.org/content/dam/oecd/en/publications/reports/2022/11/gui59dance-document-on-laboratory-and-simulated-use-testing-the-efficacy-ofbaits-and-repellents-against-tropical-ants-for-indoor-use_7526dc28/f7467670-en.pdf
25. Liu X, Li Y, Li H, Deng Z, Zhou L, Liu Z, Du S. Identification of repellent and insecticidal constituents of the essential oil of Artemisia rupestris L. aerial parts against Liposcelis bostrychophila Badonnel. Molecules. 2013;18(9):10733-46.
26. Norazlina H, Husna AA, Shakirah HL. Development and evaluation of herbal neem soap. Int J Synergy Eng Technol. 2024;5(1):1-6.
27. Verma NS, Kuldeep DK, Chouhan M, Prajapati R, Singh SK. A review on eco-friendly pesticides and their rising importance in sustainable plant protection practices. Int J Plant Soil Sci. 2023;35(22):200-14.
28. Dethier VG, Browne BL, Smith CN. The designation of chemicals in terms of the responses they elicit from insects. J Econ Entomol. 1960;53(1):134-6.
29. Ahmad Z, Hassan F, Noor S, Ahmad M. Optimum composition of developed additive-based insect repellent paint. Syst Rev Pharm. 2021;12(5):332-5.
30. Yeoh XL, Dieng H, Ab Majid AH. Mortality and repellent effects of coffee extracts on the workers of three household ant species. Pertanika J Trop Agric Sci. 2018;41(4):1557-86.
31. Vu J, Mitra H, Hardy JS, Chauhan N. Ants and spices: the potential of spices to repel pest ants (Formicidae) [Internet]. Norfolk (VA): Old Dominion University; 2022 [cited 2025 Feb 5]. Available from: https://digitalcommons.odu.edu/cgi/viewcontent.cgi?article=1000&context=reyes-2022
32. De Pedro L, Sanchez JA. Natural repellents as a method of preventing ant damage to microirrigation systems. Insects. 2022;13(4):395.
33. Iriani FA, Dehi RI, Damar AC. Repellent activity testing of an essential oil gel preparation of cinnamon (Cinnamomum burmanii) bark and kaffir lime peel (Citrus hystrix) against Aedes aegypti mosquitoes. Oshada. 2024;1(3):89-101.
34. Abo-El-Saad M, Ajlan A, Al-Eid MA, Bou-Khowh IA. Repellent and fumigant effects of essential oil from clove buds Syzygium aromaticum L. against Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae). J Agric Sci Technol A. 2011;1:613-20.
35. Nentwig G, Frohberger S, Sonneck R. Evaluation of clove oil, icaridin, and transfluthrin for spatial repellent effects in three test systems against the Aedes aegypti (Diptera: Culicidae). J Med Entomol. 2017;54(1):150-8.
36. Patel SN, Aglave B. Small plot experimental study for testing efficacy of ant repelling activity of essential oils. Int J Biotechnol Biochem. 2017;13(4):403-12.
37. Maheriya D, Rajan V, Patani P. Unravelling insect repellent power of lemongrass. J Cardiovasc Dis Res. 2023;14(12):3181.
38. Yen TTH, Oanh HT, Giang VTT. Validation of a high-performance liquid chromatographic method with diode array detection for the quantification of citral and formulation of insect repellent cream from lemongrass oil. VNU J Sci Med Pharm Sci. 2020;36(1):1-8.
39. Fernando SSST, Jayasooriya RGPT, Samarakoon KW, Wijegunawardana NDAD, Alahakoon SB. Citrus-based bio-insect repellents: a review on historical and emerging trends in utilizing phytochemicals of citrus plants. J Toxicol. 2024;2024:6179226.
40. Zhou R, Zhu J, Niu Y, Zhang J, Xiao Z, Zhao L. Identification of characteristic compounds of sweet orange oil and their sweetening effects on the sucrose solution with sweetness meter, sensory analysis, electronic tongue, and molecular dynamics simulation. Food Chem. 2024;461:140815.
41. Fernando SSST, Jayasooriya RGPT, Samarakoon KW, Wijegunawardana NDAD, Alahakoon SB. Citrus-based bio-insect repellents: a review on historical and emerging trends in utilizing phytochemicals of citrus plants. J Toxicol. 2024;2024:6179226.
42. Achimón F, Beato M, Brito VD, Peschiutta ML, Herrera JM, Merlo C, Pizzolitto RP, Zygadlo JA, Zunino MP. Insecticidal and repellent effects of the essential oils obtained from Argentine aromatic flora. Bol Soc Argent Bot. 2022;57(4):729-46.
43. Maia MF, Moore SJ. Plant-based insect repellents: a review of their efficacy, development and testing. Malar J. 2011;10(Suppl 1):S11.
44. Lopez AD, Whyms S, Luker HA, Galvan CJ, Holguin FO, Hansen IA. Repellency of essential oils and plant-derived compounds against Aedes aegypti mosquitoes. Insects. 2025;16(1):51.
45. Tapondjou L, Adler C, Bouda H, Fontem D. Efficacy of powder and essential oil from Chenopodium ambrosioides leaves as post-harvest grain protectants against six stored-product beetles. J Stored Prod Res. 2002;38(4):395-402.
46. Skaria BP, Joy PP, Mathew G, Mathew S, Joseph A. Lemongrass. In: Peter KV, editor. Handbook of herbs and spices. 2nd ed. Vol. 2. Cambridge: Woodhead Publ.; 2012. p. 348-70.
47. Zhang L, Cao S, Li J, Wang G. Effects of drying methods on the volatile compounds of Allium mongolicum Regel. Foods. 2022;11(14):2080.
48. Li B, Smith B, Hossain MM. Extraction of phenolics from citrus peels. Sep Purif Technol. 2006;48(2):182-8.
49. Li B, Smith B, Hossain MM. Extraction of phenolics from citrus peels. Sep Purif Technol. 2006;48(2):182-8.
50. Azhari NAM, Markom M, Ismail I, Anuar N. Effects of different drying methods on essential oil yield and component profile of Polygonum minus root extract. Int Food Res J. 2020;27(1):96-102.
51. Chirani MR, Kowsari E, Teymourian T, Ramakrishna S. Environmental impact of increased soap consumption during COVID-19 pandemic: biodegradable soap production and sustainable packaging. Sci Total Environ. 2021;796:149013.
52. Staff NJ. Bubble, bubble, toil and trouble. J Chem Educ. 2001;78(1):40A.
53. Eccles R, Mallefet P. Soothing properties of glycerol in cough syrups for acute cough due to common cold. Pharmacy (Basel). 2017;5(1):4.
54. Alum BN. Saponification process and soap chemistry. INOSR Appl Sci. 2024;12(2):51-6.
55. Sudakin DL, Stone DL, Power L. Naphthalene mothballs: emerging and recurring issues and their relevance to environmental health. Curr Top Toxicol. 2011;7:13-9.
56. Maotsela T, Danha G, Muzenda E. Utilization of waste cooking oil and tallow for production of toilet bath soap. Procedia Manuf. 2019;35:541-5.
57. Landrigan PJ, Fuller R, Acosta NJR, Adeyi O, Arnold R, Basu N, Baldé AB, Bertollini R, Bose-O'Reilly S, Boufford JI, Breysse PN, Chiles T, Mahidol C, Coll-Seck AM, Cropper ML, Fobil J, Fuster V, Greenstone M, Haines A, Zhong M. The Lancet Commission on pollution and health. Lancet. 2018;391(10119):462-512.