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Mosquito Repellents - A Systematic Review

Review Article

Matthew Spyriounis[1]*, Kalvin Weng[1]†, Jessica I. Cohen[1]‡

1 Francis Lewis High School, Fresh Meadows, NY, 11365

Abstract: The purpose of this systematic review was to review different types of mosquito repellents in past research studies and papers and compare the findings of each, in order to draw conclusions. Mosquitoes have posed a huge issue to humans' safety for centuries, as they have the ability to transmit fatal diseases. Usually, chemical factory made repellents are used against mosquitoes, but many species of mosquitoes have begun building resistance towards them, and they can cause harm to the environment, leading to the research and use of alternatives, in the form of organic repellents. This overall situation has sparked debates in the field based on the effectiveness of organic repellents, and the pros and cons of using them, as opposed to creating stronger chemical formulas. The methods of this project entailed performing a systematic review of articles extracted from the research databases PubMed, Google Scholar, and EBSCO, using keywords such as "Mosquitoes", "Insecticide", "Pesticide", and "Repellent", and comparing the results, conclusions, and findings of each paper. There were 7 articles analyzed in total. Of all 7 articles analyzed there was only one that indicated in its findings that there was no significant difference made in repelling mosquitoes with or without the use of organic repellent. The results of this project pointed towards the overall conclusion that various different organic natural repellents are just as effective as chemical factory made repellents in the use of mosquito control. Future works in the scientific field should further investigate organic repellents and their effectiveness against mosquitoes and other insects such as ticks, wasps, fleas, cockroaches, and flies, as well as test previously unused organic repellents against mosquitoes to evaluate their effectiveness, while keeping all organic repellents effective and environmentally friendly against mosquitoes and other insects.

Keywords: Mosquito • Repellent • DEET • Insecticide • Pesticide

1. Introduction

Mosquitoes are a threat to public health because, not only does their bite afflict humans by causing allergic reactions, but also mosquitoes pose more serious dangers with the diseases they carry. Some diseases that are spread by mosquitoes are the Zika virus, West Nile virus, Chikungunya virus, dengue, and malaria [1]. Mosquitoes are also able to transmit new diseases to humans by transmitting disease from animals to humans [2]. Mosquitoes, Culicidae, like all insects, have 3 body parts: a head, a thorax, and abdomen. Male mosquitoes live for 10 days

* *E-mail: matthewspyriounis@gmail.com*
† *E-mail: wengkalvin@gmail.com*
‡ *E-mail: jcohen@flhs.us*

or less, while females can live up to about six to eight weeks. Only female mosquitoes have a stinger in their proboscis which allows them to suck blood, which, in turn, being full of proteins and amino acids, serves as their supplement for growing mosquito eggs. Female mosquitoes, which are specifically attracted to CO_2, detect it by using their olfactory sensillum located on their antenna. When a mosquito detects and encounters carbon dioxide molecules, an electrical impulse is sent to the insect's brain [3]. The presence of CO_2 is a cue that humans are nearby and makes mosquitoes attracted to humans [4].

DEET interferes with neurons and receptors located on the mosquito's antennae. Interfering with the receptors prevents the detection of chemicals such as lactic acid and carbon dioxide. Mosquitoes are attracted by lactic acid and carbon dioxide, so upon detection of them, they fly to their source to feed on it, meaning the prevention of the detection of these chemicals is critical to repel mosquitoes from humans. By inhibiting female mosquitoes' antennae, it makes it hard for female mosquitoes to get blood. However, the effectiveness of DEET repellents is slowly declining. In one study, two repellents with DEET as the active ingredients become insignificant when compared to the control group after 240 minutes [5]. The repellency of DEET against *Aedes albopictus* mosquitoes decreased, while other repellents like cutter lemon eucalyptus, which contain oil of lemon eucalyptus, did not. Cutter lemon eucalyptus significantly reduced the number of mosquitoes trapped even after 240 minutes [5]. Repellents are a way to keep mosquitoes away, but certain factors affect their use, as they must be safe for humans. Although DEET is very effective against certain species of mosquitoes, noted side effects of DEET products are skin irritation, disorientation, dizziness, and, in extreme cases, seizures or death. Insect repellents may not be safe for infants and pregnant women. Therefore, an efficient repellent is needed to combat mosquitoes while protecting individuals.

Coffee grounds contain alkaloid compounds, flavonoids, and tannins. Caffeine (1, 3, 7-trimethylxanthine) is an alkaloid that is found in coffee, chocolate, tea, and drinks [6]. Caffeine is a nervous system stimulant and has pernicious effects on insects. Coffee grounds increase the mortality and decrease the growth rate for *Aedes aegypti* [6, 7]. Flavonoids are naturally bioactive and can be found in vegetables, grains, plants, flowers, tea and wine, and coffee grounds. Flavonoids interfere with the insect's physiological process. Flavonoids, like the ones found in coffee grounds, are starting to be used to manufacture new pesticides and factory-made insect repellents [8]. One study identified flavonoids inhibit ecdysone 20-monooxygenase activity in dipterans [9]. Ecdysone 20-monooxygenase is an enzyme that forms 20-hydroxy-ecdysone hormones, which controls embryo development and fecundity in insects [10, 11]. Condensed tannins, proanthocyanidins, have negative consequences to insects' health [12]. Tannins are an anti-nutritional deterrent to insects and contain a high amount of complex proteins which decreases insect digestion of food [13]. The disruption of endogenous metabolism in insects reduces their growth rate and reproduction.

One previous study tested the mortality rate of *Aedes aegypti* larvae when they were exposed to *Coffee arabica*. The results of this study show the control group had a 0% mortality rate but for 34g/L of the coffee ground solution, the mortality rate for *Aedes aegypti* larvae was 69.17% [7]. Out of the 120 *Aedes aegypti* larvae,

83 died from the treatment of 34g/L of coffee ground solution [7]. This experiment shows that the coffee grounds significantly increase the mortality of *Aedes aegypti* larvae. In another experiment, the scientists studied the effects of caffeine and used coffee grounds on biological features of *Aedes aegypti* (Diptera, Culicidae) and their possible use as an alternative control. The results of the experiment show that 2.0mg/mL of caffeine had a mortality of 100% of the first stage *Aedes aegypti* larvae. At 1.0mg/mL of caffeine, it hindered the development of *Aedes aegypti* larvae at their second stage. The control group had a mortality rate of only 24% [6]. This experiment shows the addition of caffeine to *Aedes aegypti* larvae has high mortality because of the significant increase in death.

Cymbopogon, also known as lemongrass, is one of the most common essential oils that can be a substitute for natural mosquito repellent. In Afify & Potter's study, the scientists test the behavioral response of different odorants on specific- species of mosquito. The results show that lemongrass oil 100% has the fastest repelling response from *Anopheles coluzzii*, *Aedes aegypti*, and *Culex quinquefasciatus* mosquitoes compared to synthetic repellents like DEET, picadarin, IR3535; and natural repellents like p-menthane-3,8-diol, and eugenol [14].

Some of the most notable compounds in Cymbopogon that repel mosquitoes are citronellol, geraniol, citronellal, and linalool. In Kline's study, the spatial repellency of female *Aedes aegypti* species of mosquito to DEET, Dehydrolinalool, and Linalool with a human attractant mixture was determined by using a triple cage. Two types of tests, competitive and non-competitive, were used in the experiment. In non-competitive tests, only one of the two ports in the olfactometer received a repellent/attractant while in the competitive test both of the ports in the olfactometer received a repellent/attractant. The results of the study yielded that out of all 3 tested substances, Linalool was the most attractive compound and had the greatest spatial repellency when combined with Dehydrolinalool at 33.6% spatial repellency. In the presence of a human attraction mixture, mosquitoes' orientation, and activation towards the three chemicals were decreased, while increasing in their absence. Overall, the tested substances proved to be effective as a spatial repellent, providing another form of protection from mosquito attacks [15].

In Govindarajan's experiment the scientist tested the effects of *Cymbopogon citratus* (lemongrass), *Cinnamomum zeylanicum* (cinnamon), *Rosmarinus officinalis* (rosemary medicinal plant) and *Zingiber officina* (ginger) on the mortality and repellency against mosquitoes. In the first part of the experiment, the scientist tested the effects of different concentrations on the four different plant essential oils on *Culex tritaeniorhynchus* and *Anopheles subpictus*. The results showed all the plant essential oils were lethal to mosquitoes, and the most lethal was *Zingiber officina* because it required the least concentration to result in an LC50 and LC90 for both species of mosquitoes. In the second part of the experiment the scientist tested the repellency of the four different essential oils at different concentrations against *Culex tritaeniorhynchus* and *Anopheles subpictus*. All the plant essential oils were effective in repelling the mosquitoes, but the most effective repellent was *Zingiber officina* [16].

In Macchinoi *et al.'s*, experiment scientists tested the effects of neem oil, *Azadirachta indica*, on the number of eggs laid by the mosquitoes and the number of mosquitoes for each species caught by the mosquito traps.

Scientists hypothesized a lethal concentration of azadirachtin, which is found in neem seeds, can inhibit the reproduction of insects which may result in neem oil being an insecticide. In the first part of the experiment, the scientists placed six ovitraps for six months and recorded the weekly number of mosquito eggs in each trap. Overall, the results show a trend of neem oil reducing the number of eggs laid by female mosquitoes compared to the control group. However, the results did not show a significant difference between the ovitraps with neem oil and without neem oil. In the second part of the experiment, the scientists used mosquito traps to collect mosquitoes in three different locations. There were more *Culex pipiens* mosquitoes caught in the treated group than the control group in all three locations [17]. This project aspires to provide a safer, more effective, organic, and eco-friendly repellent mainly for mosquitoes, but not limited to, through the use of coffee ground solutions. Mosquitoes and other insects have not only grown a resistance to factory-made repellents and pesticides but are also harmful to humans' well-being and the environment. This experiment could provide an alternative, all-around safer method of controlling mosquitoes and possibly other insects in the real world, especially nowadays that mosquitoes pose a threat at a worldwide scale.

The purpose of this systematic review is to investigate the effectiveness of tested natural organic repellents in past research studies and compare them to chemical factory-made repellents to determine how viable they would realistically be in mosquito control. Our hypothesis is that our systematic review will show organic natural repellents will be as effective as commonly used chemical factory-made repellents against different species of mosquitoes.

2. Methods

A systematic review using the Databases: PubMed, Google Scholar, EBSCO, was performed. First, articles in English were reviewed. The scholarly journal must contain a keyword from both categories of keyword for it to be reviewed in this paper. The first keyword that had to be mentioned was mosquitoes or species of mosquitoes. The second keywords that had to be mentioned was repellents that are derived from plants. Some examples are "Mosquitoes", "*Aedes Aegypti* ", "*Culex tritaeniorhynchus*", "Insecticide", "Pesticide," "Repellent," "Citronella," "Coffee ground," and "Lemongrass".

All research articles gathered and used were documented in the References section of this paper. After all articles were gathered and documented, different tables were created comparing different traits of various repellents and species of mosquitoes that this research study wished to investigate. Each table created was titled and every section of it was labeled appropriately in order to keep uniformity between all articles being compared in order to eventually generate reliable results, conclusions, and new understandings.

The first table was an Analysis of Repellent Traits which included the citation of the given article, the mosquito species tested in the research study, the insecticide type tested in the research study, the methods used to test repellency in mosquitoes in the paper, and the key findings of the paper. The second table exhibited

the Analysis of the Articles which included the citation of the given article, the mosquito species tested in the research study, the insecticide type tested in the research study, the methods used in the research study, and the key findings of the research project.

3. Results

[7]	Aditama, W., & Zulfikar, S. F. The effectiveness of arabica coffee (Coffea arabica L) grounds on mortality and growth of Aedes aegypti Larva. International Journal of Mosquito Research **2019**, 6, 34-37.
[14]	Afify, A., & Potter, C. J. (2020). Insect repellents mediate species-specific olfactory behaviours in mosquitoes. Malaria journal, 19, 1-10. doi: 10.1186/s12936-020-03206-8
[16]	Govindarajan, M.. Larvicidal and repellent properties of some essential oils against Culex tritaeniorhynchus Giles and Anopheles subpictus Grassi (Diptera: Culicidae). Asian Pacific Journal of Tropical Medicine, **2011**, 4(2), 106-11, doi: 10.1016/S1995-7645(11)60047-3
[15]	Kline D., Bernier U., Posey K., Barnard D.. Olfactometric Evaluation of Spatial Repellents for Aedes aegypti. Center for Medical, Agricultural, and Veterinary Entomology, 2003, 40, 463-467. doi: 10.1603/0022-2585-40.4.463
[6]	Laranja, A. T., Manzatto, A. J., & Campos Bicudo, H. E. M. D.. Effects of caffeine and used coffee grounds on biological features of Aedes aegypti (Diptera, Culicidae) and their possible use in alternative control. Genetics and molecular biology, 2003, 26, 419-429. doi: 10.1590/S1415-47572003000400004
[17]	Macchioni F., Sfingi M., Chiavacci D., Cecchi F.. Azadirachta indica (Sapindales: Meliaceae) Neem Oil as a Repellent Against Aedes albopictus (Diptera: Culicidae) Mosquitoes. Journal of Insect Science, 2019, 19. doi: 10.1093/jisesa/iez111
[5]	Rodriguez, S. D., Drake, L. L., Price, D. P., Hammond, J. I., & Hansen, I. A. The efficacy of some commercially available insect repellents for Aedes aegypti (Diptera: Culicidae) and Aedes albopictus (Diptera: Culicidae). Journal of Insect Science, 2015, 15, 1-5. doi: 10.1093/jisesa/iev125

Table 1: The 7 articles, i.e., [7], [14], [16], [15], [6], [17], and [5], that were collected for review and thoroughly analyzed. See the analysis in Table 2.

Table 1 exhibits the collection of 7 articles that were collected for review and analyzed in this paper. The articles reviewed tested a variety of organic and inorganic repellents on different mosquito species. A thorough analysis of these articles is present in Table 2.

Citation	Mosquito species	Insecticide	Method	Key Findings
[7]	*Aedes aegypti* Larva	28g/liter, 30g/liter, 31g/liter, 33g/liter, and 34g/liter concentration of coffee ground	**Larvicidal activity** Larvicidal activity of *Aedes aegypti* with the administration of 0g/liter, 28/liter, 30g/liter, 31g/liter, 33g/liter, and 34g/liter of arabica coffee was administered to a group of 30 *Aedes aegypti* Larva. The number of Larva alive and dead were calculated to find the mortality rate.	As the concentration of coffee ground in liters increased, the mortality rate of the mosquitoes increased While the control group of 0g/liter had no mortality rate, 28g/liter had a 6.67% mortality rate among mosquitoes, 30g/liter had 20.00% mortality rate among mosquitoes, 31g/liter had 36.67% mortality rate among mosquitoes, 33g/liter had 46.67% mortality rate among mosquitoes, and 34g/liter had 76.67% mortality rate among mosquitoes.

[14]	*Aedes aegypti, Culex quinquefasciatus, Anopheles coluzzii*	IR3535 100%, DEET 100%, Eugenol 100%, Picaridin 100%, PMD 80% Lemongrass oil 100%, 1-octen-3-ol 0.1%, 1%, 10%,100%, Benzaldehyde 0.1%, 1%, 10%, 100%, Lemongrass oil 30% Lemongrass oil 30% + DEET 30%, PMD 30%, PMD 30% + DEET 30%,	**Close proximity response assay** Mosquitoes entered a cage and they landed on the cage mesh wall. A pipette with the odorant listed was exposed to the mosquito. Scientists recorded the time within 30-seconds it took for the mosquito to fly away. **Calcium Imaging** The 11th segment of the transgenic mosquitoes was used for calcium imaging.	Lemongrass oil and PMD odorant were the most effective in repelling all different species of mosquitoes. DEET and Eugenol odorant repelled Aedes and Culex mosquitoes, but it was not effective as lemongrass oil the Anopheles mosquitoes. Human odorant was repulsive towards *An. coluzzii* at a high concentration. Mixing PMD and DEET repellents have a masking effect or reduce the efficiency of the repellent. More neuron receptors are activated when a mosquito flies away from the odor.
[16]	*Culex tritaeniorhynchus* Giles, *Anopheles subpictus* Grassi,	*Cymbopogan citrates* at 50, 100, 150, 200, and 250 ppm *Cinnamomum zeylanicum* at 50, 100, 150, 200, and 250 ppm, *Rosmarinus officinalis* at 50, 100, 150, 200, and 250 ppm *Zingiber officinale* at 50, 100, 150, 200, and 250 ppm	**Larvicidal activity** Larvicidal activity of four essential oils against *Culex tritaeniorhynchus* and *Anopheles subpictus* was assessed. 1 mL of essential oil at various concentrations was dissolved in 100 mL distilled water using acetone. Then, 25 larvae of late third instar were transferred to the test medium. Control experiments were run parallel with each replicate. **Repellent Activity** The repellency of the essential oils was assessed by the human-bait technique. The assessment was carried out in a net cage that contained 100 blood starved female *Culex tritaeniorhynchus* and *Anopheles subpictus*. Each arm of the volunteer (25 cm2)dorsal side of the skin) was exposed and the remaining area covered by rubber gloves. Essential oils were applied at 1.0, 2.5, and 5.0 mg/cm2 separately in the exposed area of the forearm. Ethanol served as control.	*Zingiber officinale* required the least concentration to reach LC50 and LC90, 98.83ppm and 186.55ppm, respectively for *Culex tritaeniorhynchus*. A concentration of 250ppm of *Zingiber officinale* resulted in 100% mortality for *Culex tritaeniorhynchus* and *Anopheles subpictus*. For both species of mosquitoes *Zingiber officinale* required the least concentration to reach LC50 and LC90, followed by *Rosmarinus officinalis*, then *Cinnamomum zeylanicum*. *Cymbopogan citrates* required the highest concentration to reach the LC50 and LC90. *Zingiber officinale* required the least concentration to reach LC50 and LC90, 57.98ppm and 104.23ppm, respectively for *Anopheles subpictus*. For repellent activity, *Zingiber officinale* was the most effective. A concentration of 1.0mg/cm2 had 100% repellency for 90 minutes, 2.5mg/cm2 had 100% repellency for 120 minutes, and 5.0mg/cm2 had 100% repellency for 150 minutes. For repellent activity, the most effective essential oil was *Zingiber officinale*, followed by *Cymbopogan citrates*. *Rosmarinus officinalis* and *Cinnamomum zeylanicum* were the least effective in repelling mosquitoes out of the four essential oils. A concentration of 1.0mg/cm2 *Rosmarinus officinalis* or *Cinnamomum zeylanicum* had 100% repellency for 30 minutes, 2.5mg/cm2 had 100% repellency for 60 minutes, and 5.0mg/cm2 had 100% repellency for 90 minutes.

[15]	*Aedes aegypti*	25µ/L, 100µ/L, 250µ/L, 500µ/L, and 1000µ/L of DEET 25µ/L, 100µ/L, 250µ/L, 500µ/L, and 1000µ/L of Dehydrolinalool 25µ/L, 100µ/L, 250µ/L, 500µ/L, and 1000µ/L of Linalool 500µ/L of Cara Sludge (mixture consist of facial hair, skin and acetone)	**Noncompetitive Test** One of the two chambers received the treatment. The other group did not receive any treatment. Scientists recorded the number of mosquitoes that flew to the treatment port, check port, and the remaining mosquitoes. **Competitive Test** Both chambers received one of the treatments. Results recorded the number of mosquitoes in port one, port two, and the mosquitoes not in either of the chambers.	Dehydrolinalool was the most effective repellent at repelling mosquitoes. 18.1% of mosquitoes were in the treatment port at 25µ/L. 9.3% of mosquitoes were in the treatment port at 500µ/L. 17.1% of mosquitoes were in the treatment port at 1000µ/L. Linalool was the least effective repellent at repelling mosquitoes. 37.5% of mosquitoes were in the treatment port at 25µ/L. 25.7% of mosquitoes were in the treatment port at 1000µ/L. DEET was a slightly better repellent than linalool, but it is less effective than dehydrolinalool. 20.3% of mosquitoes were in the treatment port at 25µ/L. 19.0% of mosquitoes were in the treatment port at 1000µ/L. 500µ/L of Cara sludge resulted in 71.9% of mosquitoes in the treatment port. In a competitive test, dehydrolinalool + Cara Sludge + linalool and Cara Sludge had the least number of mosquito traps when compared with Cara Sludge only and DEET + Cara Sludge. Generally, for competitive tests, when the concentration of the compound increases, repellents with either linalool + Cara Sludge or dehydrolinalool + Cara Sludge had a better performance. DEET + Cara sludge did not have a better repellency than linalool + Cara sludge or dehydrolinalool + Cara Sludge. A comparison at 250µ/L between linalool + Cara Sludge vs. dehydrolinalool + Cara Sludge shows linalool + Cara Sludge act as a better repellent. However, this trend is not prevalent at 500µ/L or 100µ/L.
[6]	*Aedes aegypti*	2.0, 1.0, 0.5, 0.2 and 0.1 mg/mL of Caffeine 25, 50 and 100 mg/mL of Used Coffee Grounds	**Ovicidal Activity** Mosquitoes eggs were placed into a petri dish that contains 40mL of the desired concentration. Observations were made on the mosquitos' eggs on their development.	Results show caffeine with a concentration of 1.0mg/mL or greater had a 100% mortality. As the concentration of caffeine increases, mosquito eggs have an earlier death rate. Used coffee grounds had a 42% mortality rate. The control group which used water had a 24% mortality rate. Used coffee grounds had a slightly better performance than the control group, but a lower performance than the caffeine group in terms of repelling mosquitoes.

[17]	*Aedes albopictus* *Azadirachta indica*	5g/L of neem oil which contained 0.3% Azadirachtin	**Repellency Activity** A total of six ovitraps (three control and three experiments), and six Biogent mosquito traps were set up to allow the mosquitoes to lay eggs. Treatment consisted of spraying 5g/L of neem oil which contained 0.3% Azadirachtin in 1 liter. Control groups were treated with water and emulsifier without Azadiractin. Scientists recorded the weekly number of collected eggs for each location.	No trend can be found between the number of mosquitoes collected with or without the addition of neem oil. During July, only two out of the six locations showed a significant difference in the number of eggs for July. Ghezzano had an average of 102.95 weekly collected eggs for control and the experimental group had an average of 83.91 eggs. Lucca had 120.1 weekly collected eggs for the control group and 53.31 eggs for the experimental group.
[5]	*Aedes albopictus, Aedes aegypti*	*Commercial Product, only* Repel 100 insect repellent (98.11% DEET) OFF deep woods insect repellent VIII (25% DEET) EcoSmart organic insect Repellent (1% Geraniol, 0.5% Rosemary oil, 0.5% Cinnamon oil, 0.5% Lemongrass oil) Cutter lemon eucalyptus insect repellent (oil of lemon eucalyptus, 30%, which contains 65% p-menthane-3-8-diol) Avon Skin So Soft Bug Guard Mosquito skin patch (Thiamin B1, 300 mg)	**Attraction-Inhibition Assay** Volunteer's hands were sprayed with 0.5 ml of the repellent while the other hand was covered with a nitrile glove, which acted as a control group. The treated hand was placed in one of the decision ports, the other, untreated gloved hand was inserted into the other port. Mosquitoes were given 30 seconds to acclimate to their environment and the hands of the volunteer are inserted into the port. mosquitoes were given 2 min to relocate within the tube. After 2 minutes, the number of mosquitoes was recorded in the holding port, the decision port, and shaft.	Commercial product, Repel 100 insect repellent and Cutter Lemon eucalyptus insect repellent were the most effective repellent and maintained the repellency for *Aedes aegypti*. Initially, Repel 100 insect repellent had only an average of 10% of the *Aedes aegypti* in the treatment port. After 240 minutes, there are 14% *Aedes aegypti* trapped in the port. Other repellents that contain DEET as an active ingredient were also effective in repelling *Aedes aegypti* and *Aedes albopictus*. However, after 120 minutes, there was a higher percentage of *Aedes aegypti* and *Aedes albopictus* in the treatment port. Overall, they are still very effective in repelling *Aedes aegypti* even after 240 minutes. Initially, Cutter lemon eucalyptus insect repellent had only an average of 9% of *Aedes aegypti* in the treatment port. The results for *Aedes albopictus* are similar to the results for *Aedes aegypti*, with one exception. EcoSmart organic insect repellent was more effective against *Aedes albopictus*. Initially, the treatment port only had 5% of *Aedes albopictus*. After 240 minutes there is an average of 15% of mosquitoes in the treatment port. Avon Skin So Soft Bug Guard did not show a consistent trend of repelling either species of mosquitoes. Overall, repellents that consist of Rosemary oil, Cinnamon oil, Lemongrass oil, lemon eucalyptus or p-menthane-3-8-diol, active ingredients. Citronella oil shows to be somewhat effective against mosquitoes.

Table 2: Findings from the 7 articles ([7], [14], [16], [15], [6], [17], and [5]). References, Mosquito Species, Insecticide Used, Experimental Method, and Key Findings of each article.

Table 2 exhibits the analysis of the 7 articles reviewed in this paper. Five columns are present including Citation of the Article, Mosquito Species and Insecticide(s) tested in the Article, Experimental Design Method of the experiment conducted in the paper, and the Key Findings presented by the researchers of the Article.

4. Discussions

Through our systematic review of past research papers, we noticed a mostly consistent trend among our results, which reviewed past research study findings: Natural organic repellents like Coffee Grounds, Lemongrass, and Neem Oil, appeared to be as effective in mosquito repellency as commonly used chemical factory repellents such as DEET. Although the end results largely show a consistent and reliable trend, there are notable factors that may have affected the scientific process, and by effect, our overall results. One such example, is that if researchers had errors and inaccuracies in their papers in regard to their data collection and analysis, conclusions, and new findings, that could have potentially affected our results as our comparisons of the effectiveness of different kinds of mosquito repellents, might have not been an accurate representation of how well they truly work. Another example of this, is that if data and results in past studies were affected by major confounding variables, or the data and result were yielded due to purely the situation or environment the experiments were conducted in, that could have also led us to our own inaccurate comparisons and results. A final example, is that the scientific research papers were written with a few years distance of each other and this systematic review paper, so if the effectiveness of the organic natural repellents has changed in any significant way, like if mosquitoes have built up any form of resistance towards the repellents, or if newer more potent formulas have been derived, tested, and used, those new developments are not present or reflected in our own current comparisons, analyses, and results.

A notable limitation of this project, is that many scientific research articles that concern this specific field, are blocked behind a substantially large paywall and not accessible to us, limiting the amount of data, pool of knowledge, and any other information other researchers could have discovered in their scientific project, we could have potentially gathered, in order to generate even more specific and accurate results and give us a better understanding and picture of various mosquito repellents' effectiveness.

An unexpected design change in this systematic review, is that originally, it was intended to review specifically coffee grounds as organic repellents against mosquitoes and compare their effectiveness to already existing commonly used popular chemical factory made repellents. However, there was a significant lack of existing research only on coffee grounds acting as mosquito repellents, due to it being a very narrow scope of knowledge, which would not allow for a full length systematic research review paper to be written. Therefore, we decided to incorporate past research papers that tested other natural organic repellents besides only coffee grounds, such as Citronella, Lemongrass, and Neem Oil.

5. Conclusions

Overall, the findings of our paper assert that natural organic repellents such as Coffee Grounds, Citronella, Lemongrass, and Neem Oil are as effective as chemical factory made repellents like DEET in repelling different types of mosquito species. The findings of our paper proved our hypothesis that organic natural repellents will be as effective as commonly used chemical factory made repellents against different species of mosquitoes was correct, as our data, analysis, and results based on past research studies yielded. Although there were cases where no real significant change in repellency rate was observed, like with Neem Oil against mosquitoes in Macchinoi's study [17], other reviewed research papers contend that natural organic repellents usually do have great repellent potential against mosquitoes, rivaling chemically made factory repellents. This systematic review paper fulfilled the purpose of this project by giving a clear answer to the question of how effective naturally made organic repellents are in repelling mosquitoes, and determining whether they are viable to use in the real world, especially when compared to their popular commonly used chemically factory made counterparts.

The findings of our systematic review imply that in the future, pest control companies should begin creating and using more organic natural repellents to use against mosquitoes, as they clearly have a mostly high success rate in repelling mosquitoes, and in certain cases even hold a mortality rate against them. Replacing chemically made factory repellents that mosquitoes build resistance to and harm the environment, is imperative in the fight for preserving our Earth and its environment and animals, as well as fighting to protect the health and well being of people who live close to fields where these repellents are sprayed as well as many workers who physically distribute these repellents in their line of work. Companies should also fund research concerning the development and discovery of newer and even more effective formulas of organically made natural repellents, that could potentially be used to not only combat the threat of mosquitoes, but other harmful pests as well such as ticks, flies, cockroaches, fleas, and wasps.

6. Future Works

Based on the results, findings, and conclusions of our experiment, the scientific field concerning this topic should move forward in further investigating the effectiveness of already established organic natural mosquito repellents, as well as testing organic natural repellents against other pest insects besides mosquitoes such as flies, cockroaches, fleas, wasps, and ticks. Researchers should also look into ways to strengthen already existing organic mosquito repellents, while still keeping them environmentally friendly and making sure mosquitoes and other potential insects will not build up a quick resistance towards the repellents, rendering them ineffective. Besides the already established organic repellents, researchers should actively look for new natural organic repellents to create and use against mosquitoes and other insects and investigate ways to potentially combine different natural organic repellents to use together against insects.

7. Acknowledgments

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8. Conflict of Interest

Authors of this article declare that they have no conflict of interest.

9. Human Studies/Informed Consent

No human studies were carried out by the authors for this article.

10. Animal Studies

No animal studies were carried out by the authors for this article.

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