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Promoting health: Introducing an eco-friendly herbal mosquito repellent extracted from local sweet orange peels

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Abstract

With time, mosquitoes have grown to pose a severe threat to human health. Thus, the necessity to provide a sustainable solution to the mosquito problem in our environment emerges. Using mosquito coils and other locally produced ones has been documented in previous research. There is a health danger from mosquito coil smoke. Severe headaches, nausea, vomiting, respiratory issues, and exacerbation of asthmatic patients' respiratory symptoms have been reported as a consequence. Although numerous methods of mosquito control exist, an affordable, long-term solution still has to be created. The research goal was to use locally available plant materials in distant places to create a safe, economical, and environmentally friendly herbal insect repellent. Orange sweet peels are used to extract oil, which is then followed by material shrinkage and distillation. The two most common chemical components found in orange peels are limonene and linalool molecules. These findings suggest that the essential oil extracted from sweet orange peel may possess antibacterial and antioxidant properties, making it a highly efficient spray-on mosquito repellant for a variety of mosquito species.

Keywords: Human health; Antioxidant; Locally sourced plant resources; Insect repellent

1. Introduction

Mosquitoes are a common vector of dengue, malaria, and yellow fever, all of which can be lethal when not handled effectively and are found throughout Africa. The World Health Organisation (WHO) estimated that 15,000 people of all ages die in Nigeria each year. Both urban and rural regions need to implement mosquito prevention strategies; the most effective strategy is to limit mosquito reproduction with non-hazardous insecticides (Neeraj et al., 2010). Although the formulations of mosquito repellents on the market have an impressive safety record, children may experience rashes, swelling, eye irritation, and other major issues due to the repellents' toxicity towards the skin and neurological system (Neeraj et al., 2010). This prompted a few scholars to conclude that natural mosquito repellents made of biomaterials are better than chemically based ones. Plants provide the bioactive ingredients in biobased insect repellents. These bio-based treatments are essential for getting rid of pests in areas where using chemicals is prohibited because of resistance in mosquitoes and environmental concerns. These mosquito repellents contain a variety of ingredients, including basil (Ocimum basilicum), oils of Castor, Cedar, Clove, Fennel, Citronella (Trongtokit et al., 2005), Eucalyptus, Neem

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(Caraballo et al., 2000), Rosemary and Catnip oil of Nepeta species and it includes nepetalactone, celery extract (Apium graveolens), and Solanum villosum berry juice. These natural resources have a pleasant flavour and are beneficial to the environmenet al., 2008). Human perspiration contains lactic acid and carbon (IV) oxide, which attracts mosquitoes to humans. The reason for the attraction is due to chemo-receptors found in mosquito antennae that detect perspiration odour. Natural mosquito repellent has the unique ability to cover up human odour. The majority of plants have substances that can be utilised to fend against plant-eating insect attacks. Repellants, feeding deterrents, poisons, and growth regulators are among categories for these. Plant-based repellents are readily biodegradable and pose no threat to people or domestic animals. When it comes to human safety, natural products are safer than synthetic ones (Patel and Oswal 2012). Therefore, a thorough investigation must be conducted to investigate environmentally safe biological components for the management of insect pests.

Diseases like malaria, encephalitis, yellow fever, dengue fever, and epidemic polyarthritis are believed to be caused by a number of mosquito species (Narsinah et al., 2004). The World Health Organisation (WHO) estimates that these illnesses claim the lives of around 3 million people each year. The best course of action is always to avoid mosquito-borne infections like malaria, even though there are numerous therapies available. Thus, repellant for mosquitoes and other insects was born. By using topical or other repellent for insects, mosquito bites can be avoided. Naturally occurring or synthetic repellents are both possible to make. Inherently coiling mosquitoes: Most synthetic chemical-based repellents, especially DEET, are easily taken in via the skin and can cause several accidental poisonings, especially in children. They have the ability to poison wildlife as well. The environmental effects of DDT (dichlorodiphenyltrichloroethane) are highly evident, and DEET-N,N-Diethyl-meta-toluamide is thought to be a carcinogen, teratogen, or mutagen. Thus, the need arises for an additional method of insect repelling that is preferably non-toxic. Insect and mosquito repellents are known to be found in many natural substances (Braverman et al., 1999). Mosquitoes carry a great deal of tropical and subtropical diseases that can be fatal to humans. The most prevalent and deadly diseases associated with mosquitoes are malaria, yellow fever, filariasis, schistosomiasis, Japanese encephalitis (JE), and the most deadly dengue hemorrhagic fever, which is spread by Aedes aegypti (Das and Ansari 2003). (Udonsi, 1986). Wuchereria Bancrofti is spread by the pantropical pest mosquito Culex quinquefasciatus, which also carries filariasis (Samuel et al., 2007). Due of their roles as vectors for dengue and filarial fever, respectively, which are major public health issues in nations like India, attention has been drawn to the control of Aedes aegypti and Culex quinquefasciatus.

Mosquito repellents are compounds that make surfaces unappealing to insects. It can be used on the skin or other surfaces to deter mosquitoes from landing there. These chemicals usually include secondary compounds that help with the delivery of cosmetic appeal in addition to active ingredients that serve as mosquito repellents. These repellents come in a variety of forms, including creams, lotions, and oils, although they are most frequently offered as aerosol treatments. There are also repellents that work by producing sounds; these include ultrasonic repellents, which produce high frequency sounds that are incomprehensible (Sah et al., 2010). Numerous materials have been used previously to deter mosquitoes. These consist of tars, muds, oils, plant extracts, and smoke. The majority of insect repellents function by obstructing the mosquito's homing mechanism. Numerous chemical receptors are included in this homing system, which is found on the organism's antennae. The lactic acid, carbon dioxide, and excretory chemicals found in the sweat of warm-blooded mammals draw female mosquitoes.

Lactic acid, which permeates from warm-blooded animals' skin spontaneously, activates the chemical receptors. Conversely, evaporative repellents such as DEET (n-ndiethylmetatoluamide) also vaporise when used directly. According to Chew et al. (2004) and Sah et al. (2010), repellents induce the lactic acid receptors to block, preventing mosquitoes from flying upwind and causing them to lose connection with their target. In effect, this "hides" the protected individual from the mosquito. The tropical environment of the Northeast makes it a breeding ground for mosquito-borne diseases including dengue and malaria. A vector for the spread of these fatal illnesses is the mosquito. It seems more crucial that we defend ourselves against their bites. Government-provided literature on mosquitoes generally suggests using insect repellents on a regular basis, with DEET being the most common chemical ingredient. Long-term DEET use, either directly or indirectly, is linked to a number of health issues, including headaches, breathing issues, heart attacks, etc. Many are searching for safer insect repellents these days, ideally with a herbal base. Many nearby plants possess specific essential oils that are frequently shown to be effective insect repellents. These plants, which are mostly shrubs or herbs, are frequently regarded as weeds. Regretfully, only certain ethnic groups are aware of their use. From ancient times, many ethnic groups have included the usage of herbs as insect or mosquito repellents in many of their cultural practices.

In addition to causing a variety of allergic symptoms, such as swelling and stinging, mosquito bites can spread bacteria from humans to animals. Zika, dengue, and yellow fever pathogens are mainly conveyed by the Asian tiger mosquito, or Ae. albopictus (Skuse) (Kraemer et al., 2019). According to Geetha (2014), controlling mosquito populations and protecting people from mosquito bites are currently the most efficient approaches of preventing these illnesses. Use of insect repellents is one of the most popular methods. Two types of repellents are available for insects: contact and spatial. They use distinct action modes. According to Choi et al. (2016), spatial repellents are often quite volatile and have the ability to permeate into the air in treated areas. Examples of these chemicals include certain synthetic pyrethroids and botanical compounds.

Sporadic repellents emit vapours that cause host-seeking mosquitoes to behave in an unpleasant manner and have a negative physiological reaction. Contact repellents such as DEET, picaridin, and IR3535 work by directly suppressing or reducing the amplitudes or the frequency of action potentials that come from olfactory receptor neurons. This reduces the mosquito antennal response to a range of attractive human and veterinary odorants.

The new norm for synthetic repellents, represented by DEET, is to apply them directly to human skin. According to Noris et al. (2010), there are a number of environmental and public health issues with the use of artificial repellents to reduce mosquito populations. Nevertheless, natural essential oils (EOs) have drawn our attention because of their benefits, which include low toxicity, numerous modes of action, minimal residue, and a broad spectrum of activity against mosquitoes. Strong aromatic components in volatile oils that impart a particular flavour, fragrance, or odour to aromatic plants are known as essential oils (EOs). It has been discovered and used that several natural essential oils have the ability to repel insects. Primarily utilised in several formulations, citronella oil was the most popular among them prior to the 1940s (Ray et al., 2017). Lemon, lavender, clove, and eucalyptus oils are some more. After synthetic repellents became popular and developed quickly, the creation of natural repellents was disregarded in modern times. However, the growing desire for safe, environmentally friendly alternatives has expedited the investigation and innovation of natural essential oils for use as mosquito repellents once more.

Mosquitoes have become a serious menace to human health over time. Therefore, the need to create a long-lasting remedy for the mosquito infestation in our surroundings arises. Many techniques for controlling mosquitoes have been found, but a long-lasting, low-cost solution must be developed.

The aim of the research was to develop a mosquito-repelling herbal solution that is safe, affordable, and eco-friendly by utilising locally accessible plant resources.

The primary objective of the research initiative is to produce pesticides that repel mosquitoes using plant extracts at a low cost, with high efficacy, that are widely accessible, especially in remote areas; Identification of the extract's chemical components; To ascertain whether the extract has any mosquito-repelling qualities; Use the extract to make a repellant for mosquitoes.

According to research reports, mosquito coil smoke is a health risk. It can cause severe headaches, nausea, respiratory problems, vomiting, and worsen respiratory symptoms in asthmatic people. In order to prevent mosquito bites and diseases, it is necessary to create mosquito repellents that don't endanger human health and that use biodegradable plant products.

The creation of natural plant material mosquito repellents and their chemical analysis will be the main objectives of the initiative. Mosquitoes carry the Zika virus, yellow fever, chikungunya, malaria, and other ailments. Among these, in countries where it is endemic, malaria adds greatly to morbidity and mortality. Out of an expected 228 million cases that were recorded, the World Health Organisation (WHO) predicts that 405,000 individuals died from malaria in 2018 (WHO 2018). Sub-Saharan Africa accounted for the majority of recorded cases, with pregnant women and children under five years old being the most susceptible to malaria. According to data from the World Health Organisation (WHO, 2018), children accounted for approximately 67% (or 272,000) of all deaths that year. UN Sustainable Development Goal 3.3 (good health and wellness for everyone) involves an ambitious target to end the malaria epidemic by 2030. This could be achieved by reducing or eliminating the frequency of transmittable bites from mosquitoes, which have the potential to cause systemic reactions such as urticaria and skin edoema, as well as additional illness, ache, discomfort, and allergic responses in individuals who are extremely sensitive (Islam et al., 2017). The goal of malaria management has evolved throughout time to include eradicating or drastically lowering mosquito populations. There are numerous strategies for managing the malaria vectors. Long-term insecticidal nets (LLINs) and indoor residual spraying (IRS) are the two most important management measures recommended by the World Health Organisation. However, these methods are useless in outdoor environments where people spend their day and early evenings. Braack et al. (2015) observed the biting behaviours of African malaria vectors to identify the human body parts they usually bite. The study used vectors from Anopheles arabiensis from Malahlapanga, South Africa, and Anopheles gambiae and funestus from the northern region of Uganda. The outcome showed that the ankles and feet are where more than 93% of mosquito bites occur on those who are sitting or standing outside. Additionally, the study showed that mosquitoes are attracted to the smell of feet and ankles. By covering or shielding the feet and ankles, however, mosquitoes are unlikely to bite higher than the ankle. Instead, they will go for other hosts with exposed feet and ankles. Reddy et al. (2011) investigated Anopheles melas and An. gambiae behaviour outdoors on Equatorial Guinea's Bioko Island. Mosquito bites outdoors were more probable at night and in early in the evening and early in the day according to the survey. These results underline the necessity of more research on the significance and immediacy of creating novel strategies to prevent mosquito-borne illnesses when people are outdoors. Applying repellents to oneself to guard against mosquitoes has become a helpful habit that can lessen and/or stop the spread of many diseases carried by insects. Known as volatile chemicals, mosquito repellents work by repelling mosquitoes away from human skin and away from their source, preventing contact and bites. For outdoor protection, a wide variety of repellent-based solutions, including lotions, roll-ons, and sprays, are available on the market. Nevertheless, the majority of these apps only offer a few hours of extremely limited protection. This encompasses therapeutic skin treatments as well, which need to be used frequently because of environmental factors including high perspiration, humidity, and activity from insects. Lower-income neighbourhoods would not be able to buy repellent goods because of the regular application required. It is therefore necessary to provide longer periods of protection against mosquito bites.

The efficiency of ethyl butyl acetyl amino pro-pionate (IR3535) repellent in combination with nonanoic acid against An. arabiensis biting for up to four hours was investigated by Izadi et al. (2017). This research endeavour aimed to achieve long-lasting repellency.

In terms of both fatality and repellency, nets infused with the repellant N,N-diethyl-3-methylbenzamide (DEET) lasting six months proved to be fairly effective against Aedes aegypti, according to Guessan et al. (2008). Akhtar [12] studied the repellent's release from the polymer matrix and developed a polymer matrix based on natural mosquito repellant. Sibanda et al. (2018) reported on the slow release of DEET from polymer fibres. Their results showed efficiency for a maximum of twenty weeks against An. arabiensis.

An overview of repellent formulations with monitored release is given in this work in terms of:

- The fundamentals of making formulations based on repellents.
- The method by which repellents are released from formulations.
- The efficacy against mosquitoes.

Additionally, there is a presentation and discussion of mathematical models for repellant release and application.

Wearable technology based on commercially available insect repellents Applying personal protection goods has been linked to a decrease in illness incidence and mosquito bites, according to earlier research.

The military gear sprayed with repellents proved to be successful in drastically lowering mosquito bites in the covered areas, according to Schreck and Kline (1989). Malaria infections have been shown to be effectively decreased with repellent, such as DEET-based detergents. Moreover, multiple studies have documented the effectiveness of distinct spray-on repellents on diverse mosquito species.

2. Materials and Methods

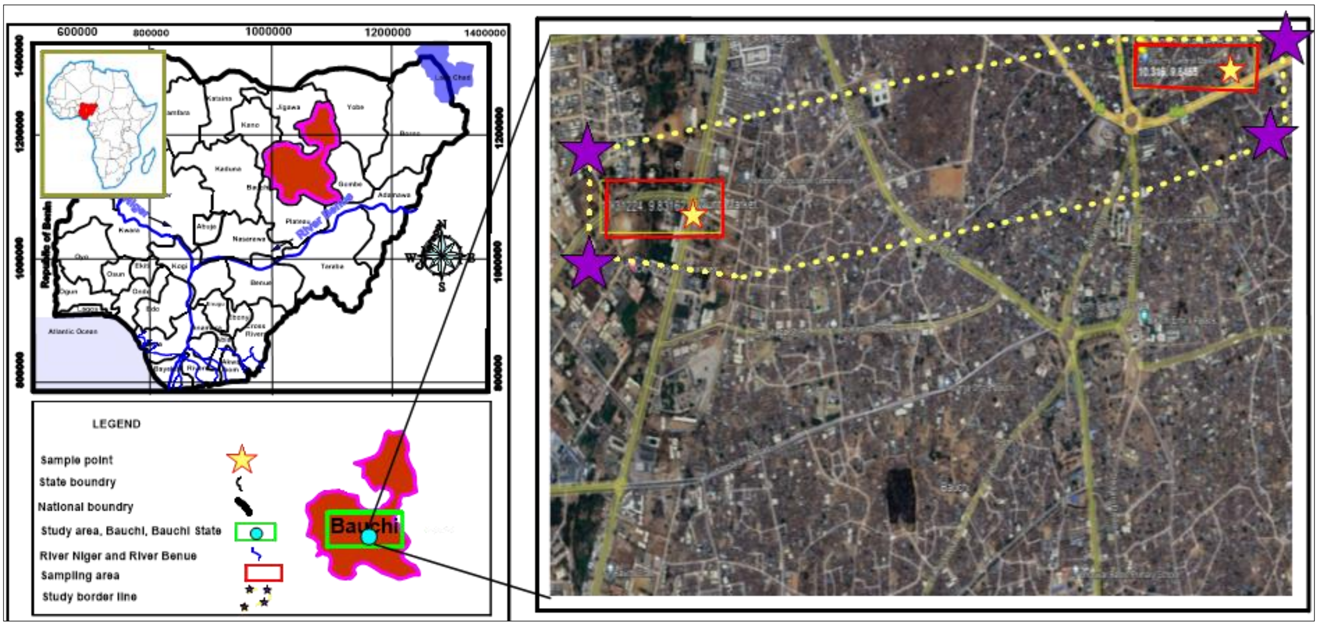

Figure 1 A map showing the location area and the sample points (modified after Akagbue et al., 2023a; Baba Aminu 2023; Akagbue 2023b; Abdulbariu et al., 2023b; Ibrahim et al., 2023.; Akagbue et al., 2023c)

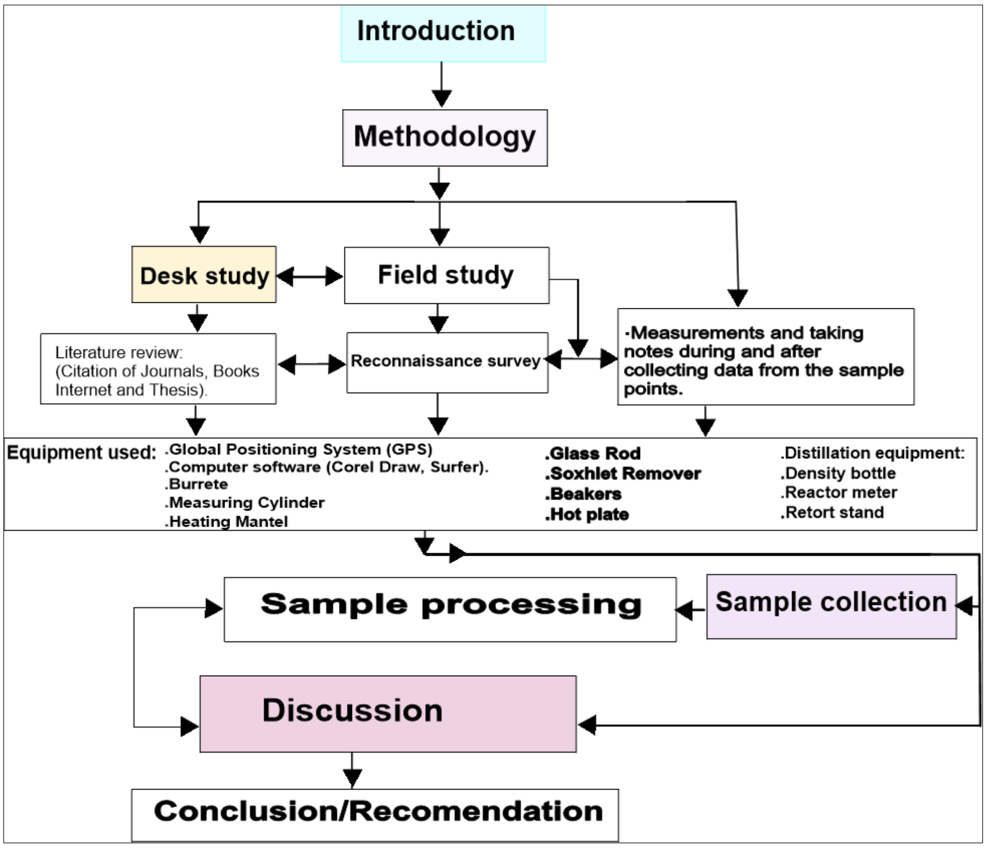

Figure 2 A research methodology flow chart (modified after Baba Aminu et al., 2023; Abdulbariu et al., 2023a; Babale et al., 2022; Aminu et al., 2022).

2.1. Materials

Burrete, Measuring Cylinder, Heating Mantel, Glass Rod, Soxhlet Remover, Beakers, and Distillation equipment analytical Assessing equilibrium, Density bottle, Reactor meter and retort stand

2.1.1. Chemical and Reagent

Hydrochloric acid (HCl), phenolphthalein, N-hexene petroleum ether, distilled water, alcohols, and potassium hydroxide (KOH)

2.2. Gathering of Samples

The samples of the fresh orange peel were taken in Wunti market, Muda lawal marke, Central market in Bauchi state's capital city.

2.3. Sample Preparation

The samples were cleaned with water, let to air dry, and then dried again. The plant peels were cut with a knife and spread out on a clean piece of plywood. A manual grinding mill was used to turn the dried peels into a powder, which was then kept in an airtight container.

2.4. Extraction

1000 millilitres of n-hexane will be placed in a soxhlet device together with 500 grammes of the powdered sample. For almost six hours, the oil will be extracted at temperatures between 68 and 68 degrees Celsius. To lower the temperature and let the leftover diethyl ether to evaporate, the extract will be left overnight.

2.5. Preparation of Liquid Repellent

All that is needed to make pesticide is plant oil; this oil contains limonene, which can be extracted and used to generate insecticide spray. Following the crushing, drying, and alcohol-soaking process, the mixture is passed through filters to let the alcohol evaporate.

2.6. Physical and Chemical Analysis of the Extracted Oils

2.6.1. Solubility

In the test tube with eight drops of water, four drops of extracted oil will be added. Using a glass rod, the substance will be well mixed. Five minutes are allotted for the mixture to remain. We're going to see two distinct liquid stages. It will be determined whether the essential oil is soluble in water by measuring the pH of the water phase.

2.6.2. Boiling Point

A capillary tube with a sealed end is inserted into a tiny test tube with the closed end facing upward and 5 ml of the plant's extracted oil is added. The test tube, fixed on a ring stand, is going to have a thermometer attached to it. Place a 250 ml beaker on the hot plate after halfway filling it with water. Carefully slide the test tube containing the combination and thermometer into the water-filled beaker. The resulting mixture will be cooked slowly on a hot plate. A few bubbles will emerge from the end of the capillary tube as the oil approaches boiling. The temperature when the oil started flowing into the capillary tube will be recorded at the moment where steady bubble streams are visible. We are going to carry out a similar experiment with orange peel oil. (Hognadottir et al, 2003).

2.6.3. Specific Gravity (Sg)

A dry density bottle with a capacity of 25 millilitres will be weighed in order to establish the initial weight of W0. Weighing it again to determine yield will occur after adding water (W1). When the water is gone, the bottle will be clean. It will then be weighed to create (W2) after essential oil has been applied. Next, using the data below, the specific gravity will be determined.

$$\text{Specific gravity } (Sg) = W1 - W2/W3 - W2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where, °C
WI = Specific gravity bottle mass + oil extract
W2 = The specific gravity bottle's empty mass.

W3 = Specific gravity + bottle mass Water

2.6.4. Refractive Index

The refractive index of the oils will be ascertained using Abbe's refractometer. Refractive index is represented as nD 25; n is the refractive index measured with sodium light (D-line) at 25 °C.

2.6.5. Acid Concentration/amount

A dried conical flask will be filled with 10 g of the oil extracted by weight. Three drops of phenolphthalein and 50 millilitres of ethyl alcohol will be added to the conical flask. The solution will be titrated up to the end point (pink colour) using 0.1N KOH. It will be noted how much KOH was used in the titration. Maria et al., (2012). using the following formula, the acid value will be determined:

$$Acid\ value = TD \times N \times 56.1/M \ldots\ldots\ldots\ldots (2)$$

Where, TD = Titre Difference = B - S
B = Titre value blank;
S = Titre value with sample
N = Normality of titrating solution
M = Mass of sample (g)

2.6.6. Saponification Value

Two grammes of grape peel oil will be placed in a 250 ml conical flask along with 50 ml of 0.5 M alcoholic KOH. The combination will be continually stirred for an hour, after which reflux will occur. Add three drops of indicator phenolphthalein to the mixture, then titrate it with 0.5 M HCl until the pink colour disappears. The saponification value will be obtained using the following equation:

$$SV(mg\ KOH/g\ sample) = S - B \times M \times 56.1 \ldots\ldots\ldots\ldots (2)$$

Weight of sample

Where,
S = Sample titre value (mL),
B = Blank titre value (mL),
M = Molarity of the HCI

3. Results and Discussion

First handling of the peels of delicious oranges. The raw materials must undergo a number of initial procedures in order to boost essential oil production as well as quality. Less precise preliminary treatments for the basic components before distillation may result in a considerable loss of essential oil and degrade the quality, according to Bakkali et al. (2018). These initial procedures consist of shrinking the material, drying, dehydrating, incubating, and fermenting the microbes. The first steps in producing the natural oil from sweet peels of oranges were to reduce the size of the peels and dry them. The freshly cut sweet orange peels were trimmed in size to approximately 0.3–0.5 cm before drying.

The goal of the size reduction was to increase the number of open oil glands by expanding the surface areas of the sweet orange peels. Oil glands, glandular hairs, or channels surround the essential oils found in plants. Only after the water vapour passes through the plant tissues and rises to the top via a process known as hydro-diffusion can the oil be recovered. The procedure will go extremely slowly if the materials are not broken. Due to the importance of thickness decrease in the process of diffusion, the essential oil can vaporise during the process of distillation more quickly. After that, the cabinet drier was used for two days to dry the sliced delicious orange peels. The aim of the drying process, according to Nerio et al., (2010), was to eliminate water from the components so that the distillation process could go forward more quickly and effectively. The materials' water vapour caused the oil cells to break apart, which facilitated the extraction of the oil during the process of distillation. During the drying process, the water content of the delectable orange peel slices decreased from 77.45% to 52.31%. After that, the dried delicious orange peel slices were put to the boiler to begin the process of distillation.

3.1. Natural Oil derived from Peels of Sweet Oranges

The essential oil was extracted from the dried out pieces of sweet peels of oranges using the steam distillation method. During the course of distillation, a process known as hydro-diffusion occurred. This involved water seeping through the plant cells' tissues, breaking down the cell walls and expelling the contained oil (Elissa, 2004). Orange peels have oil glands in the flavedo and albedo that are easily pushed by the water vapour that is produced after the lysis of the orange peels' cell walls. This is because the water vapour produced by the process of combustion within the distillation equipment comes into contact with the previously organised orange peels. The oil particles in the peels of oranges will start to evaporate after the water vapour. Upon visual inspection, the essential oil extracted from sweet peels of orange was colourless and exhibited the distinct orange oil aroma following the distillation process, resulting in a yield of 0.54%.

3.2. Results

Table 1 Orange peel oils physiochemical characteristics

Properties	**Orange Peel Oil**
Specific gravity	0.831
Refractive index	1.340
Solubility in Water	Insoluble
Saponification value (mg/KOH Oil)	15.44
Acid Value (mg/KOH Oil)	1.87
Peroxide value	65

The natural oil extracted from the peels of sweet oranges had a specific gravity (Sg) of 0.831g/ml. One crucial factor in assessing an essential oil's quality is its specific gravity. The specific gravity of essential oils at 25 °C typically ranges from 0.693 to 1.187 g/ml, according to Elissa et al. (2004). The chemical elements in an essential oil have an impact on its Sg value. Additionally, Sg indicates the mass fraction to mole fraction of the essential oil. With a higher mass fraction, Sg rises (Udonsi, 1986). In addition, Sg is often linked to the oxidation process that takes place in essential oils. In general, the oxidation process may be the source of a greater specific gravity value. Oil oxidation, which produces a new molecule and raises the specific gravity value, may occur during the drying process.

3.3. Index of Refraction

The ratio of speed of light in air to a substance's speed at a certain temperature is known as the refractive index (Caraballo, 2000). The natural oil was made from the peels of sweet oranges and has a refractive index of 1.320. The index and the constituents of the essential oil are closely related. When longer-chain components, such as oxygen-cluster components, are extracted in larger amounts, the essential oil medium becomes denser and produces an essential oil with a higher refractive index. (Bakkali, 2008).

3.4. Acid concentration/amount

The index and the constituents of the natural oil are closely related. When longer-chain components, such as sesquiterpene or oxygen-cluster components, are extracted in larger amounts, the essential oil medium becomes denser and produces an essential oil with a higher refractive index. Indonesia's national standard is met by the essential oil extracted from the peels of Kisar sweet oranges. A lower acid number in a natural oil indicates higher quality. The rationale is that acid is susceptible to oxidation processes in the atmosphere, which might result in changes in scent, acid is not commonly found in essential oils.

3.5. Solubility in Water

The solubility test establishes the oil's solubility in alcohol. The number of polar molecules in an essential oil determines how well it dissolves in alcohol. This characteristic is crucial for determining the essential oil's quality. The essential oil's solubility in alcohol is dependent on the kind of chemicals that comprise it. The solubility of unoxygenated terpene diminishes as its quantity increases since it is considered a non-polar molecule without functional clusters (Rodriguez, 2015). The essential oil extracted from the peels of sweet oranges had a dissolution ratio of 1:9, indicating that the finished essential oil contained relatively little oxygenated hydrocarbon. The oxygenated hydrocarbon complex dissolves in alcohol more easily than the unoxygenated hydrocarbon component does. Similar to terpene, the oxygenated hydrocarbon molecule is relatively more polarised than the terpene cluster.

Table 2 Functional group Present in Orange Peel oil

Wave Number (cm^{-1})	Type of Vibration	Nature of Functional Group
3345.230	OH-Stretching	Carboxylic OH
2938.526	C-H Stretching	Akane
1736.021	C=O Stretching	Esters
1009.312	C-O-C	Esthers ester

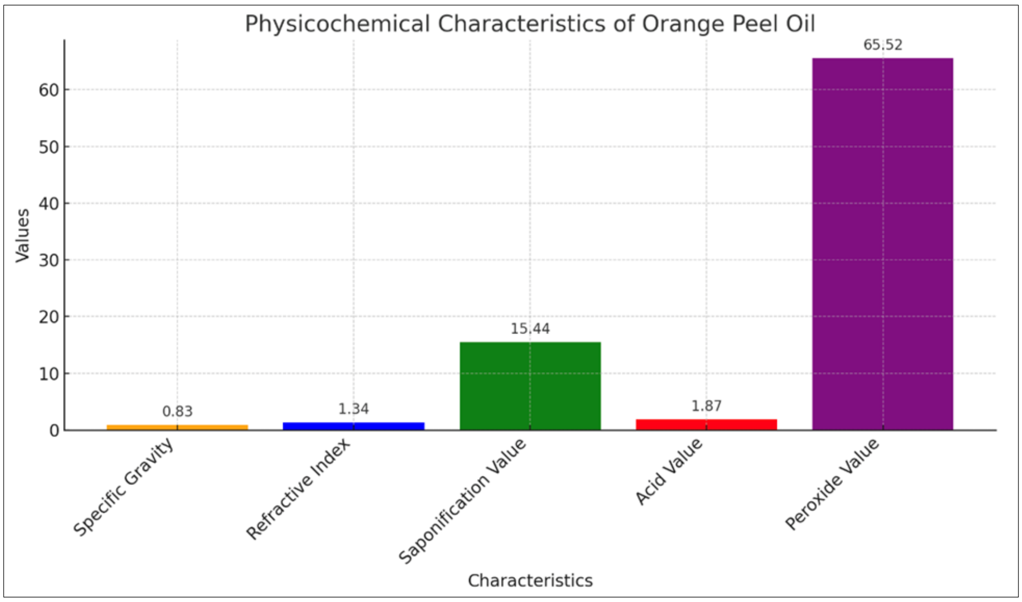

Figure 3 Bar graph representing the physicochemical characteristics of orange peel oil, based on the values given in the table 1

The specific Gravity: Shown in orange, indicating it is less dense than water with a value of 0.831.

- Refractive Index: Shown in blue, indicating how much light bends when entering the oil with a value of 1.340.
- Saponification Value: Shown in green, representing the amount of alkali needed to saponify the oil with a value of 15.44 mg/KOH.
- Acid Value: Shown in red, indicating the free fatty acid content of the oil with a value of 1.87 mg/KOH.
- Peroxide Value: Shown in purple, representing the extent of primary oxidation with a value of 65.52.

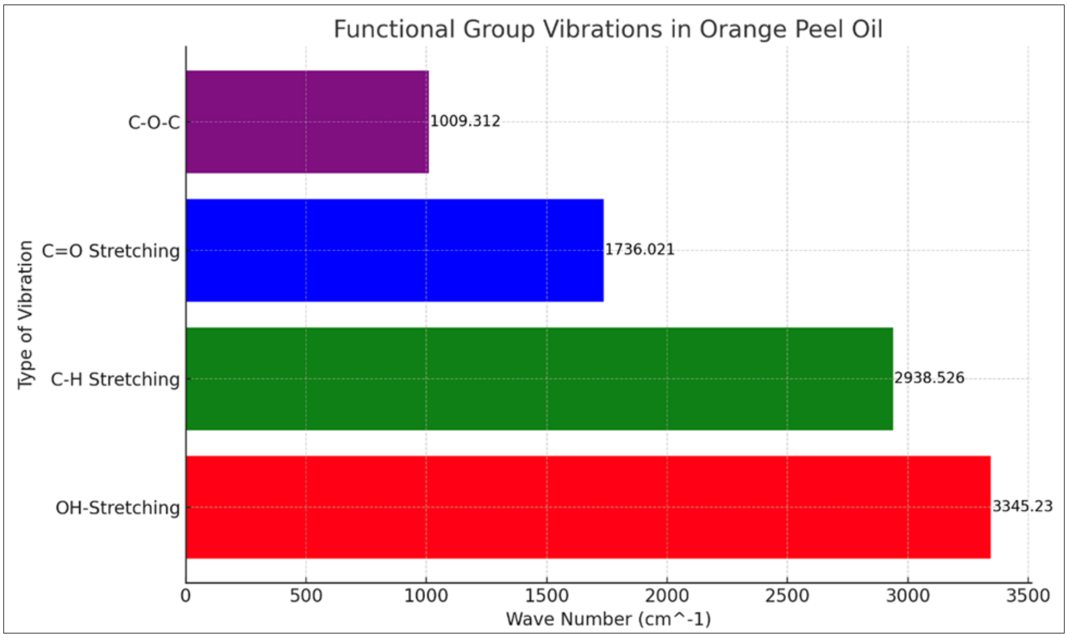

Figure 4 A horizontal bar graph representing the functional group vibrations in orange peel oil

Here is the horizontal bar graph representing the functional group vibrations in orange peel oil, with each bar corresponding to a different wave number and type of vibration See fig 4:

- OH-Stretching (Carboxylic OH): Represented by the red bar, indicating the vibration at a wave number of 3345.23 cm^-1.
- C-H Stretching (Alkane): Shown by the green bar, corresponding to a wave number of 2938.526 cm^-1.
- C=O Stretching (Esters): Represented by the blue bar, with a vibration at a wave number of 1736.021 cm^-1.
- C-O-C (Ethers ester): Illustrated by the purple bar, indicating the vibration at a wave number of 1009.312 cm^-1.

The graph (see fig 4) clearly shows the characteristic vibrations associated with different functional groups present in orange peel oil, which can be identified through infrared spectroscopy. The wave numbers are indicative of the energy associated with the vibrations of the molecular bonds within the functional groups.

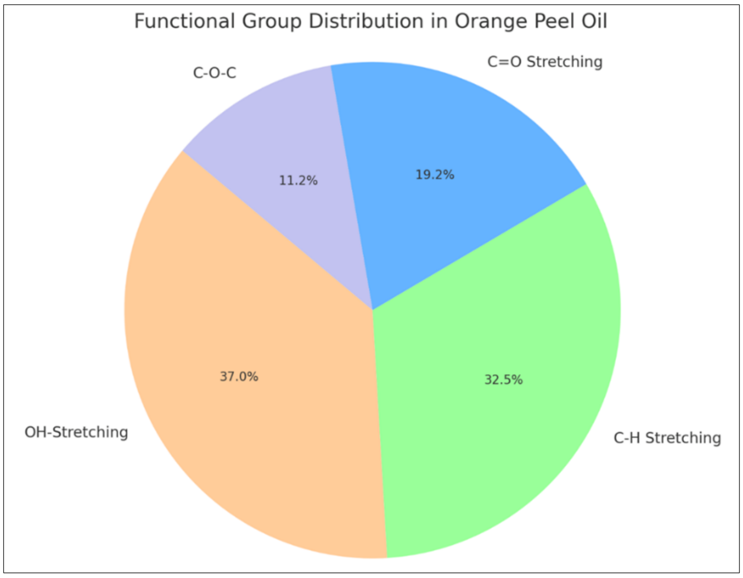

Figure 5 A Bar Chart of Functional Group Distribution in Orange Peel Oil

4. Conclusion

Steam distillation was used to isolate the essential oil from sweet orange peels that had been dried in a cabinet dryer. With a non-pale-yellow color and an orange oil scent, the generated essential oil had an output of 0.53%, a specific gravity of 0.831, refractive index of 1.340 (20 °C), acid value of 1.87, ester number of 8.05, and insoluble solubility in water. The essential oil that was isolated from the peels of delicious oranges was detected using GC-MS. Eleven distinct chemical components were found in it, with limonene and linalool molecules being the two prominent ones. These results imply that the sweet orange peel essential oil may have antioxidant and antibacterial qualities.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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