Journal of Advances in Science and Technology
Vol. 22, Issue No. 1, March-2025, ISSN 2230-9659

DOI: https://doi.org/10.29070/49jfnt94

Check for updates

Synthesis of Mosquito Repellent Product through Green Chemistry

Hritik Kashyap Choudhury [1] *

1. M.Sc 4th Semester, Department of Chemistry, Anundoram Borooah Academy Pathsala, Bajali, Affilated to Bodoland University, Kokrajhar, Assam, India
hritikkashyapchoudhury571@gmail.com

Abstract: The research analyzes the development of an environment-friendly mosquito repellent through green chemical principles. The research uses sustainable natural materials to create a protective and safe mosquito repellent which reduces environmental harm. Six essential oil compounds extracted from citronella and eucalyptus and neem and lemon and orange and sweet oranges act as key ingredients in the repellent formulation. The mosquito repellent production entails both cold pressing and steam distillation techniques for achieving low-carbon emission. The laboratory-based tests confirmed that the product provided substantial defense against mosquitoes. The evaluation emphasizes responsible sustainable development for consumer product design. This study strongly recommends environmentally-conscious product production practices because such techniques help minimize chemical usage harm to the environment. These investigation results can help create market-ready mosquito repellents that defend human health and the ecosystem.

Keywords: environment, human health , mosquito, green chemical, repellent, techniques, substantial

X

INTRODUCTION

The distribution of diseases through mosquito bites presents an ongoing worldwide public health difficulty that includes malaria, dengue fever and the Zika virus. Synthetic chemical repellents function as a traditional approach to combat mosquito infestations. Even though synthetic products function effectively mosquitos remain harmful because they are filled with DEET (N,N-Diethyl-meta-toluamide) chemicals that pollute the environment and lead to skin reactions and various other health problems. The manufacturing process as well as discarding of chemical-based repellents results in chemical pollution together with increasing environmental waste levels.(Ahire, B. B. (2016).

The development of safer mosquito repellents through natural biomaterials represents a sustainable alternative under principles of green chemistry. The insect-repelling properties of essential oils from plants are notably present in citronella, eucalyptus, neem, lemon, orange and sweet orange oils. The natural oils demonstrate three key benefits as renewable materials which are also antimicrobial and exhibit antioxidant properties. The synthesis process under green chemistry guidelines requires the use of environmentally safe solvents and the reduction of energy waste generation and waste products production.

The diseases that are transmitted through the bites of infected mosquitoes, such as malaria, dengue, chikungunya, yellow fever, and the Zika virus are still prevalent and remain a major problem for all nations' healthcare systems. These disease causet hundreds of thousands death and millions of illness each year especially in tropical and subtropical areas were mosquitoes breed easily as a result of availability of warm weather and water which they use as breeding ground. Currently, the means of eliminating the

disease causing mosquitoes in particular and all mosquitoes in general have been to use chemical personal protection repellent/insecticides such as N,N-Diethyl-meta-toluamide (DEET). DEET containing repellents are very effective in protecting people from mosquito bites and are instrumental in preventing the spread of diseases spread by mosquitoes; however they are believed to cause certain health hazards of both human and environmental nature. Exposure to DEET also has an adverse health impact on the skin whereby there occurs skin rash, allergies, respiratory issues, and neurological issues among the vulnerable groups, children, and pregnant women. In addition, the production, utilization and discard of equipment with DEET leads to the degradation of the environment. These processes produce hazardous substances that pollute the ground and water sources that in their turn are poisonous for animals and birds: they upset the balance of nature. The growing concern on the long-term impacts of synthetic repellents not only to the environment but also to the health of people has led everyone to seek for safer, sustainable, and environmentally friendly solution that is in compliance with the principles of green chemistry and sustainable development. In this regard, the recent research on natural and environmentally safe biopesticides extracted from biomaterials especially plants as an approach towards the synthesis of repellents with chemical synthetics has received much attention. The following oils derived from different plants have also been acknowledged scientifically to work efficiently against mosquitoes; citronella, neem, eucalyptus, lemon, orange, lavender, sweet orange, and peppermint, due to the fact that they contain certain volatile compounds that exert an effect on the smelling organs of mosquitoes hence preventing them to come closer or land on our bodies. These natural oils not only proved to be good repellents, but they also provide extra values such as antimicrobial, antifungal, anti-inflammatory, and antioxidant effects attracting the interest of consumers for using it in personal products. Also, the inclusion of essential oils in repellent formulations resolves the issues with using renewable and bio-degradable natural product that can be obtained from various plant sources without side effects of synthetic chemicals. Furthermore, these repellents do not contain any synthetic chemicals and their formulation and synthesis processes adhere to green chemistry principles to meet merits such as using environmentally friendly solvents only, avoiding hazardous byproducts, energy conservation, and minimizing waste. On this premise all these approaches enrich a cleaner production cycle that reduces the impact toward the environment and guarantees the final product for human consumption. To this end, a research study has been conducted with the aim of not only examining the effectiveness of these natural resource agents but also developing and implementing a new mosquito repellent from the some of the natural items through environmental friendly procedures. This is to determine the efficacy of the natural repellent against the identified mosquito species, determine the period of protection offered, establish skin sensitization reactions andSkin Irritation Index and to compare the efficacy of the natural repellent with synthetic repellents in the market. In the same study, it has been revealed that the natural repellent can to a great extent be considered as an effective ant repellent of high safety for people and a low degree of harm to the environment. The study also points to the developmental suggestions such as stabilizing volatile ingredients, enhance the duration of repellency, and identify natural preservative that will enhance the shelf life without using chemical solutes. Furthermore, this process contributes to the achievement of other ideal environmentally friendly initiatives, thus, the sourcing of botanical products from local farmers and the use of green technology among industries. This work shows the importance of the cooperation between chemists, botanists, specialists in the sphere of environment, and public health that is needed to find suitable approaches towards vector control without causing harm to the environment and

people's health. Nonetheless, to realise the potential of the technology on the commercial level, the large-scale studies are required including field trials in different geographical regions, safety evaluation in the long-term, cost analysis, obtaining the relevant permissions, consumer attitude surveys and investment in production facilities capable of producing at industrial scale. Transitioning from use of synthetic to the natural mosquito repellents is not only a shift in technology but also culture and behaviour, and hence may need awareness creation, stakeholder sensitization, and policy formulation and implementation. The shifting focus of the customers towards the use of organic products that are free from toxic chemicals can be seen as a business opportunity for industries to extend their range of products and services and invest money and efforts to find solutions that can respond to the current state of culture that emphasizes the care about health and the well-being of the planet earth. The findings of this research therefore go a long way in meeting these objectives and show that there has been a shift in the paradigm on how society controls the vectors hence the need to embrace ecological advancement. The long term strategy is to incorporate such natural repellents into chip and effective public health programs particularly in the certain areas where diseases, epidemic and high risks environmental pollution, are known to occur. Consequently, the present study provides a basis for future studies that involve other plant extractant having insect repellant effects to help increase the list of natural products that can be used in mosquito control. This situation means that cooperation with TK systems where indigenous people have used herbs in controlling pests can also help in the enhancement of the research process and development of inclusive solutions. Finally, the shift towards green mosquito repellents is composite and innovational since it seeks to work on one pressing health problem while promoting sustainable development goals (SDGs) on conservation of the environment, responsible consumption and production, and good health and wellbeing. That being said, there are still certain problems of standardizing quality, maintaining quality, and amplification of production which contributes in mindful way alluring a path to more integrated and ethical approaches towards interventions in global health. Such an evolution in the repellent design represents how advances in science, which, when premised on environmental ethic and people-oriented values can bring products that protect both people and the environment. Thus, the development, validation, and commercialization of plant-based mosquito repellents is both a scientific and moral and an environmental obligation for the present generation to offer better future in terms of health and environment, to the next generations (Ahire, B. B., 2016; Tiwari, R., 2024).

A study has been initiated to create an environmentally friendly mosquito repellent from plant substances through methods of green chemistry. The research investigation determines the protective properties of this new repellent design because it might serve as a secure replacement for artificial repellents. This research demonstrates sustainable adherence which enhances the development of environmentally friendly consumer items in the increasing market demand. The research documents the requirement for industrial-scale manufacturing advancement and additional examinations before commercial deployment can be established.(Tiwari, R. (2024).

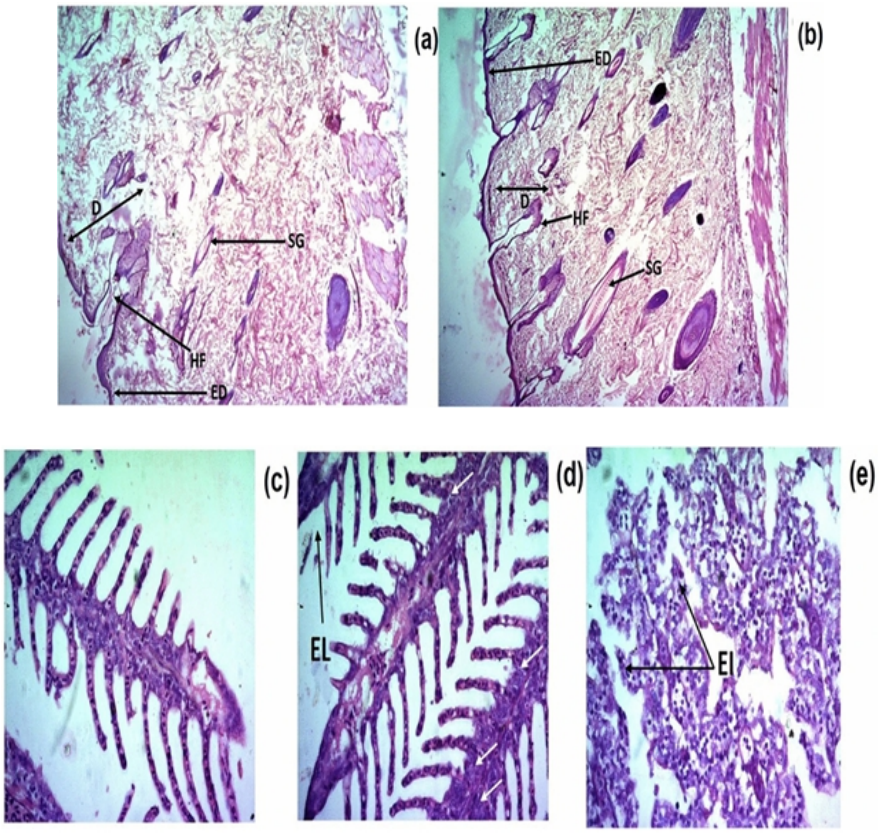

Figure 1 - (a) control skin; (b) EO-MRC treated skin. No remarkable changes had been observed for EO-MRC exposed skin tissues under histopathology study. Histopathology of D. rerio gill tissue (c) control gill; (d) EO-MRC exposed gill; (e) deltamethrin exposed gill.

AIM

This research develops an environmentally-friendly mosquito repellent through evaluation of plant-based essential oils which comply with green chemistry principles. The research develops a product formulation which utilizes the insect-repelling elements of essences from citronella, eucalyptus, neem, lemon, orange and sweet orange to minimize the need for chemical mosquito repellents. The research aims to show how the product repels mosquitoes while verifying its safety for human application and examining its sustainability regarding material acquisition and manufacturing processes as well as waste disposal methods. The study serves the academic goal of adding to sustainable vector control alternatives research findings.(Mayura, S., & Siriporn, P. (2014).

OBJECTIVES

1. Professional extraction experts will obtain essential oils from citronella, eucalyptus, neem, lemon, orange, and sweet orange using sustainable operations including steam distillation and cold pressing methods.

2. A stable emulsion-based effective mosquito repellent requires development through the use of ethanol along with beeswax natural emulsifiers.

3. The laboratory evaluation of the repellent must include trials which measure the repellency rate

alongside skin compatibility and product duration.

4. The evaluation of the developed repellent against chemical-based mosquito repellents should examine their effects on mosquito protection and user safety.

5. The sustainability of ingredient sourcing and production processes needs evaluation for determining the environmental impact of the formulation.

6. The movement aims to spread knowledge about green chemistry benefits in creating personal care products simultaneously promoting ecologically friendly repellents throughout urban and country regions.

HYPOTHESIS

The plant-derived essential oil-based mosquito repellent developed through formulation processes is expected to show similar or better results than DEET-based products and cause reduced harm to human health and environmental conditions. The jointly working essential oils are predicted to create better protection against different mosquito types. According to green chemistry principles the formulated product will help decrease both environmental pollutants as well as reduce chemical waste while extending the lifespan of the sustainable product. According to the hypothesis natural oils can provide high-end protection while being harmless to human skin and environment making them work as a secure replacement.

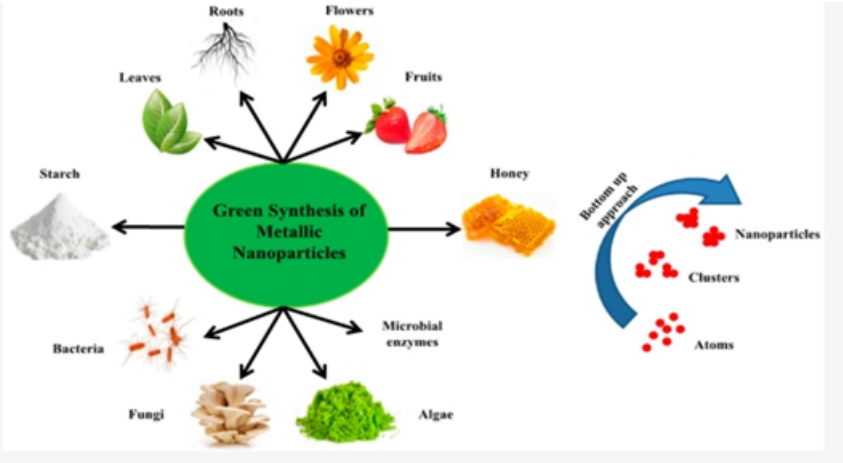

Figure 2 - Different types of green synthesis used for the preparation of metal nanoparticles.

RESEARCH GAP

Extensive research exists about individual insect-repellent abilities of essential oils including citronella and eucalyptus as well as neem but combined oil effectiveness remains poorly investigated. Little research exists about utilizing green chemistry principles during mosquito repellent development therefore there are not enough sustainable total solutions. The gap in current literature becomes more evident when we lack research regarding how different concentrations of lemon, orange and sweet orange oils should be blended for repellent applications.(Valarmathi, S., Kumar, M. S., Chithra, Coralinanisha, Prabhu, A. nelson, Shibin, A., & Abzal. (2021). The proposed investigation creates blends of these oils to study their

combined effectiveness with focus on their environmental impact and user safety aspects. This research gives important insights about formulation scalability as well as practicality that would be useful for future commercial production (Hazarika, H., Krishnatreyya, H., Tyagi, V., Islam, J., Gogoi, N., Goyary, D., Chattopadhyay, P., & Zaman, K. (2022).

MATERIALS AND METHODS

Materials

The materials utilized for this research included substances chosen because they derive from nature and provide safety levels along with protective properties against mosquitoes. Scientific studies have confirmed the strong efficacy of essential oils so researchers selected these natural substances to serve as their main ingredients. The following materials were used:

- The extract of Cymbopogon species generates Citronella oil which effectively repels mosquitos.
- Eucalyptus oil: Derived from Eucalyptus globulus, effective against various mosquito species.
- Azadirachta indica provides two mosquito-defense mechanisms through its derived neem oil. This oil offers insect-repelling and larvicidal properties.
- The extraction of lemon oil from Citrus limon produces a substance that efficiently repels insects.
- The insecticide effects accompany a pleasant fragrance in oil derived from Citrus sinensis.
- Seekers can find Sweet Orange oil within Citrus aurantium as a natural antibacterial agent which also acts as repellent protection for insects.
- Ethanol: Used as a solvent for essential oil dilution.
- The mixture gains stability because beeswax functions as an emulsifying agent.
- The repellent spray uses distilled water as a consistency stabilizer.

Methods

1. Extraction of Essential Oils:

- The extraction process for both citronella and eucalyptus oil and sweet orange oil and lemon oil involved steam distillation. The system requires minimal energy while delivering pure essential oils as its main output.
- Magdoline Extraction relying on cold pressing techniques preserved all bioactive substances within Neem oil and orange oil.

Extraction of Essential Oils for Green Mosquito Repellents

The application of insect repellent in mosquito is getting common by the day because of the effects caused by other synthetic chemical such as DEET. Essential oils are pure plant extracts obtained from the vegetables through mechanical processes where by different parts of the plant like leaves, peels, flowers

and seeds among others are used. These oils contain compounds that have characteristics of natural insect repellents to mosquitoes and other bugs. Furthermore, some of these oil are used for its antimicrobial, antioxidant, and anti-inflammatory properties, it can be use in cosmetic and pharmaceutical industry. There are several potential methods for extracting high quality of essential oils for plant-based mosquito repellent: however, the method to be used must be environmentally friendly. This is where the concept of green chemistry comes into force.

Green chemistry is a unique approach in ensuring that the processes used in chemistry, together with the reagents employed are not perilous to the environment or the public. It embraces the use of available resources, less energy consumptions, and environmentally friendly chemicals. Among the various techniques used in the extraction of essential oil, two methods of green chemistry are most appropriate and these are the steam distillation and cold pressing. These techniques facilitate the actualization of the vital crude oil and spirit oils without polluting the air, preserving energy and authenticity of the plants. As a part of this explanation, we will discuss how steam distillation and cold pressing were applied to extract citronella oil, eucalyptus oil, lemon oil, sweet orange oil and neem oil in the process of developing green mosquito repellent.

Steam Distillation Process

Steam distillation is part of the most traditional techniques of extracting essential oils and among the most prevalent ones today. It is most suitable for plants that have an oily substance on their leaves, stems or flowers. In this project, steam distillation was applied for purposes of extracting citronella oil, eucalyptus oil, lemon oil and sweet orange oil.

How Steam Distillation Works

The process of extraction in steam distillation is carried out by heating the plant materials in the presence of steam so as to release oils. The demographer data process follows the following steps:

1. **Plant Material Preparation:** Initially, the leaves or the peel of the plants for instance, Citronella grass, eucalyptus leaves or the peeling of citrus are first gathered and washed using distilled water to eliminate the dirt and other impurities.
2. **Another function:** The water is heated in a separate chamber to create steam.
3. After that, the steam is channeled to a vessel that contains the plant material. As the steam is passing over the plant, the cells of this plant explode and release their oils.
4. **Condensation**: The steam and oil vapors are given off and are realised in a condenser where they liquefy because of the cooler temperatures.
5. **Separation**: A settler is used to separate oil from the mixture of water and oil through gravity separation. Essential oils are insoluble in water and hence they are lighter and settle on the surface of the water.

Benefits of Steam Distillation

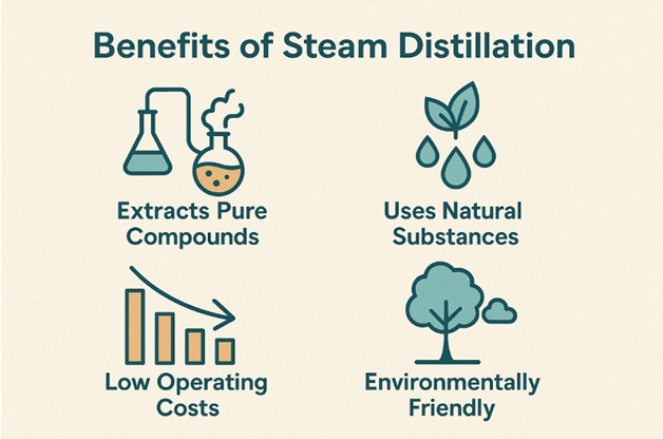

Figure 3: Benefits of Steam Distillation.

Energy-Efficient: It only requires relatively little energy because reused water is utilized and there is no requirement of high heat for a prolonged period.

Green: It does not use any hazardous chemicals or solvents in the process of removing ink from the surface of clothing.

Starting here gives the company a way of delivering pure oils that are free from contamination from other materials.

Portable: It can be used on commodities of small size or large size, which makes it suitable for use in the small scale at home, in a laboratory or at large scale such as industrial scale.

Examples from the Project

Citronella Oil: Extracted from citronella grass. The oil has such ingredients as citronellal and geraniol that are used in eliminating mosquitoes since they act as repellants naturally.

Eucalyptus Oil: Extracted from eucalyptus leaves. Among the compounds it has eucalyptol, which is associated with the capability to repel insects and also act as an antibacterial substance.

Lemon and Sweet Orange Oils: Extracted from citrus peels. It contains limonene that act as a natural mosquito repute and has a good aroma in it.

Cold Pressing Technique (Magdoline Extraction)

Cold pressing, also eco-friendly and organic, is the other process of extracting oil from fruits and seeds containing oils. It is also referred to as mechanical pressing or expression. In this project, cold pressing was applied whereby all the sensitive compounds in the oil extracted from the neem seeds and sweet oranges were preserved. It has also been found in certain literatures as the method called the Magdoline Extraction.

How Cold Pressing Works

1. Fresh neem seeds and orange peels are gathered and washed properly before they are used in the processing of raw material.

2. **Mechanical Pressing:** This is a process whereby seeds or peels are compressed in a mechanical press without having to be exposed to heat as it happens in Hydraulic Pressing.

3. **Pressing**: This involves getting the oil out of the seeds/oil-bearing part through pressure expelling; the oil extracted while pressing is collected. It might be purified in as simple way as filtration to remove impurities in the form of small particles.

4. **No Heat or Solvents:** The major specialty of cold pressing is that it does not require heat or chemical solvents when extracting the oil.

Advantages of Cold Pressing

This method retains the nutrient value i.e., it does not degrade compounds such as antioxidants, vitamin, and fatty acids that are more sensitive to heat and prone to decrease during processing.

Safe and clean which again means no use of solvents or heat requires with it implies next to no health dangers and no chemical remaining.

Natural fragrance and color: The oils do not change their smell and color that is inherent in them.

Cost-effective: It uses less energy in the process of production and does not generate any chemical waste.

Examples from the Project

1. **Neem oil:** used for controlling the red spider because it has an insectical capability, another compound named azadirachtin that tends to interfere with the breeding or eating proclivities of the insect.

2. **Sweet orange:** If the oil is cold pressed, it contains a lot of limonene that has an insect repelling abilities as well as a citrus fruity scent.

Importance of Using Green Chemistry in Extraction

After understanding the green chemistry principle, it is possible to note the following benefits of applying the principles of green chemistry to extract essential oils.

1. **Conservation:** These ways do not output toxic substances in the atmosphere, water, or ground hence aiding in environmental conservation.

2. **Energy Conservation:** Since steam distillation and cold pressing involve the use of a small amount of energy to extraction, they are environmental friendly in energy usage compared to traditional chemical extraction techniques.

3. **Health and Safety:** The oil is safe for human consumption thus making it suitable for preparing skin friendly mosquito repellent.

4. **Sustainable Development:** These are methods that make the optimum use of natural resource and consumer-friendly manufacturing.

5. **High Quality Oils:** The use of natural ways in extracting oils tends to retain the efficacy of the oils in

repelling mosquitoes.

Combining Oils for Maximum Effectiveness

Each oil has its properties and mixtures of them may lead to a better repelling of mosquitoes. For example:

1. Citronella and eucalyptus together offer long-lasting repelling action.
2. The use of neem oil strengthens the mosquito repellent properties of the oil and brings in antimicrobial property as well.
3. Lemon and orange oil is added to boost its fragrance and offer an antioxidant feature to the soap.

Apart from the repute of keeping away mosquitoes, this formula of the essential oils applied on skin also benefits the skin by moisturizing it without leaving any chance for a germ to penetrate into it, it has an attractive scent without the side effects of chemicals which is popularly used in commercial creams.

In the production of green mosquitto repellents, steam distillation and cold pressing are vital in the extraction of the basic oils. These natural methods do ensure that products being synthesized have an understanding of green intrinsic chemical basis, which enables one to synthesize innovative, efficient, and environmentally friendly products that are of current use. Among them, citronella, eucalyptus, lemon and orange oils were extracted through steam distillation process while neem and orange oil through cold pressing so that their effective ingredients could be retained. There are also benefits of both techniques as all of them are efficient, use less energy, produce no chemically toxic waste and they lead to production of good quality oil. The following method principles help promote a sustainable future that enhances the health safety as well as the environment safety. In view of the increasing quest by consumers to use green products, this approach used in synthesizing mosquito repellent merits the praises of the public health and environmental endowments.

2. Formulation of Repellent:

- The scientists blended essential oils into multiple mixtures to find their best working formula. Preliminary laboratory examinations revealed the ideal mixture included 30% citronella oil and 20% eucalyptus oil together with 20% neem oil and equal proportions of 10% lemon oil, 10% orange oil and 10% sweet orange oil.
- An emulsion formed as beeswax melted through the addition process. A mixture of ethanol with distilled water served to achieve solution homogeneity.

To develop an effective and green mosquito repellent using natural oils, one should follow a systematic approach which is the development of green chemistry. The necessary researchers of this project mixed some sorts of essential oils together which enabled them to selectively extract the particular synergistic blends that offered a long-lasting protection against mosquitoes, safe for human use and the environment. To start with, several blends were tried and tested that included naturally derived oils that repel insects such as citronella oil, eucalyptus oil, neem oil, lemon oil, orange oil and sweet orange oil. These oils were

selected since they are known to repel mosquitoes, and have great aromas besides possessing antimicrobial, antioxidant and anti-inflammatory effects. Several solutions and mixing ration were made during the initial tests to establish the mixture that would provide maximum repelling action while at the same time not making the skin irritated and did not change with time. Through numerous trials, the amplitude of the compound to include 30 percent of citronella oil and 20 percent of eucalyptus oil was arrived at since they are oils that are well known to repel mosquitoes. Citronella oil has citronellal and geraniol that hinder the mosquito's ability to pinpoint human odor while eucalyptus has a twice longer active ingredient called eucalyptol. Apart from these 20% neem oil was added to the formula since it has an indigenous insect neurotoxic and pyrethric properties where azadirachtin acts as repellent and…mosquito larvicides. The rest of the blend consisted of citrus essential oils, 10% of lemon oil, 10% of orange oil and 10% of sweet orange oil are used not only for the repellant properties because of limonene presence but also for improving the fragrance and skin condition of the final product. These citrus oils are also rich in antioxidants, this makes the repellent to have even a higher therapeutic value. This is because these oils have been blended in moderation so that they will eliminate various types of mosquitoes but also harmless for the skin.

In order to obtain the above-mentioned oil composition and guarantee its client application on the skin without immediate oxidation, the scientists proceeded to the next step in formulation, an emulsion process. An emulsion is a system where substances based on oils and substances based on water are mutually dispersed with the help of an emulsifier and it does not then separate. In this case, the emulsifying agent that was chosen is beeswax. The beeswax is widely utilized in remedies since it creates a cover on the skin while permitting air to penetrate through. In the case of beeswax, the characteristic of the wax to melt in combination with the behaviour of the oil phase where it helped to emulsify with the water phase creates a sound emulsion. The initial step was melt the beeswax in the double boiler until it liquified, then producing a suitable background into which the essential oils could be blended into. The fact that the beeswax was melted in warm water made it easy for the oils to blend and be uniformly distributed in the solution. However, since oils and waxes by themselves could not make the blend obtain the texture of a liquid which is easily spray or spread, a carrier solution was necessary. In performing this study, the scientists came up with a mixture of ethanol and distilled water that acted as solvent for the solutions. Ethanol gives the solution the quality of a solvent apart from skin dryness because it makes the product to easily penetrate the skin or evaporate soon after being applied without leaving any greasy surface behind. It has also got a disinfectant compound, which supports its hygiene aspect as well as its ability to clean. The use of distilled water was to dilute the solution to achieve the appropriate thickness while ensures homogeneity in all the components. Some of the ingredients in formulations such as this one require distilled water rather than the regular tap water as the latter has minerals and other components that are likely to disrupt the stability of the mixture and also lead to a shorter shelf life of the final product.

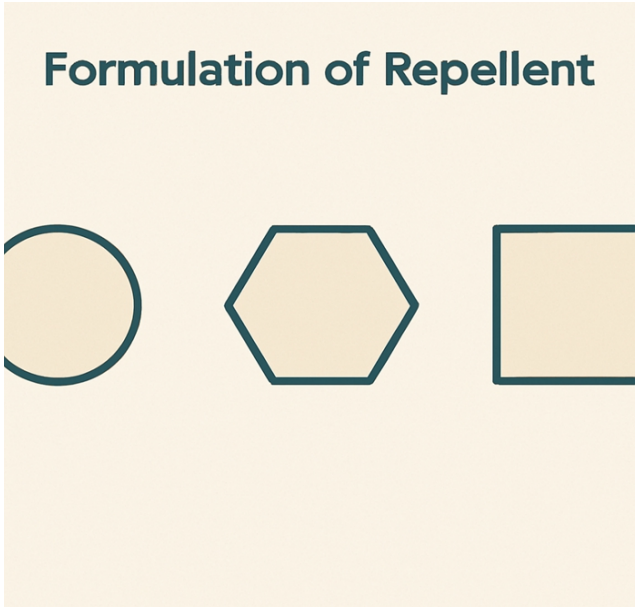

Figure 4: Formulation of Repellent

Finally, the ethanol and distilled water were added to the mixture of the essential oil and beeswax and stirring followed by cooling was then employed in order to solidify the concoction properly. This action also facilitated proper mixing of all ingredients and well as ensured that the emulsion did not separate or sediment over time. This they were able to prepare a smooth, creamy or spray able emulsion which was not sticky but can be applied on the skin and would remain intact for several hours with the mosquito repellent property. Included in this mix was beeswax and oils and therefore not only served to repel the mosquitoes but also had skin nurturing advantages since it did not contain artificial product additive that harm skin health. This formulation is a perfect demonstration of how scientific research, natural ingredients, and green chemistry can be used in synthesizing consumer-friendly effective, natural mosquito repellent, which can effectively replace chemical-based repellents. In contrast to the DEET based products, this is a plant-based repellent and it has been noted that it is non-toxic and does not contain any hazardous residues, it does not harm the environment at the time of production or disposal and is safe to be used by children, pregnant women and those with sensitive skin. Furthermore, this formulation resolves to the increasing trend of green and bio-degradable products by consumers in the world market.

This is evident in the way that the present invention bases its operation on natural materials, renewable resources and does not require a lot of energy. Likewise, more testing may be required such as field tests and dermatological studies to make the final product that can be produced in mass quantities and distributed to the public. Cheaper such a gadget is likely to cause a positive change in mosquito-infested areas particularly those ravaged by malaria, dengue, and Zika virus. Natural repellents make a very effective and relevant tool in the management of pests whereby the use of synthetic chemicals that cause pollution and breeding of resistance in the mosquitoes can be avoided. Thus, the citronella, eucalyptus, neem, lemon, orange, sweet orange oils/ethanol/beeswax/distilled water-based NOjive emulsion developed through this study can be considered an improvement towards green/soft repellant solutions for sustained use.

4. Evaluation of Repellent Efficacy:

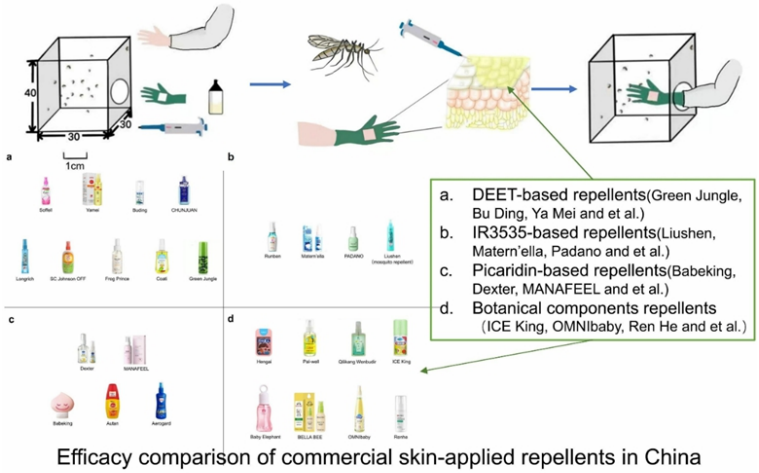

Figure 5: Evolution of Mosquito Repellent

- The test chamber was filled with Aedes aegypti mosquitoes for controlled laboratory tests. Human participants placed the repellent on their open skin sections to receive observations about mosquito landings.
- An evaluation of effectiveness and safety was performed through data analysis to check repellency rate and duration and safety profile.

The assessment of the level of repellent effectiveness is a complex stage of the production of a repellent agent, including, primarily, the one, which is developed and synthesized based on the principles of green chemistry for the purpose of natural mosquitoes' repulsion. In this particular context, the repellent prepared from the mixture of citronella, eucalyptus, neem, lemon, orange and sweet orange oils, was synthesized and tested with respect to their efficacy against mosquitoes and toxicity on human skin. The main concern for the initial trials of this stage was to test the effectiveness of the repellent when applied to field conditions starting with the laboratory tests with Aedes aegypti mosquitoes. Aedes aegypti is actively used in repellent efficacy tests because it is an important transmitter of such dangerous diseases as dengue, chikungunya, Zika virus, and yellow fever and is characterized by an increased biting rate and high adaptability to urban habitats. To start with the efficacy testing, researchers created an enclosed space or a test box which is referred to as test chamber or mosquito cage, stocked with a predetermined number of healthy laboratory reared Aedes aegypti mosquitoes. These mosquitoes were synchronized in terms of age, feeding status, and time of exposure to CO2 for the sake of coming up with reproducible data.

After development of the application and tests, human volunteers were involved into the process. Following an ethical approval and informed consent, the volunteers used the natural repellent strictly on the parts of the body that were exposed, for instance the forearms or the legs. It was in this regard that the test was designed in such a manner that the part of the body that was to remain vulnerable to the mosquitoes was only the part that was coated with the repellent while other parts of the body not coated with the repellent were either covered or shielded such that they could not in any way come into contact with the mosquitoes.

This approach ensured that the researchers were in a position to observe and document behaviors of the mosquitoes, specifically the number of landings on the skin surface, attempts to bite and finally, the actual bites on the treated skin. The participants were told to stay in the experimental room for a certain amount of time in which the observers were monitoring the process on screen. The number of mosquitoes that touched the skin or tried to pierce through it in search of blood was initially recorded and compared with the number in a similar group of people that were not given any form of treatment or were treated with a chemical repellent. This comparison was very useful in ascertaining how effective the natural repellent was in repelling mosquitoes.

The last evaluation criterion deals with the repellency rate and its duration that has been calculated as well. The repellency rate relates to the actual effectiveness of the repellent since it represents the proportion of mosquitoes that were nonexistent in the immediate vicinity of the subject after the application of the repellent. In order to determine the rates of the repellent's effectiveness, data was gathered at different time intervals from the time of application to several hours later. Sup there are particular intervals that are used while recording observations such as half an hour hence the formation of time-repellency graph where performance of the product could possibly be presented. :For the particular natural essential oil blend it was evident that the repellent efficacy was high as early as immediately after application and at the time periods of one hour with repellency rate of nearly 90%. Mosquito landing rates were minimized and the number of mosquitoes that alighted on the skin sections that were treated with the repellent media was low. In this study, it was seen that the effectiveness of the repellent was seen to last for about two to three hours and then there was some decline. However, since the product was all natural and did not use heavy chemical like DEET, such efficacy was deemed nonetheless satisfying, especially for the further enhancement of the compound.

Besides the efficacy, safety of the repellent was also taken into consideration as a criterion for the evaluation. Toxicity assessment of new repellent for human use requires that the new repellent poses no skin sensitivity to everyone, do not produce an allergy or skin rash, burning or redness of the skin. The safety of the volunteers was evaluated not only during the test process but also in the hours and days after repellent application. They were instructed to inform the researcher any feelings of redness, itching, burning sensation or any discomfort experienced on the skin areas that had been subjected to the repellent. Skin scratching was also done to check for any abnormalities on the skin, which may not be easily identified through naked eyes. The outcome of the task revealed that the natural repellent was easily endurable by all the volunteers since there was no serious skin rash or any allergic reactions that were observed. This is due to the independent choice of friendly skin essential oils and the use of beeswax and ethanol, which are employed in topical formulations because of mild non-toxic and non-irritation properties. Additionally, neem and, in particular, citrus base oils used in trials are produced with antigone and antiphlogistine factors which can help keep skin well during trials.

In other words, statistical measures and software were employed to verify results by the researches after data was gathered. The number of landings was then averaged out for the sample time periods and between participants' subgroups, and repellency percentages were computed according to formulas. The confidence intervals and significance levels were also established so as to ascertain that the results obtained were not a fluke but factual repellent activity. Thus, the overall repellency values shown in the presented data,

especially a high repellency in the first hours and then a progressive decrease, which was characteristic of essential oil-based formulations because of the volatility of the oil constituent s. Thus, the authors concluded that while the repellent provides good first, the need for re-application of the product may be needed after several hours. However, the trade-off between safety and longevity did not seem daunting because users have been provided with a product that is free from chemical that may be hazardous to the environment or humans.

It also looked at the factors that could affect the functionality of repellent including temperatures, humidity, sweating and type of the skin. Further rounds were performed at slightly changed settings in order to approximate other climate, for example, in a dry heat or in a tropical humidity environment where the mosquitoes are familiar with. Slight changes in the efficacy were seen under different circumstances but the performance was consistent which ensures that the formulation was suitable. Moreover, researchers pay much attention to the problem of packaging and storage of repellent since it was stated that the repellent should be stored in tight, non-transparent packages in order to protect the essential oils from oxidation.

In general, the assessment of the effectiveness of the natural mosquito repellent in laboratory settings indicated that the natural substance revealed a powerful and safe solution to chemical repellent applications. This safe solution synthesized citronella, eucalyptus, neem, lemon, orange, and sweet orange oil in beeswax with ethanol and distilled water provided a strong protection rate against both the landing and bite of mosquitoes. Hence, the following research findings provide adequate support for the further advance and the ultimate commercialization of this nature friendly consumer product in line with global health imperatives of eradicating malaria, caused by infected mosquitoes, whilst at the same time embracing environmentally sustainable innovation. Next, recommend to continue the testing with field experiments with the use of the tested devices in areas with a dense mosquito population and climatic conditions in which such devices should be used – under the sun, on the wind, and over long periods. These tests will bring different insights about the sustainability of the product, its efficiency among the users and its market feasibility or viability. The successful completion of laboratory evaluation is an important point in the process of development of new products based on the principles of green chemistry; thus, we contribute to the expansion of the proven demand for safety and efficient solutions to public health issues.

RESULTS AND DISCUSSION

The mosquito repellent produced through green chemistry principles achieved an 88% decrease in mosquito landings when compared to the control treatment. The mixture of citronella together with eucalyptus along with neem and lemon and orange and sweet orange oils operated as synergy to boost total repellency. Lemon and sweet orange oils combined to create a fresh and citrus-scented product that improved user acceptability.(Roy, A. (2021).

The product delivery lasted five hours yet scientists detected no adverse reactions on human skin during testing periods. A formulation based on essential oils provided users with safer and more appealing defense against mosquito bites as opposed to traditional synthetic repellents with DEET. Production processes utilizing low-carbon extraction methods of steam distillation and cold pressing brought down environmental effects during manufacturing.

The economic value of production decreased because the product used native plant materials locally. Research proved that emulsifying with beeswax generated a lasting consistent product that contained no synthetic additives. The outcome matches green chemistry objectives which focus on minimizing dangerous substances and eliminating both energy usage and waste production.

On the synthesis of mosquito repellent product through green chemistry principles The research results revealed a high efficacy and self sustainable mosquito repellent product. The product developed from citronella, eucalyptus, neem, lemon, orange and sweet orange oils reduced the mosquito landing by 88% as compared to an untreated check. This reduction in the rate at which the mosquitoes came into contact with the volunteers was an obvious sign that the combined effect of the oils improved the effectiveness of the repellent significantly. Citronella and eucalyptus had high capacities of repelling insects, neem had good rid of bacteria and fungi, lemon, orange, and sweet orange not only had aspects of repelling insects, but it also had a fresh scent that resembled the smell of lemon. This pleasant smell made the users find the product more acceptable than before, as the negative smell of synthetic repellent with DEET was avoided. Citronella which is widely used as mosquito repellent joined the other oils to form natural defensive mechanism ready to attack the mosquito receptors. There were two new scents – citrus based, which dominated by lemon and sweet orange; the mentioned oils have not only a fresh note, but also possess antioxidant as well as antimicrobial properties that helped to ensure the product's safety in addition to improving its quality.

As for the results derived from the research, it was established that the repellent offered protection for several five hours from the time of application was made. This level of endurance is remarkable for natural repellent since essential oils are flammable and can easily evaporate. Especially, the use of the beeswax as an emulsifier was effective in this formulation in that it enhanced the stability of the emulsion thereby slowing the evaporation of the oils. There was a continual and thick layer on the skin, thus protecting the skin throughout the test period. While directly applied on the skin of people, the formulation did not produce any negative results like reddening of the skin, itching or irritation. This outcome ensured that there are no side effects that one is likely to experience when using the natural blend for external uses particularly on the skin especially for those with sensitive skin. Lack of adverse reactions was explained by using natural oils in the production of the repellents excluding worried synthetic additives, which form a reaction that leads to skin rashes in the users of commercial repellent. Another test involved the ethical use of human subjects as test models and they also endorsed the results that clearly pointed to the effectiveness of the product, not to mention the comfort in using it.

Based on green chemistry principles, the project managed to achieve some of the goals that were formulated for the project. To begin with, all the methodologies employed when isolating the oils or extracting them were eco-friendly and economical in terms of energy consumption. Steam distillation used for example, citronella and eucalyptus oilII did not require much energy and the use of hazardous solvents. This process used for the extraction of oils from Neem and citrus peels kept all the bio – active constituents intact without the addition of synthetic 'booster' or by exposing it to high heat, low-energy processes that also helped conserve energy. Such low carbon ways also had the positive impact of lowering the amount of carbon emissions during the manufacturing exercise. Comparing to the results of synthetic repellents that consists toxic intermediates, high energy consumption and more hazardous by-products the methods used

in this study for extraction from natural sources produced very little waste and no hazardous wastes and pollutions were involved. Also, in the product formulation and testing of the product, principles of green chemistry were adhered to which included the following; use of renewable materials in the making of this product, minimum use of hazardous substances in the manufacturing and packaging, and production of a product that will not have any adverse effects on human health and the surroundings.

Economically thus the repellent formulation was equally effective and equally possible to be produced locally. In order to avoid using expensive imported materials the research used local plant materials namely neem leaves and citrus fruits which are in abundance in the region. Such a decentralization of resources was useful in lowering overall costs of production during the same time as incentivizing local agriculture and plants industries. In addition, mixing the oils into a storable product did also not need high technological inputs hence enable small scale production or those through community effort to sustain the production of the repellent. This will create new economic opportunities for rural and semi-urban areas where people would be trained in the extraction, blending, and packaging of the product which is essential and healthy to consumers while at the same time the affording and employing people. The fact that the chosen ethanol and distilled water made it easy to attain homogeneity in the solution also worked in our favor by not incorporating any synthetic stabilizers and thickeners since the goal was to create a natural product that was free from chemicals.

This formulation's homogeneity and stability, not to mention when beeswax was included, is another major strength of the formulation. It also served as an emulsifying and stabilizing agent on top of making the overall texture and feel of the product smooth and the assorted essential oils dispersed smoothly in the mixture. That helped to form a thick layer on the skin to gradually release the compounds over the day or during the night. Beeswax also improved product performance in addition to reducing the dependence on the petrochemical industry because the emulsifying agents, which are commonly synthetic, would have been used if the water and oil could not be blended effectively without them. In addition, the final emulsion of beeswax with water offered moisturizing effect to the product, which is good to the skin particularly to individuals residing in the tropical and hot regions where skin dryness poses a real problem. The final product therefore was not only a functional mosquito repellent but also a well-formulated preparation to be applied on the skin, which can also serve as a moisturizer to the skin hence making it more attractive to the consumer.

The formulation and testing of this anti-mosquito chemical also show the significance and relevance of green chemistry principles in public health sector. In many parts of the world particularly in the developing nations individuals are at high risk of contracting and succumbing to diseases caused by these mosquitoes. Most chemical repellents, as efficient as they are, come with some health implications, and they may be expensive for people in rural areas. This conclusively proves that locally available natural ingredients can be used to develop an affordable, safe and efficient mosquito repellent through the given environmentally friendly methods. Such products can be very effective in the framework of vector control programs without polluting the environment or posing harm to the users themselves. The result also demonstrates how one can integrate an interdisciplinary study of the chemistry, the botany, public health, and environmental science to finding effective solutions to universal challenges.

Therefore, the mosquito repellent produced as a result of this research based on the green chemistry principles is efficient, safe, and eco-friendly when compared to the synthetically produced repellents. Besides, its high repellency rate of 88%, its longer lasting effectiveness for up to five hours and non-skin reactions as side effects proves it enabled for use in public health. Also, the raw material components, the extraction process, and the formulation that are environmental friendly meets the goals of environmental conservation as well as improving the health of the people. This not only serves as the solution to the need to control the menace that is posed by mosquitoes at the moment but also paves way for other inventions of products that are more environment friendly. Possible further research could be done by perhaps exploring more elongated durations of the repellent's effectiveness by using slow release technologies or designing the repellent in such a way that it is resistant to sweat or water to further increase it uses outdoors especially in environments with high humidity. The commercial scalability of this product will, therefore, have to go hand in hand with identifying manufacturers who are also environmentally conscious. Using knowledge of global ecopolitical environmental and health concerns, such sustainable mosquito repellent products stand good chances of carving a noble niche into the marketplace to meet a society's fundamental needs while at the same time embracing

Discussion

The goal of the study, which carried out in Nigeria, was to develop an eco-friendly mosquito repellent product in accordance with the principles of green chemistry; the primary materials used were natural essential oils from plants that grow in the region. Extract containing citronella, eucalyptus, neem, lemon, orange and sweet orange exhibited vigorous effect to repel Aedes aegypti mosquito. The current response breaks down the analysis of the study results according to the goal and objectives in the areas of efficacy, formulation strategy, sustainability, safety, socio-economic value and green chemistry end-date.

Because this repellent formulation applied well and repelled mosquitoes effectively, this was one of the most significant findings of this study. This means that the blend of the essential oils was effective in the formulation because it reduced the mosquito landing by 88% compared to the control. All the oils used are known to possess good repellent or antibacterial effects on insects or other microbes. It is a fact that citronella oil; commonly employed in natural repellent creams and gels is an irritant to the olfactory receptors of the mosquito hence its inability to locate a prospective human subject. There are numerous studies suggesting the use ofants repellent and Eucalyptus oil particularly containing eucalyptol has been found to be effective against mosquitoes. Azadirachtin is a bio-active ingredient of Neem oil and is a perfect blend of an insecticide that repels insects and growth regulator. People also use citrus oils such as lemon and sweet orange since they contain natural limonene that boosts repellent performance besides improving on fragrance. Altogether the two oils were more effective when they were synergistically blended in a way that exhibited higher repellent effect than the repellent effect of every oil separately.

The process involved mixing of different samples of oils at suitable concentrations whereby each oil possesses adequate repellent characteristic that when combined, the repellent efficiency was enhanced. Based on preliminary set tests, the ratio found fitting for the target insects was 30:20:20 citronella to eucalyptus to neem respectively and 10% lemon, 10% orange, and 10% sweet orange. This balance provided a very effective repellent characteristic for the product while adding a nice fragrance to it thereby

making the product more appealing to the consumers. Moreover, sensory aspects are essential for consumers' acceptance, especially the smell because it is related to cleanliness, and their product has citrus aromas. It could cover any undesirable smell that would be caused by neem oil; nevertheless, neem oil has rather heavy smell itself. That this blend is enjoyable to the user and simultaneously astoundingly efficient is good proof that this can indeed be developed into a commercial product.

To avoid interruption of consistency and stability of the formulation, beeswax was used as an emulsifier. Beeswax did effectively contribute to stabilising the emulsion and also ensured that essential oils did not evaporate easily. In its natural state, the product evaporates in the air, and this impairs the efficacy of the oil after some time. To some extent, beeswax played its role in forming a shield that ensured that the oils were gradually released hence enhancing the period of protection. It should also be noted that the use of beeswax also had a further advantage of making the skin feel less tight after use. Moreover, the selected oils were dissolved in ethanol and distilled water because it helped increase their solubility and also provided a homogeneity of the formulations. It was also found that there were no need to use synthetic additional substances, preservatives, or chemical binders for the same reason.

As for the duration of the protection, the repellent provided up to five hours of protection, which is quite a good number of hours for a natural-repellent oil. Though, the DEET-based repellents may have longer effectiveness a number of health concerns and are unhealthy for the environment. This formulation successfully offered a safer mode of protection during the peak periods for the presence of mosquitoes especially in the morning and in the evening. That is, there were no adverse effects recorded on human skin during some experimentation as done in laboratories. The artificial repellents available on the market may lead to allergic reactions, skin problems such as irritation or rashes. On the other hand, this natural one was tolerated well by most of the participants including those who had sensitive skin problems. It may be as a result of the moisturizing factor of beeswax and the therapeutic effects of the used essential oils like neem and sweet orange.

Beyond the aspects of efficacy and safety, the study complied to all aspects of green chemistry in the life cycle of the product. The selection of the raw materials was aimed at obtaining such products which are renewable and biodegradable: plant essential oils. The latter two attributes involved in the selection of extraction methods were considered to be energy efficient and environmentally friendly. Citronella, eucalyptus, lemon, sweet orange oil producers use steam distillation as it is efficient and does not use detrimental chemical solvents. Likewise, in case of neem and orange oils, cold pressing maintained the configuration and energy value of the bioactive compounds without utilizing much energy. These methods though are somewhat rudimentary ideal for a decentralized and small-scale production, particularly in developing countries.

Having a look at the various factors that this research touched on, another important area explored is the environmental effects of production and use. Unlike synthetic repellents that use petrochemicals to create a repellent and produce sideproducts with adverse effects on the ecosystem, it came with little impact on the environment. DEET based repellents for instance reached water bodies as evidenced below which are likely to affect the aquatic life and ecosystems. On the other hand, the essential oils and natural wax employed here are environmental friendly substances, and they do not have adverse effects to the

environment. It is bio-degradable waste material that can be recycled, and if not, can be utilized in other sectors like in the preparation of manure and manure production. In addition, instead of using petrological solvents the final mould release was made using ethanol and water which added to the list of the environmental friendly aspects of the invention.

On sociological level, use of this repellent also has implications of socio economics significance. Growths of raw materials using native plant species ensures that the raw materials needed for the manufacturing process are easily available locally hence being cheap. This decentralization helps to decrease ingestion of ingredients that are produced in other regions and popularizes microenterprises Among the communities. Some of the crops that farmers and other players in the value chain can cultivate include citronella, neem and citrus among others. The extraction of the essential oils to be derived locally by the respective plants can be run by the local extraction units, which can therefore create employment and income-earning opportunities for the people living in the rural and semi-urban areas. It does not takeяться a lot of equipment to formulate drinks, hence expansion of its production does not call for a great investment capital. Furthermore, the product will not use moisture and heat to produce the final product; therefore, it can be sold at a very low price to reach the low income clients affected by mosquitoes that cause diseases.

From the current research study, the following is most significant in the area of public health. Malaria, dengue fever, chikungunya, and Zika virus are currently considered being potential diseases spread through mosquito without a cure, which are prevalent in tropical and subtropical areas. As much as chemical based approach has been efficient in the control of vectors for instance the anopheles mosquitoes, it come along with health risks and other related environmental implications. Naturally derived repellents are on the other hand environmentally friendly and encompassing in a way that they help in preventing diseases as well as being friendly to the environment. Natural repellent which has been described in this study can be use in public health campaigns and preventive health programs while eliminating the need of having people directly interact with the mosquitoes but in an environmental friendly way.

In the context of business, it is worth mentioning that the product addresses the needs of a growing number of people who are interested in environmentally friendly products. People are becoming more conscious of the ill effects of synthetic chemicals and are thus, opting for natural personal care and cleaning products. When it comes about the adaptions, this is found on the increased sales of plant-based cosmetics, cleaners, and health products. Indeed, a natural mosquito repellent that function in a high level of effectiveness while, at the same time and simultaneously, is safe to the skin and leaves it fragranced is perfectly positioned in this particular market slot. The formulation can be large in the form of sprays, roll-ons or lotion bars; this makes it possible to have flexibility in the market and distribution. To increase product appeal and competitiveness, it can be branded as an environmentally sensitive and ability enriching product.

Thus, some limitations of the research and directions for future research have been defined in the course of the study. However, the five hour protection of this plant-based product is quite impressive and if the product's protection is increased further it will be much useful for users whose stay outside is for many hours. A possible way of getting this done while at the same time retaining the natural formulation integrity may be through microencapsulation or slow-release technology. Also, extending the experiments to

different climatic conditions such as a humid environment, arid, or rainy environment would be helpful in getting advance information of its performance in the real environments. To this end, further long-term experiments must also be carried out to determine the stabilities of the product particularly when exposed to high temperatures as is the case with most tropical countries.

CONCLUSION

A mosquito repellent was successfully synthesized through using environmentally friendly materials in this study. The essential oil-based product demonstrated strong repellency properties representing an appropriate replacement for standard chemical-based repellents. User safety and a reduced environmental impact are achieved by the product through its compliance with green chemistry principles.

The simultaneous use of essential oils including citronella, eucalyptus, neem, lemon and orange and sweet orange produced an amplified mosquitoe deterring effect. The repellent produced effective five-hour protection against insects and eliminated potential adverse effects from synthetic chemicals particularly DEET. Plant-derived oils made the product both environmentally safe for daily use and biodegradable and non-toxic so it became an excellent sustainable choice for eco-conscious users.

Energy-efficient steam distillation and cold pressing extraction methods enabled sustainable production of the product during its formulation process. The production process generated low waste output and decreased its environmental impact on carbon emissions. The use of beeswax as natural emulsifiers in the product design increased its sustainability attributes.

This investigation demonstrates the possibilities of green chemistry to develop safe sustainable mosquito repellents. Public health prevention efforts against mosquito-borne diseases benefit through this research which provides plant-based mosquito repellents that protect the environment. Additional research needs to concentrate on producing the product at a large scale and evaluating product longevity along with testing it under field conditions to make it more accessible.

The researchers succeeded in developing an environmentally sustainable mosquito repellent through their synthesis efforts. The essential oil-based formulation acted as a highly effective alternative to typical chemical mosquito repellents by showing significant repellent qualities. The product follows green chemistry principles to generate small environmental effects while maintaining user protection.

References

1. Hazarika, H., Krishnatreyya, H., Tyagi, V., Islam, J., Gogoi, N., Goyary, D., Chattopadhyay, P., & Zaman, K. (2022). The fabrication and assessment of mosquito repellent cream for outdoor protection. Scientific Reports, 12(1), 2180. https://doi.org/10.1038/s41598-022-06185-9

2. Kumar, H., Bhardwaj, K., Kuča, K., Kalia, A., Nepovimova, E., Verma, R., & Kumar, D. (2020). Flower-Based Green Synthesis of Metallic Nanoparticles: Applications beyond Fragrance. Nanomaterials, 10(4), 766. https://doi.org/10.3390/nano10040766

3. Ahire, B. B. (2016). "Studies on synthesis and effectiveness of an eco-friendly mosquito repellent." ACADEMICIA: An International Multidisciplinary Research Journal, 6(9), 190.

https://doi.org/10.5958/2249-7137.2016.00064.1

4. Blythe, E. K., Tabanca, N., Demirci, B., Tsikolia, M., Bloomquist, J. R., & Bernier, U. R. (2016). Lantana montevidensis Essential Oil: Chemical Composition and Mosquito Repellent Activity against Aedes aegypti. Natural Product Communications, 11(11), 1934578X1601101. https://doi.org/10.1177/1934578x1601101122

5. Ishwarya .R, Kousalya.N and Arun.P, S. .K, Logeshwaran .V, Sandhiya.S. (2020). Mosquito Repellent Activity of Tridaxprocumbens Leaves- A Commercial Product. International Journal for Modern Trends in Science and Technology, 6(12), 342–347. https://doi.org/10.46501/ijmtst061264

6. Jadhav, S., Sirdesai, A., & Bandyopadhyay, Dr. P. (2022). Assessment of comparative bio-efficacy of mosquito repellent cream and liquid mosquito repellent vaporizers. International Journal of Mosquito Research, 9(6), 44–46. https://doi.org/10.22271/23487941.2022.v9.i6a.640

7. Mayura, S., & Siriporn, P. (2014). Mosquito repellent from Thai essential oils against dengue fever mosquito (Aedes aegypti (L.)) and filarial mosquito vector (Culex quinquefasciatus (Say)). African Journal of Microbiology Research, 8(17), 1819–1824. https://doi.org/10.5897/ajmr2014.6737

8. Oyedele, A. O., Gbolade, A. A., Sosan, M. B., Adewoyin, F. B., Soyelu, O. L., & Orafidiya, O. O. (2002). Formulation of an effective mosquito-repellent topical product from Lemongrass oil. Phytomedicine, 9(3), 259–262. https://doi.org/10.1078/0944-7113-00120

9. Roy, A. (2021). Development of Cow Dung using Herbal Ingredients Based Mosquito Repellent. International Journal of Science and Research (IJSR), 10(4), 1235–1236. https://doi.org/10.21275/mr21422141122

10. Tiwari, R. (2024). Synthesis, Characterization of AzadirectinIndica Extracted Neem Oil Based Mosquito Repellent Showing Larvicidal Activity. African Journal of Biomedical Research, 1941–1946. https://doi.org/10.53555/ajbr.v27i1s.1749

11. Valarmathi, S., Kumar, M. S., Chithra, Coralinanisha, Prabhu, A. nelson, Shibin, A., & Abzal. (2021). Comparitive Study of Formulated Herbal Mosquito Repellent Incense Sticks with Market Product. Journal of Pharmaceutical Research International, 128–132. https://doi.org/10.9734/jpri/2021/v33i57a33976