World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Formulation and evaluation of bio-mosquito repellent air freshener gel from oil extract of *cymbopogon citratus* (DC.) Stapf (lemon grass) plant.

Gushit John Stephen [1, 2], Ogbe Idoko [1 *], Shimuan Jacob Toekwal [2], Idoko Jennifer Ene [3] and Chibuike Enyia [4]

[1] *Department of Science Laboratory Technology, University of Jos, Jos, Plateau State, Nigeria.*
[2] *NRF Research Laboratory, Main Campus, University of Jos, Jos, Plateau State, Nigeria.*
[3] *Chendu Institute of Biology, Chengdu, People Republic of China.*
[4] *Department of Chemistry, Federal University of Technology, Owerri, Imo State, Nigeria.*

World Journal of Advanced Research and Reviews, 2023, 19(01), 496–507

Publication history: Received 10 May 2023; revised on 30 June 2023; accepted on 03 July 2023

Article DOI: https://doi.org/10.30574/wjarr.2023.19.1.0778

Abstract

Synthetic based mosquito repellents pose varying degrees of threats to public health in most developing nations. The developments has necessitated the need for environmentally friendly alternatives, which will have non-toxic, and biodegradable attributes. In this work, a mosquito repellent gel formulation was prepared from the essential oils of *Cymbopogon citratus* (DC.) Stapf (lemon grass) extracted using a steam distillation system. The yields of the extracted oils were determined and calculated under varying conditions. The oil extract was then purified in the micro column parked with silica gel and characterized using Gas Chromatography-Mass Spectrometry (GC-MS). The GC-MS analysis of the essential oil revealed the presence of β-pinene, isoneral, nerolidol and squalene chemical constituents. The optimized gels were evaluated for their appearance, pH, spreadability, macroscopic stability test, swelling index, and hedonic evaluation. The mosquito repellent potential was simultaneously compared with the positive control '*Odomos*', a commercial gel sold in the open market within Jos, Plateau State, Nigeria by varying the repellency time. The outcome of the evaluations confirmed that the formulated gels were stable with normal skin pH. The hedonic test indicated that formulation F5 is the most potent gel with a *C. citratus* oil concentration of 5% in the formulation. This gel formulation promises to be an environmentally sustainable alternative for repelling mosquitoes.

Keywords: *Cymbopogon citratus*; Insect repellents; Essential Oils; Volatile; Formulation.

1. Introduction

The term pesticide covers a wide range of compounds, including insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides, plant growth regulators, and others. Pesticides are chemical substances designed to kill the particular groups of organism. Some pesticides are specific, and others are broad spectrum. The first pesticides used in United States (US) agriculture in the 1930s and their adverse effects were discussed in a wild life conference, during which about 30 pesticides, including pyrethrum, nicotine, calcium arsenate, mercurial fungicides dinitro-ortho-creasol were in use [1]. Both types affect wildlife, soil, water and humans. The insecticidal properties of pp-dichlorodipheny-trichloroethane (DDT) were discovered in Switzerland in 1939 by Muller, who was awarded the Nobel Prize in 1948 [2]. DDT was very effective and has been used to control head and body lice and other agricultural pests until the 1970s. The discovery of DDT and its subsequent application in agricultural pests, together with other synthetic pesticides such as organochlorines, benzene hexachloride (BHC), and chlordane, were introduced during World War II. Among these, organochlorine (OC) insecticides were used successfully in controlling a number of diseases, such as malaria and typhus fever. They were later banned or restricted after the 1960s in most technologically advanced countries. Two cyclodene organochlorines (aldrin and diedrin) were later introduced and used as herbicides and fungicides, which contributed

* Corresponding author: Gushit John S

greatly to pest control and agricultural output. Ideally, a pesticide must be lethal to the targeted pests but not to non-target species, including humans. Unfortunately, this is not the case, so the controversy of the use and abuse of synthetic pesticides is associated with the risk of havoc on human and other life forms. The setbacks associated with synthetic pesticides, which include insect resistance, high operational costs, environmental pollution, skin permeation, allergies, and toxic reactions on application, with an odour that is unpleasant to some people is obvious [3].

These obvious setbacks has necessitated the need for developing alternative products to control many pests. Common among such approaches is the usage of essential oils as an alternative to control many field and household insect pests [4]. For instance, *C. citratus* (Figure 1) has been proven to repel different pest and exhibit low acute toxicity in laboratory animals [5]. That could explain why the oil extract has been adopted as an antiseptic, antispasmodic, diuretic, and febrifuge despite its several observed limitations. It is also reported that the oil is an effective repellent for body lice, head lice, and stable flies [6]. Although this might not be unconnected to the characteristics of short-lived effectiveness, occurring as a result of the high volatility of the active ingredients [7]. Various studies have evaluated the mosquito repellent activity of *C. citratus* extracted from the *Cymbopogon* genus, particularly *Cymbopogon nardus*, while *C. citratus* and its active components grown in Jos, Plateau State, Nigeria, have not been extensively investigated for their repellency potential. This study seeks to assess the mosquito repellency of the bioactive components obtained from *C. citratus* essential oil against *Aedes aegypti*. In addition, its formula optimization in the form of an air freshener gel was also conducted to improve the essential oil longevity.

Figure 1 A diagram of Cymbopogon *citratus* (DC.) Stapf (Lemon grass**)**

2. Materials and methods

2.1. Sample collection and identification

The *C. citratus* fresh leaves were collected within a protected area in Jos, Plateau State, Nigeria and identified by a Botanist who assigned a Voucher Number (JUHN21000390) to the stored specimen at the Herbarium of the Department of Plant Science and Biotechnology, University of Jos, Nigeria. The weather conditions were recorded during sample collection in both the dry and rainy seasons

2.2. Sample preparation and extraction of the essential oil

The *C. citratus* plant was freshly obtained and slashed into small sizes using a stainless steel knife before introducing it into the extractor. The essential oil was subsequently obtained through a steam distillation method [8]. The yield of the oil was calculated using the formula:

$$\text{Yield of essential oil (\%)} = \frac{\text{Amount of essential oil obtained (g)}}{\text{Amount of raw materials used (g)}} \text{X } 100$$

The calculated yields were compared to ascertain the best season to obtain a higher yield of the essential oil.

2.3. Characterization of the essential oil extracts.

The gas chromatography mass spectrometry (GC–MS) analysis was carried out on an Agilent Technology GC–MS instrument model GC 7890A gas chromatography coupled with an MS 5975C VL MSD mass spectrometer detector provided with an HP-5MS capillary column.

2.4. Formulation and bioassay of insect subjects.

2.4.1. Formulation of Air Freshener Gel

The process of upgrading the formula for air freshener gel with percentages of *C. citratus* oil was conducted using various concentrations of the relevant ingredients. Distilled water was added to agar-agar, sodium benzoate, and NaCl, which was then stirred, followed by heating of the mixture at a temperature of 75^{o}C, which was later lowered to 65^{o}C. In addition, the gum, ethylene glycol, and polysorbate 80 were added and further stirred until they were dissolved. The 1%, of *C. citratus* oil was added to the mixture after removal from heat. This formulation was stirred to achieve homogeneity and then subsequently inserted into a sample container and allowed to stand at room temperature [9]. The same process was repeated for 2%, 3%, 4%, and 5% and the formulated oil was put in the sample container for bioassay and stability test.

2.4.2. Bioassay of the Insect Subjects.

This study makes use of cotton wool impregnated with the formulated semi liquid gel for testing the repellency against mosquitoes.

Repellent Assay

The repellent activity of the formulated mosquito repellent gel was tested against pre-identified mosquitoes (*Aedes aegypti*). Cotton wool impregnated with test semi liquid (fomulated gel) was put in the treatment cage, while cotton wool without the test semi- liquid (formulated gel) was put in the control cage. Fifty (50) mosquitoes were introduced and allowed to acclimatize to the test environment for 30 minutes without any treatment. After acclimatization, the doors of the cages were opened for exposure. The number of mosquitoes were observed and recorded. The experiment was repeated three times in order to get the mean percentage repellent activity, which was calculated using the formula:

$$\% \text{ Repellent activity} = \frac{\text{Mosquitoe number in control cage} - \text{Mosquitoe Number in treatment cage}}{\text{Mosquitoe Number in control cage}} \text{X}100$$

The experiment was once again repeated in a similar manner for both the optimized gels, and the repellent activity was appropriately compared.

2.5. Evaluation of the formulated products

2.5.1. Irritation test

The 0.5 g quantity of each gel was applied to the normal hairless skin in an area to check for irritation and then covered with a semi-occlusive bandage for a duration of 1 hr. After the application time, the bandage was removed, the applied gel completely scrapped off, and the area was visually inspected for any rashes or similar symptoms. The test was conducted for a period of 7 days. The results were expressed in terms of grades [10].

2.5.2. Wash- ability

The ability of the formulated gels to be washed was determined by applying the gel on the skin, and observing the ease and degree of washing it away with distilled water through manual scrubbing [11].

2.5.3. Physical evaluation

The formulated gel was visually evaluated for color, appearance, and transparency. The smoothness of the gel was estimated by rubbing the formulation between the fingers to observe the smoothness, clumps, roughness, and homogeneity [12].

2.5.4. pH and Spreadability.

The probe of the digital pH meter was immerse in a solution made by dissolving 0.5 g of the gel formulations in 25 mL of distilled water. Similarly, the spreadability of the gels was measured by spreading 0.5 g of the gel on a circle with a 2 cm diameter pre-marked on a glass plate. Then, a second glass plate was placed on top. A heavy mass was applied to the upper glass plate to remove any trapped air and form a uniform film between the slides. The gel was then dragged with an intensity of 0.5g intensity [13]. The time needed for the top glass to force the gel to cover a distance of 2 cm was determined using the formula:

$$\text{Spreadability}(S) = \frac{\text{Mx L}}{\text{T}}$$

Where, M = weight tied to the upper slide (15 g); L = length of glass slide (2 cm); T = time taken (sec) for the gel to cover a pre-marked distance

2.5.5. Macroscopic Stability Analysis of the Formulation

The formulated gels were visually inspected for colour, liquefaction, and phase separation. The clarity was determined using natural light, and a macroscopic analyses were recorded at different temperatures (4^{o}C, 27^{o}C, and 40^{o}C)

2.5.6. Swelling Index

The swelling index of the prepared formulated gel was determined by taking 2.0 g of the gel in a beaker containing 10 mL of distilled water. After 1 hr, the swelled formulation was removed from the beaker and placed on a petri dish [14]. The content was re-weighed, and the swelling index calculated using the formula:

$$\text{Swelling index} = \frac{(Wt - Wo)\ \text{x}\ 100}{Wo}$$

where, Wt = weight of swollen at t time; Wo = original weight of gel at zero time

2.5.7. Hedonic Test

Hedonic test is a method used to measure the level of preference for products using an assessment form. The minimum number of panelists in one test is 6 people. According to [15], the National Bureau of Standards [NBS] 2006 defined the terms panelists as follows: i) Attracted by the organic test sensory and willing to participate ii) Consistent in making decisions

A test was conducted by Godbole to determine the level of panelist preference for the formulated air freshener gel preparations [16].Testing was performed using 10 students as panelists, who were asked to smell the air freshener gels. The percentage of preference for each formulation was calculated using the assessment criteria for air freshener gel preparation.

3. Results

3.1. Weather Conditions during *C. Citratus* samples Collection

The average weather during the period of sample collection are presented in Tables 1. In December, January, and February, the maximum temperatures ranged from 29.5°C to 32.9°C, while the minimum temperatures ranged from 14.2°C to 16.1°C. The humidity levels during these months were relatively low, ranging from 22.0% to 26.0%. In contrast, during June, July, and August, the maximum temperatures ranged from 25.1°C to 29.2°C, while the minimum temperatures ranged from 18.3°C to 20.0°C. The humidity levels during these months were considerably higher, ranging from 74.0% to 87.0%.

The results suggest that *C. citratus* cultivation for essential oil extraction may be influenced by temperature and humidity variations. Higher temperatures during the months of December to February may contribute to increased growth of the plant, resulting in higher yields of essential oil. Conversely, lower temperatures during June to August may have a slight impact on growth and yield. The higher humidity levels during these months may also affect the quality and quantity of essential oil extracted.

Table 1 The Average Weather Conditions for *C. Citratus* samples Collection

Weather Condition	December	January	February	June	July	August
Max. temperature (∘C)	29.5	30.5	32.9	29.2	26.4	25.1
Min. temperature (∘C)	15.0	14.2	16.1	20.0	18.8	18.3
Humidity (%)	26.0	24.0	22.0	74.0	83.0	87.0

3.2 The Yield (W/W) of Essential Oils Extracted from *C. Citratus* Plant

Table 2 indicates variations in the oil yields extracted at 9am during different months. In December, the oil yield was 3.80%, while in January and February, it was 3.20% and 3.01%, respectively. A yield of 2.10% was obtained in June and 1.92% in July. The lowest oil yield was observed in August, with a value of 0.49%.

The observed variations in oil yields can be attributed to several factors, such as temperature and humidity during different months can affect the growth and oil production of *C. Citratus* plants. Additionally, the stage of plant maturity and the time of extraction can influence the oil yield. It is important to note that the extraction technique used in this study may also have an impact on the oil yield.

Table 2 Percentage oil yield (w/w) of essential oils extracted from *C. citratus* plant at 9am

Months	Essential oil obtained (g)	Amount of raw materials used (g)	(%) Oil yields
December	38.0	1000	3.80
January	32.0	1000	3.20
February	30.1	1000	3.01
June	21.0	1000	2.10
July	19.2	1000	1.92
August	4.9	1000	0.49

Table 3 below presents the percentage oil yields of essential oils extracted from *C. citratus* plants at 5pm for different months. The highest oil yield was observed in December (0.2000%), followed by January (0.1000%) and August (0.1000%). February showed a relatively lower oil yield (0.0500%), while June and July had the lowest oil yields of 0.0052% and 0.0031%, respectively.

The findings of this study align with previous literature sources that have reported variations in *C. Citratus* essential oil yields extracted at different times and months [17]. The results indicate that oil yields are influenced by seasonal factors, with higher yields observed in December and January, and lower yields in June and July. These variations in oil yields could be attributed to factors such as climate, plant growth stage, and environmental conditions.

Table 3 Percentage oil yield (w/w) of essential oils extracted from *C. citratus* plant at 5pm

Months	Essential oil obtained (g)	Amount of raw materials used (g)	(%) Oil yields
December	2.000	1000	0.2000
January	1.000	1000	0.1000
February	0.500	1000	0.0500
June	0.052	1000	0.0052
July	0.031	1000	0.0031
August	1.000	1000	0.1000

Table 4 and Figure 2 presents the results of the GC-MS characterization of *C. citratus* oil extract. The bioactive compounds identified included β-pinene, nerolidol, isoneral, and squalene. β-pinene has a chemical formula of $C_{10}H_{16}$, with mass to charge ratio (m/z) of 136.23, and a retention time of 6.06. Nerolidol has a chemical formula of $C_{15}H_{26}O$, m/z value of 222.19, and a retention time of 17.71. Similarly, isoneral has a chemical formula of $C_{10}H_{16}O$, m/z of 152.23, and a retention time of 10.56. Lastly, squalene has a chemical formula of $C_{30}H_{5}0$, m/z value of 410.72, and a retention time of 39.37.

The identified β-pinene is a monoterpene, an organic compound found in plants. It is one of the two isomers of pinene, the other being α-pinene. β-pinene was isolated, and when tested against mosquitoes it was found to have insecticidal properties showing good larvicidal activities against *Aedes* and *culex* mosquitoes [18]. The β-pinene woody-green pine-like smell also may indicate danger to living insects, prompting them to avoid places where the smell comes from [19]. β-pinene also doubles as a antimicrobial, antimalarial, antioxidant, and anti-inflammatory. Nerolidol which is well known for a nuanced floral aroma is of great economic value in the production of cosmetics products [20]. The oil also contains isoneral which is mainly used in pharmaceutical, cosmetics and food industries. Squalene was also present in the essential oil, and it possess antioxidant properties which appears to be critical in reducing free radical oxidative damage to the skin [21].

Table 4 Result of GCMS Characterization of *C. citratus* oil Extract

Compounds	Chemical Formula	m/z	Retention time
β-pinene	$C_{10}H_{16}$	136.23	6.06
Nerolidol	$C_{15}H_{26}O$	222.19	17.71
Isoneral	$C_{10}H_{16}O$	152.23	10.56
Squalene	$C_{30}H_{50}$	410.72	39.37

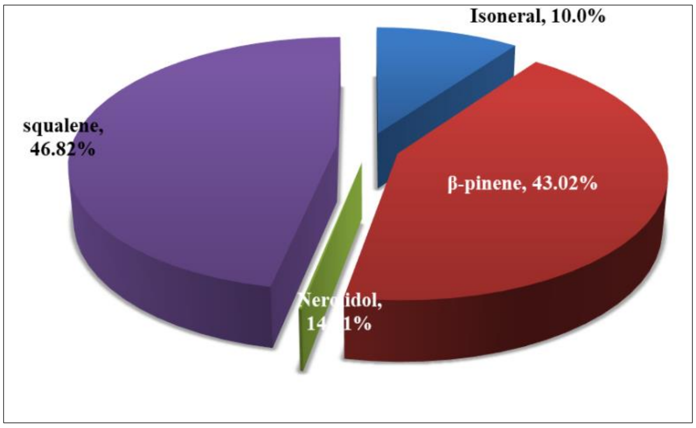

Figure 2 GC-MS of C*. citratus* oil extract indicating the percentages of various compounds

Table 5 presents the composition and functions of the optimized gel formulations. The concentration of *C. citratus* extract increased progressively from 1.0% to 5.0% in formulations I, II, III, IV, and V, respectively. Agar-agar, known for its emulsifying properties, was consistently present at a concentration of 2.0% in all formulations. A gum was added (1.0%) to enhance the gel's viscosity. Sodium benzoate, acting as a preservative, was included at 0.5% to ensure formulation stability. Ethylene glycol, functioning as a humectant and moisturizer, was included at 1.5% in all formulations. Polysorbate 20, an emulsifier, was incorporated at 1.0% to facilitate the uniform dispersion of ingredients. Sodium chloride (NaCl) which functions as a binder and improving holding capacity, was added at 1.0% in all formulations. Aquadest formed the bulk of the composition, ranging from 88.0% to 92.0%, its role is to enhance solubility and diffusion of other components. The optimized gel formulations exhibited variations in the concentration of *C. citratus* oil extract, while the other ingredients remained constant. The inclusion of *C. citratus* oil extract holds the potential to incorporate its bioactive compounds into the gels, which put into the gel the repelling properties.

In the conventional mosquito repellent gel, carrageenan is widely used as slow releasing base and a substance that enhances the gelly nature of the products [22]. However, many end users are concerns about its safety. For instance some scientists [23] maintained that carrageenan can cause inflammation, digestive problems, such as bloating and irritable bowel disease (IBD), therefore in an attempt to upgrade the formula of air fresher gel with inflammation reduction and improved respiration, carrageenan was replaced with agar-agar powder made from the same seaweed extract, since it has higher gelling strength and less harmful.

Table 5 Composition of the optimized formula gels and their functions

Composition	**Uses/ Functions**	**I**	**II**	**III**	**IV**	**V**
C. Citratus oil	Extract	1.0%	2.0%	3.0%	4.0%	5.0%
Agar Agar	Emulsifies water and oil together	2.0%	2.0%	2.0%	2.0%	2.0%
Gum	Increases gel viscosity	1.0%	1.0%	1.0%	1.0%	1.0%
Sodium Benzoate	Preservative	0.5%	0.5%	0.5%	0.5%	0.5%
Ethylene Glycol	Humectants and moisturizer	1.5%	1.5%	1.5%	1.5%	1.5%
Polysorbate 20	Emulsifier	1.0%	1.0%	1.0%	1.0%	1.0%
NaCl	Binder/Improve holding Capacity	1.0%	1.0%	1.0%	1.0%	1.0%
Aquadest	Enhances solubility and diffusion of substances	92.0%	91.0%	90.0%	89.0%	88.0%

The bio-mosquito repellent activity of a formulated gel was evaluated at three different time intervals: 1 hour, 2 hours, and 3 hours. The results are presented in Tables 6, 7, and 8, where the percentage of repellency for each of the optimized gel formulation (F1-F5) and the control group is indicated. Table 6 indicates that at 1 hour, the formulated gel (F1-F5) exhibited repellent activities ranging from 84.06% to 91.29%. The control group, which represents the standard formulation, demonstrated a higher repellent activity of 98.04%.

In Table 7, at 2 hours, the repellent activities of the gel formulations ranged from 81.02% to 91.71%. Once again, the control group showed a higher repellent of 93.31%. Similarly, at 3 hours, the repellent activities of the gel formulations declined further, ranging from 66.67% to 80.33%. The control group maintained a relatively higher repellent of 90.03% (Table 8,).

Comparing the results of each table with the control group, it is evident that the formulated gels have lower repellent activities at all times. However, some formulations, such as F5, still exhibited significant repellent activities, although lower than the control group. *C. citratus* oil gel formulated is a bio-based mosquito repellent with a reduced inflammation and improved respiration, having replaced carrageenan in the commercial gel repellent with agar-agar powder which makes it more harmless to end users.

Table 6 Bio-mosquito repellence results of the formulated gel at 1 hours

Optimized Gels	**%Repellent activity (1hr)**
F1	84.06±0.10
F2	85.41±0.40
F3	88±0.01
F4	89.20±0.03
F5	91.29±0.40
Control	98.04±0.06

Table 9 presents the results from the physical evaluation, washability, and irritability of the formulated *C. citratus* gel. The evaluated parameters include color, transparency, smoothness, washability, and irritability. The results for each gel formulation (F1-F5) are provided. The outcomes is similar to a work reported [24]. All the gel formulations appeared bluish in color. In terms of transparency, F1 and F2 were less translucent, while F3 and F4 were translucent. F5, on the other hand, was more translucent. All formulations were reported to be smooth in texture. In terms of washability, all formulations showed good washability property. Additionally, there were no reports of irritability observed in any of the gel formulations. Table 10 presents the pH evaluation and spreadability of the formulated gels. Each formulation's pH and spreadability (measured in g.cm/sec) are provided. On a general note, the pH of the gel formulations ranged from 7.01 to 7.51, indicating a slightly acidic to neutral pH range. The results obtained is higher than the similar work reported in the formulation and evaluation of topical herbal gel for the treatment of arthritis in animal model were the pH was found to be in the range from 3.95 ± 0.01 to 3.83 ± 0.03 [25].

The spreadability of the formulated gels ranged from 5.04 to 15.03 g.cm/sec, indicating variations in the ease of spreading with viscosity. This aligns with a study which correlates spreadability and viscosity of a gel, which affirms that as the viscosity increases, spreadibility decreases [26].

Table 7 Mosquito repellent potential of the formulated gel at 2 hours

Optimized Gels	%Repellent activity (2hr)
F1	81.02±0.02
F2	82.23±0.20
F3	86.80±0.08
F4	87.04±0.04
F5	91.71±0.07
Control	93.31±0.03

Table 8 Mosquito repellent potential of the formulated gel at 3 hours

Optimized Gels	%Repellent activity (3hr)
F1	66.67±0.01
F2	70.02±0.03
F3	73.00±0.01
F4	77±0.90
F5	80.33±0.50
Control	90.03±0.30

Table 9 The Physical evaluation, washability, and irritability of the formulated gel using C*. citratus* oil

Gels	Colour	Transparency	Smoothness	Washability	Irritability
F1	Blue	Less Translucent	Smooth	Good	No irritation
F2	Blue	Less Translucent	Smooth	Good	No irritation
F3	Blue	Translucent	Smooth	Good	No irritation
F4	Blue	Translucent	Smooth	Good	No irritation
F5	Blue	More Translucent	Smooth	Good	No irritation

Table 10 pH evaluation and spreadability of the formulated gels

Formulations	pH	Spreadability= $\frac{M x L}{T}$ (g.cm/sec)
F1	7.01± 0.01	15.03± 0.05
F2	7.51 ± 0.01	10.07± 0.10
F3	7.42± 0.03	7.50± 0.01
F4	7.34± 0.03	6.04± 0.05
F5	7.15± 0.02	5.04± 0.03

The results from Table 11 indicate that the formulated gels using *C. citratus* oil exhibited excellent macroscopic stability. At 4°C, 27°C, and 40°C, there were no observable color changes, phase separations, or liquefaction in any of the gel formulations (F1-F5). This suggests that the gel formulations are resistant to temperature variations and maintain their physical integrity under different conditions. These findings are significant as they demonstrate the stability of the gel formulations, which is crucial for their shelf life and usability. Table 12 provides insights into the swelling index of the formulated gels. The swelling index values ranged from 106.45 to 122.58, indicating that the gel formulations have a notable ability to absorb and retain fluid. This means that the gels can effectively absorb moisture or other substances, resulting in an increase in their weight and volume. Higher swelling index values suggest a greater capacity of the gels to absorb and retain fluid. This characteristic can be advantageous in applications where moisture absorption or retention is desired, such as wound dressings or skincare products.

The implications of these findings are twofold. Firstly, the macroscopic stability of the formulated gels indicates that they can withstand temperature fluctuations without undergoing any visible changes in color, phase separation, or liquefaction. This is crucial for ensuring the consistency and efficacy of the gels over time, especially during storage and transportation. Secondly, the observed swelling index values suggest that the formulated gels have the potential for effective absorption and retention of moisture or other substances. This characteristic can be advantageous in various applications, including skincare products, where moisture absorption or retention is desired for hydration and improved product performance.

Based on the observed results, it can be concluded that the formulated gel exhibits favorable characteristics as an air freshener gel. The gel demonstrates stability and is deemed safe for human use, which aligns with previous research on the development and evaluation of a gel formulation containing the monoterpene borneol [27]. The obtained results further validate the formulated gel's stability, as it successfully passed the stability test. These findings highlight the potential of the gel as an effective and reliable air freshener, ensuring a pleasant and safe environment.

Table 11 Macroscopic Stability Analysis of the formulated gels using *C. citratus* oil

Formulations	T ^{O}C	CC	PS	L
F1	4	No	None	No
F2	4	No	None	No
F3	4	No	None	No
F4	4	No	None	No
F5	4	No	None	No
F1	27	No	None	No
F2	27	No	None	No
F3	27	No	None	No
F4	27	No	None	No
F5	27	No	None	No

F1	40	No	None	No
F2	40	No	None	No
F3	40	No	None	No
F4	40	No	None	No
F5	40	No	None	No

Table 12 Evaluation of the swelling index of the formulated gels using *C. citratus* oil

Formulations	Mt	Mo	Mt-Mo	Swelling index = (Mt-Mo/Mo)x 100
F1	6.4	3.1	3.3	106.45
F2	6.9	3.2	3.7	115.63
F3	6.5	3	3.5	116.67
F4	6.8	3.1	3.7	119.36
F5	6.9	3.1	3.8	122.58

The hedonic test was carried out using assessment criteria of air freshener gel preparation in Table 13. The results obtained from the hedonic test are presented in Table 14. At the initial time (M1), formulation F5 exhibited the highest fragrance intensity (score: 5 - Very Fragrant), followed by F4 (score: 4 - Fragrant), F3 (score: 3 - Moderate Fragrant), F2 (score: 2 - Less Fragrant), and F1 (score: 1 - Minor Fragrant). As time progressed, the fragrance intensity decreased for all formulations. However, formulation F5 consistently maintained the highest fragrance level throughout the test period.

From the test results of organoleptic test by 10 panelists, it can be seen that the formula F5 is the most preferred by the panelists and still meet the requirements at a temperature of 25 to 40 ° C and can last up to weeks [28].

Table 13 Assessment criteria of air freshener gel preparation

Number	Criteria	Score
1	Very Fragrant	5
2	Fragrant	4
3	Moderate Fragrant	3
4	Less Fragrant	2
5	Minor Fragrant	1
6	No Fragrant	0

Table 14 Results of hedonic test at various time intervals and various formulas

Time	F1	F2	F3	F4	F5
M1	Minor Fragrant	Less Fragrant	Moderate Fragrant	Fragrant	Very Fragrant
M2	No Fragrant	Minor Fragrant	Less Fragrant	Moderate Fragrant	Fragrant
M3	No Fragrant	No Fragrant	Minor Fragrant	Less Fragrant	Moderate Fragrant
M4	No Fragrant	No Fragrant	No Fragrant	Minor Fragrant	Less Fragrant
M5	No Fragrant	No Fragrant	No Fragrant	No Fragrant	Minor Fragrant

4. Discussion

In this research, *C. citratus* leaves oil was successfully extracted using steam distillation, the calculated yields were higher in the leaves harvested during the dry season. The extracted oil was used to formulate air freshener which has proven to be very effective as insect repellent particularly at higher concentration of 5.0%w/w. The five formulations, replaces carrageenan which causes inflammation and respiratory infectous disaeses with agar-agar powder made from the same seaweed extract. The repellency properties of the formulated gels containing essential oil was evaluated and determined. The results of this study indicate that the best gel formula F5 with 5.0% concentration of the oil. The order of repellency of the formulations at varying time is F5>F4>F3>F2>F1. The GC-MS analysis revealed the presence of four different chemical constituents from the essential oils with high repellent activity. They include β-pinene, isoneral, nerolidol and squalene components. The presence of these compounds indicates that *C. citratus* leave oil will not only proffer repellant benefits but will also add preserving and nourishing benefits which is kind and friendly to the skin when used in the formulation of a air freshener gel. When subjected to macroscopic tests, the optimized gels proven to be good, and stable air freshener gel with normal skin pH that is safe for human use. Formula F5 is the most stable and preferred by the panelists which still meet gel requirements at a temperature of 25 to 40^{o}C.

5. Conclusion

This study reaffirms the possibility of using indigenous Nigerian plants with insecticidal property for the control of mosquitoes, malaria and other mosquito-causing diseases. The stable gel formulation obtained is effective with promise of minimal harmful effects recorded. Which goes on to stand as alternative solution for ecologically friendly solution left to be explored for use for control and management of mosquito.

Compliance with ethical standards

Acknowledgments

We would like to thank the Tertiary Education Trust Fund (TETFund) for providing the necessary financial support through the NRF Research Grant. This funding has been instrumental in carrying out all the experiments.

Disclosure of conflict of interest

The authors declare no conflict of interest regarding the publication of this research on the formulation and evaluation of a bio-mosquito repellant air freshener gel from the oil extract of *Cymbopogon citratus* (DC.) Stapf (lemon grass) plant. There are no financial or personal relationships that could potentially bias the interpretation or presentation of the research findings. The research was conducted with the primary objective of advancing scientific knowledge and contributing to the field of mosquito repellants, without any external influences or competing interests.

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