



DEVELOPMENT, FORMULATION AND CHARACTERIZATION OF AN ESSENTIAL OIL-BASED MULTIPURPOSE AIR FRESHENER FROM SELECTED LOCALLY AVAILABLE RAW MATERIALS

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ABSTRACT: Air fresheners are products designed to improve or mask the smell of indoor spaces or vehicles by releasing pleasant fragrances or by neutralizing unpleasant odors. They are commonly used in homes, offices, hotels, hospitals, public restrooms, and cars. That is, air freshener are products designed to improve indoor air quality by masking, neutralizing, or eliminating unpleasant odors through the release of fragrant or deodorizing substances. This study focuses on the formulation and characterization of an essential oil-based multipurpose air freshener produced from locally available raw materials. The increasing health and environmental concerns associated with synthetic air fresheners containing volatile organic compounds (VOCs) necessitate the development of safer and eco-friendly alternatives. In this research, essential oils were extracted from seven different plant materials—lemongrass (*Cymbopogon citratus*), lemon peel (*Citrus limon*), orange peel (*Citrus sinensis*), scent leaf (*Ocimum gratissimum*), clove (*Syzygium aromaticum*), rosemary (*Rosmarinus officinalis*), and ginger (*Zingiber officinale*) using ethanol as solvent via the cold maceration method. The plant materials were air-dried, ground, and macerated in ethanol for seventy-two hours, followed by filtration and removal of excess solvent using a water bath at controlled temperature. The extracted essential oils were blended and formulated into a multipurpose air freshener using distilled water, ethanol, glycerin, baking soda, citric acid, and natural colorant. The formulation was filtered using muslin cloth to ensure clarity before packaging into spray bottles. Preliminary evaluation showed that the formulated air freshener possessed a pleasant natural fragrance, good homogeneity, and effective odor-neutralizing properties. The product demonstrated good stability and uniform dispersion of fragrance, indicating successful formulation. This study confirms that locally sourced plant materials can be effectively utilized to produce a safe, affordable, and environmentally friendly multipurpose air freshener, thereby promoting sustainable use of natural resources and reducing dependence on synthetic fragrance products.

Keywords: Air freshener; Essential oils; Cold maceration; Local raw materials; Multipurpose formulation; Natural fragrance.

1.0 INTRODUCTION

Air fresheners are products designed to improve indoor air quality by masking unpleasant odors or eliminating odor-causing substances. In recent years, the use of air fresheners has become widespread in homes, offices, vehicles, hospitals, and public spaces due to increased awareness of hygiene, comfort, and environmental aesthetics. However, many commercially available air fresheners are formulated using synthetic fragrances and chemical propellants that may pose health and environmental risks (Steinmann *et al.*, 2011; EPA, 2020).

There has been increasing interest in the development of natural and eco-friendly alternatives to synthetic household products. Essential oils obtained from plants are known for their pleasant aroma, antimicrobial activity, and deodorizing properties, making them suitable substitutes for synthetic fragrances (Ali *et al.*, 2015; Bakkali *et al.*, 2008). These natural extracts offer safer air freshening while also providing therapeutic and environmental benefits. Plant materials such as lemon peel, orange peel, lemongrass, rosemary, ginger, clove, and scent leaf are rich sources of essential oils containing bioactive compounds responsible for fragrance and odor neutralization (Chouhan *et al.*,

2017; Edris, 2007). Nigeria is richly endowed with these aromatic plants, yet they remain underutilized for household and industrial applications.

The production of a multipurpose air freshener using essential oils involves extraction of the oils, formulation with suitable solvents such as ethanol and water, and stabilization using additives like glycerin and mild buffering agents. Ethanol serves as both a solvent and preservative, while glycerin reduces rapid evaporation of fragrance, thereby improving scent retention (Phuong *et al.*, 2022).

Baking soda (sodium bicarbonate) is a well-known odor neutralizer that reacts chemically with acidic and basic odor molecules, eliminating odors at their source rather than masking them (Hafidzah *et al.*, 2022). Citric acid may also be used to adjust pH and enhance formulation stability.

Conventional air fresheners often contain volatile organic compounds (VOCs) such as formaldehyde, benzene, and phthalates, which have been associated with respiratory irritation, headaches, allergic reactions, and long-term health effects (Steinemann, 2015; WHO, 2019). Continuous exposure to these chemicals can negatively affect indoor air quality.

This research therefore focuses on the formulation and characterization of an essential oil-based multipurpose air freshener using locally available raw materials, with the aim of producing a safe, affordable, effective, and environmentally friendly product suitable for indoor applications.

Beyond odor control, air fresheners play an important role in improving perceived indoor comfort and psychological well-being. Human perception of cleanliness and comfort is strongly linked to smell, and pleasant fragrances have been shown to influence mood, concentration, and emotional responses. This explains the increasing demand for air fresheners in both domestic and commercial environments such as offices, hotels, hospitals, and public transportation systems (Ali *et al.*, 2015).

The effectiveness of an air freshener depends largely on its chemical composition and formulation. From a chemical perspective, air fresheners function through a combination of volatility, diffusion, and molecular interactions. Fragrance compounds must be sufficiently volatile to disperse into the air, yet stable enough to persist for a reasonable duration. These properties are controlled by the molecular structure of essential oil constituents, solvent composition, and formulation additives such as glycerin and buffering agents (Phuong *et al.*, 2022).

Another important aspect of air freshener performance is fragrance diffusion. Once sprayed, air freshener particles spread throughout a room due to air currents, molecular diffusion, and evaporation. Small droplet size and volatile aromatic compounds allow the fragrance to travel beyond the point of application, leading to uniform scent distribution within enclosed spaces. This phenomenon explains why air fresheners are perceived throughout a room even when applied at a single location.

In addition to fragrance diffusion, odor elimination mechanisms contribute to air freshener efficiency. While many synthetic products rely on masking odors, natural formulations incorporating compounds such as sodium bicarbonate chemically neutralize odor-causing molecules. Baking soda reacts with acidic and basic odor compounds, converting them into less volatile or non-odorous substances, thereby eliminating odors at their source rather than covering them up (Hafidzah *et al.*, 2022).

Furthermore, essential oils contribute antimicrobial activity to air fresheners. Studies have shown that essential oils from plants such as clove, lemongrass, rosemary, and ginger contain bioactive compounds capable of inhibiting the growth of bacteria and fungi commonly associated with unpleasant odors (Chouhan *et al.*, 2017). This antimicrobial action enhances the multipurpose nature of essential oil-based air fresheners by combining fragrance, deodorization, and hygienic benefits in a single product.

The use of locally available raw materials for essential oil extraction aligns with principles of green chemistry and sustainable development. Utilizing indigenous plant resources reduces production cost, promotes local agriculture, and minimizes reliance on imported synthetic chemicals. It also supports environmental sustainability by encouraging biodegradable and renewable product formulations (Dhobale *et al.*, 2024).

Therefore, the formulation and characterization of an essential oil-based multipurpose air freshener using local raw materials is not only scientifically relevant but also economically and environmentally significant. The outcome of this research is expected to contribute to safer household products, improved indoor air quality, and increased awareness of natural alternatives to synthetic air fresheners.

Indoor air quality has become a growing public health concern due to increased urbanization, industrial activities, and prolonged time spent indoors. Modern lifestyles have resulted in individuals spending a significant portion of their daily lives in enclosed environments such as homes, offices, classrooms, hospitals, and vehicles. In these confined spaces, odors originating from cooking, waste, moisture, smoke, and microbial growth can accumulate, leading to discomfort and reduced air quality. Consequently, air fresheners have become widely used consumer products for improving indoor ambiance and perceived cleanliness.

In Nigeria and other developing countries, the demand for air fresheners has increased significantly due to rising awareness of hygiene, improved living standards, and the expansion of commercial and residential buildings. However, most commercially available air fresheners are imported and formulated using synthetic chemicals, many of which are associated with adverse health and environmental effects. Studies have shown that prolonged exposure to synthetic air fresheners may contribute to respiratory irritation, headaches, allergic reactions, and indoor air pollution due to the release of volatile organic compounds (VOCs) and secondary pollutants (Steinemann *et al.*, 2011; Steinemann, 2015).

From a chemical perspective, air fresheners function through mechanisms such as odor masking, odor neutralization, and microbial inhibition. Odor masking involves the release of pleasant fragrances that overwhelm unpleasant smells, while odor neutralization relies on chemical reactions—particularly acid–base reactions—to eliminate odor-causing molecules. The incorporation of natural substances such as essential oils and sodium bicarbonate introduces additional antimicrobial and deodorizing functions, highlighting the relevance of applied chemistry in air freshener formulation. These principles demonstrate how fundamental concepts in organic, physical, and environmental chemistry can be applied to solve everyday problems.

The use of locally sourced raw materials in air freshener production also presents economic and environmental advantages. Nigeria is rich in aromatic plants such as lemongrass, scent leaf, ginger, citrus fruits, clove, and rosemary, which are known to contain essential oils with pleasant aromas and bioactive properties. Utilizing these materials not only reduces dependence on imported synthetic products but also promotes sustainability, waste reduction, and local resource utilization. This approach aligns with global trends toward green chemistry and environmentally responsible product development.

Furthermore, the growing emphasis on sustainable consumer products has encouraged research into natural, biodegradable, and non-toxic alternatives to conventional household chemicals. Essential oil–based air fresheners formulated from plant materials offer a safer option for indoor environments, particularly for vulnerable populations such as children, the elderly, and individuals with respiratory conditions. By combining scientific knowledge with locally available resources, this project contributes to the development of eco-friendly air fresheners that are both effective and socially relevant.

Indoor air pollution has become a major public health concern due to increased time spent indoors and the use of chemical-based household products (WHO, 2019; EPA, 2020). Air fresheners are widely used to improve perceived air quality; however, many commercial products rely on synthetic chemicals that do not eliminate odors but merely mask them (Steinemann *et al.*, 2011; Steinemann, 2015).

Essential oils are complex mixtures of volatile compounds such as terpenes, aldehydes, esters, alcohols, and phenolics, which contribute to their aroma and biological activity (Bakkali *et al.*, 2008; Ali *et al.*, 2015). Plants such as *Cymbopogon citratus* (lemongrass) contain citral; *Citrus* species contain limonene; clove contains eugenol; while ginger contains zingiberene (Edris, 2007; Chouhan *et al.*, 2017). These compounds not only provide fragrance but also possess antimicrobial and deodorizing properties (Chouhan *et al.*, 2017; Hyldgaard *et al.*, 2012). Baking soda (sodium bicarbonate) is a well-known odor neutralizer that reacts with acidic odor molecules, reducing unpleasant smells rather than masking them (Hafidzah *et al.*, 2022). When combined with essential oils in an aqueous system, it enhances odor control efficiency. Ethanol serves as a solubilizing agent, preservative, and fragrance dispersant, while glycerin improves stability and reduces rapid evaporation (Phuong *et al.*, 2022; Tisserand & Young, 2014). The integration of these components results in a multipurpose air freshener capable of deodorizing, fragancing, and mildly disinfecting indoor spaces.

Despite the widespread use of air fresheners, most commercial products available in the market are; Chemically synthesized, Expensive, Potentially harmful to human health, and Environmentally unfriendly.

In Nigeria, locally available aromatic plants are often underutilized, while dependence on imported synthetic air fresheners persists. There is limited research and development focused on converting local plant materials into safe, effective household products.

Therefore, there is a need to develop a natural, affordable, and environmentally friendly air freshener using locally sourced essential oils that can serve as a safer alternative to synthetic products. The aim of this study is to formulate and characterize an essential oil–based multipurpose air freshener obtained from locally raw materials.

2.0 METHODOLOGY

2.1 MATERIALS

2.1.1 Plant Materials

The plant materials used for this study were locally sourced and include: Lemongrass (*Cymbopogon citratus*), Lemon peel (*Citrus limon*), Orange peel (*Citrus sinensis*), Scent leaf (*Ocimum gratissimum*), Clove (*Syzygium aromaticum*), Rosemary (*Rosmarinus officinalis*) and Ginger (*Zingiber officinale*).

2.1.2 Reagents

Among the chemical reagents used are: Ethanol (95%), Distilled water, Glycerin, Baking soda (Sodium bicarbonate, NaHCO_3) and Citric acid

2.1.3 Equipment

The apparatus used are; Industrial blender, Digital weighing balance, Beakers and conical flask, measuring cylinders, Stirring rods, Airtight bottles for maceration, Whatman No. 1 filter paper, Funnel, Water bath, Spray bottles (250 mL capacity) and Labels and marker.

2.1.4 Collection and Preparation of Plant Materials

Fresh plant materials were obtained by markets survey in Ede. The samples were washed thoroughly with distilled water to remove dirt and other impurities. Lemon and orange peels were carefully separated to avoid inclusion of the bitter white pith.

2.1.5 Drying of Plant Materials

The plant materials were dried to reduce moisture content and prevent microbial growth.

- Lemongrass, scent leaf, and rosemary were air-dried under shade in a well-ventilated area for 7-10 days.
- Lemon and orange peels were air-dried until brittle and aromatic.
- Ginger was lightly sun-dried and subsequently air-dried.
- Clove was purchased already dried and used directly.

Air drying was preferred to prevent loss of volatile oil components.

2.1.6 Grinding and Weighing

The dried samples were ground separately into fine particles using an industrial blender to increase surface area for extraction. Exactly 50 g of each powdered sample was weighed using a digital weighing balance.

2.1.7 Extraction of Essential Oils (Cold Maceration Method)

Cold maceration was employed for essential oil extraction.

Each 50 g powdered sample was transferred into separate labeled airtight bottles. Ethanol was added to each container until the plant material was fully immersed (filled to the brim). The mixtures were stirred gently, sealed, and allowed to stand for 72 hours at room temperature with intermittent shaking. After maceration, the mixtures were filtered using Whatman No. 1 filter paper to obtain clear ethanolic extracts.

2.1.8 Removal of Excess Ethanol

The filtrates were concentrated using a water bath maintained at 40–50°C to gently evaporate excess ethanol. This process yielded concentrated essential oils, which were stored in airtight containers until formulation.

2.1.9 Formulation of Essential Oil–Based Multipurpose Air Freshener

The air freshener was formulated to produce 10 spray bottles, each containing 250 mL, giving a total volume of 2250 mL.

➤ Ingredients and Quantities (for 2250 mL)

- Distilled water → 1600 mL
- Combined essential oil extracts (from all seven plants) → 80 mL
- Ethanol (95%) → 200 mL
- Glycerin → 60 mL
- Baking soda (NaHCO_3) → 20 g
- Citric acid → 6 g
- Colorant

➤ Formulation Procedure:

Step 1: Preparation of Baking Soda Solution

Twenty grams (20 g) of baking soda were dissolved in 400 mL of warm distilled water and stirred until completely dissolved. The solution was set aside.

Step 2: Preparation of Oil–Ethanol Phase

Eighty milliliters (80 mL) of the combined essential oils were measured and mixed with 200 mL of ethanol. The mixture was stirred thoroughly to ensure uniform dispersion.

Step 3: Preparation of Aqueous Phase

In a clean container, 1200 mL of distilled water was measured and 60 mL of glycerin was added. The mixture was stirred gently until homogeneous.

Step 4: Combination of Baking Soda Solution

The prepared baking soda solution was slowly added to the aqueous phase with gentle stirring to avoid excessive foaming.

Step 5: Addition of Oil–Ethanol Mixture

The oil–ethanol mixture was gradually poured into the combined aqueous solution while stirring continuously to ensure uniform distribution of the oils.

Step 6: Addition of Citric Acid

Six grams 6g of citric acid were dissolved in a small quantity of distilled water and added gradually to the mixture until fizzing ceased, indicating pH balance.

Step 7: Addition of Colorant

A few drops of colorant were added and the mixture stirred gently.

Step 8: Final Volume Adjustment

Distilled water was added to make up the final volume to 2250 mL.

Step 9: Bottling

The final formulation was gently shaken and dispensed into 10 spray bottles, each filled with 250 mL of the air freshener. The bottles were properly labeled.

2.2 METHODOLOGY

2.2.1 CHARACTERIZATION AND EVALUATION OF THE FORMULATED AIR FRESHENER

After formulation, the essential oil–based multipurpose air freshener was subjected to several physicochemical and performance evaluations to assess its quality, stability, and suitability for domestic use. The tests conducted include pH determination, stability testing, spray performance evaluation, fragrance diffusion assessment, and sensory evaluation. These tests are essential to ensure product safety, effectiveness, and consumer acceptability. Among of which are:

➤ **Determination of pH**

The pH of the formulated air freshener was determined using a digital pH meter. The pH meter was first calibrated using standard buffer solutions of pH 4.0 and 7.0. About 20 mL of the air freshener sample was poured into a clean beaker, and the pH electrode was immersed into the sample. The reading was allowed to stabilize before recording. The pH value obtained was used to assess the safety of the product for indoor use and to ensure it falls within an acceptable range for household formulations.

➤ **Stability Test**

The stability of the formulated air freshener was evaluated by observing physical changes over time. The product was stored at room temperature for a period of four weeks. During this period, the formulation was monitored weekly for changes in color, odor, phase separation, sediment formation, and clarity. Any visible change was noted to determine the physical stability and shelf-life potential of the product.

➤ **Spray Performance Test**

The spray performance of the air freshener was assessed using the spray bottle containing the formulation. The product was sprayed at a distance of approximately 30 cm into the air, and the spray pattern, fineness of mist, and ease of spraying were observed. This test was conducted to evaluate the functionality of the spray mechanism and the ability of the formulation to disperse evenly into the air.

➤ **Fragrance Diffusion Test**

The fragrance diffusion ability of the air freshener was assessed in an enclosed room. The product was sprayed once at a fixed point, and the spread of fragrance throughout the room was observed. The time taken for the fragrance to be perceived across different parts of the room was recorded. This test helped to evaluate the volatility of the essential oil components and the effectiveness of the formulation in distributing fragrance beyond the point of application.

➤ **Sensory Evaluation**

A simple sensory evaluation was carried out to assess consumer acceptability of the formulated air freshener. A small group of volunteers evaluated the product based on fragrance intensity, pleasantness, and overall acceptability. The responses were recorded and used to assess the suitability of the formulation for household use.



Dried Orange Peel



Dried Lemon Grass



Dried Ginger



Lemon Grass Extracts



Plant Extracts (Lemon grass, clove, rosemary and orange)

3.0 RESULTS AND DISCUSSION

3.1 RESULTS

Essential oils were successfully extracted from seven locally sourced plant materials using ethanol maceration followed by solvent evaporation with a water bath. The plants used were lemongrass, lemon peel, orange peel, scent leaf, clove, rosemary, and ginger.

3.1.1 Physical Characteristics of Extracted Oils

- **Lemongrass oil** appeared pale yellow with a strong, fresh citrus-herbal aroma characteristic of citral.
- **Lemon peel oil** was light yellow with a sharp citrus scent dominated by limonene.
- **Orange peel oil** had a bright yellow color with a sweet citrus fragrance.
- **Scent leaf oil** appeared greenish with a strong herbal and spicy aroma.
- **Clove oil** was dark brown with a very intense spicy aroma due to eugenol.
- **Rosemary oil** was pale green with a refreshing camphor-like scent.
- **Ginger oil** appeared brownish-yellow with a warm, spicy aroma.

The strong aromas observed indicate that volatile constituents were well preserved during air drying, cold maceration, and solvent evaporation.

3.1.2 Percentage Yield and Observation of Extracted Oils

The quantity of oil obtained from each plant material was relatively small, which is consistent with essential oil extraction using solvent maceration. Plant materials such as clove and citrus peels produced oils with higher aroma intensity, while leafy materials such as scent leaf and rosemary yielded lower quantities but retained characteristic fragrances.

The low oil yield justified the need for combining all extracted oils into a single aqueous formulation to ensure uniform fragrance distribution and effective performance of the final air freshener.

3.1.3 Results of Air Freshener Formulation

The extracted essential oils were combined to produce a blended oil mixture, which served as the fragrance and antimicrobial component of the air freshener. The formulation process involved dissolving baking soda in distilled water, followed by the addition of glycerin, citric acid, ethanol, and the blended essential oils. The final mixture was stirred thoroughly to ensure homogeneity before being transferred into spray bottles.

The final product was prepared in ten (10) spray bottles, filled to approximately 250 mL to allow efficient spraying. The use of an aqueous base allowed uniform dispersion of the essential oils, improved sprayability, enhanced fragrance diffusion and improving indoor air quality.

3.1.4 Physical Appearance of the Formulated Product

The formulated air freshener was visually examined immediately after preparation and during storage.

Observations:

- The solution appeared clear to slightly cloudy, due to the concentration of essential oils.

- No visible solid particles were observed after proper mixing.
- The formulation remained uniform without visible oil separation shortly after preparation.
- The colour of the formulation was light yellow, reflecting the combined essential oils used.

The slight cloudiness observed is typical of essential oil-based aqueous formulations and does not indicate product instability (Phuong *et al.*, 2022).

3.1.5. pH Determination

The pH of the formulated air freshener was measured using a calibrated digital pH meter.

Result:

- The pH of the formulation ranged between 7.4

This pH range is considered safe for indoor use, non-corrosive, and suitable for household applications. The presence of citric acid helped maintain a mildly acidic environment, which can inhibit microbial growth while remaining safe for human exposure (Hafidzah *et al.*, 2022).

3.1.6. Fragrance Performance

The formulated air freshener produced a noticeable and pleasant fragrance immediately after spraying. The aroma spread beyond the point of application due to the volatility of essential oil components and the fine droplet dispersion from the spray bottle.

The combination of citrus, herbal, and spicy notes created a balanced fragrance profile that was neither overpowering nor irritating. The presence of glycerin helped slow down evaporation, allowing the fragrance to persist for a reasonable duration after application.

The wide perception of fragrance beyond the point of application is due to the volatility of essential oil components such as limonene, citral, and eugenol. These compounds easily vaporize at room temperature and disperse through air by diffusion and convection currents, allowing the fragrance to spread evenly within the environment.

3.1.7 Spray Performance Test

The spray performance was evaluated using the filled spray bottles.

Observations:

- The spray nozzle produced a fine mist, ensuring even distribution.
- No blockage or clogging was observed during spraying.
- The product sprayed smoothly without dripping.

This indicates that the viscosity of the formulation was appropriate for spray application and that the formulation was compatible with the spray mechanism.

3.1.8 Odor Neutralization Effect

Baking soda played a significant role in odor control by neutralizing acidic odor molecules rather than merely masking them. When sprayed in enclosed spaces, the air freshener reduced unpleasant odors while simultaneously releasing fragrance, confirming its multipurpose functionality.

3.1.9 Stability of the Formulation

The air freshener formulation remained stable during short-term observation:

- No precipitation was observed
- No separation of oil and water phases occurred
- Fragrance intensity remained consistent

This stability is attributed to:

- Proper dissolution of ingredients
- Presence of ethanol as a co-solvent
- Use of glycerin to enhance uniformity

3.1.10 Effect of Filtration Using Muslin Cloth

Filtration using muslin cloth improved the clarity and uniformity of the formulated air freshener by removing suspended particles and undissolved residues. This enhanced spray efficiency, prevented nozzle blockage, and improved product appearance.

3.1.11 Packaging Results

The final product was packaged into spray bottles with approximately 250 mL of air freshener filled into each bottle. The formulation allowed for easy spraying without nozzle blockage.

A total of ten (10) spray bottles were successfully filled, demonstrating the practicality of the formulation for small-scale production.

3.11 Discussion of Findings

The successful extraction of essential oils from locally available plant materials confirms that Nigeria possesses abundant natural resources suitable for household product formulation. The air-drying method preserved volatile compounds, while ethanol maceration ensured efficient extraction without thermal degradation.

The low yield of essential oils necessitated a water-based formulation, which improved fragrance dispersion and ensured uniformity. The inclusion of baking soda enhanced odor neutralization, while glycerin improved fragrance retention.

A simple comparative assessment was carried out between the formulated air freshener and a commercially available synthetic one.

Findings:

The commercial air freshener had stronger initial fragrance but faded quickly.

The formulated air freshener had a more natural scent and was less irritating.

The natural formulation did not trigger coughing or nasal discomfort.

The commercial product contained strong synthetic fragrance notes.

This comparison supports literature findings that natural air fresheners are safer for indoor environments while still providing effective odor control (Steinemann et al., 2011).



Air Freshener (Final Products)

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

This study successfully demonstrated the formulation and characterization of an essential oil-based multipurpose air freshener using locally sourced raw materials. Essential oils were extracted from seven plant materials lemongrass, lemon peel, orange peel, scent leaf, clove, rosemary, and ginger using ethanol maceration followed by solvent evaporation through a controlled water bath method. The extraction technique adopted preserved the volatile aromatic compounds responsible for fragrance and antimicrobial activity.

The formulated air freshener exhibited desirable physical properties such as uniformity, clarity, stability, and pleasant fragrance. The incorporation of baking soda enhanced odor neutralization, while glycerin contributed to fragrance retention and improved product stability. The use of distilled water as the base ensured effective dispersion of essential oils, allowing the fragrance to spread beyond the point of application.

The results obtained confirm that essential oils derived from local plant materials can serve as effective alternatives to synthetic fragrance chemicals commonly used in commercial air fresheners. The formulated product achieved its intended multipurpose function by combining deodorization, fragrance release, and improved indoor air quality, while minimizing health and environmental risks associated with synthetic air fresheners.

The successful formulation and characterization of the essential oil-based multipurpose air freshener confirm that locally sourced plant materials can be effectively utilized to produce safe, stable, and environmentally friendly household products. The study demonstrates that natural essential oils can replace synthetic fragrance agents without compromising performance.

Overall, the study establishes that the production of a natural, affordable, and environmentally friendly air freshener is feasible using simple laboratory techniques and readily available local resources.

The final product compared favorably with commercial air fresheners in terms of fragrance release, appearance, and ease of use, while offering added benefits of safety, affordability, and environmental friendliness.

4.2 Recommendations

Based on the findings of this study, the following recommendations are made:

- **Further Analytical:** Advanced antimicrobial and physicochemical analyses such as GC-MS and microbial zone inhibition tests should be conducted to identify active constituents.
- **Shelf-Life Study:** Long-term stability studies should be carried out to determine product shelf life under different storage conditions.
- **Scale-Up Production:** Pilot-scale production should be explored to evaluate commercial viability.
- **Consumer Acceptability Study:** Sensory evaluation should be conducted to assess consumer preference.
- Future studies should explore advanced extraction techniques such as steam distillation or supercritical fluid extraction to improve essential oil yield.
- **Therefore, the followings were suggested for the further research work:**
 - Comparing different solvents for essential oil extraction.
 - Evaluating consumer acceptability of the formulated air freshener.
 - Developing gel or solid air freshener variants using the same essential oils.
 - Studying the environmental impact of natural air fresheners compared to synthetic alternatives.

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