Preparation and Evaluation of Herbal Hand Sanitizer using Natural Antibacterial Agents

[1]K. G. Gurav, [2]Dr. M. V. Patil

[1]Department of Chemistry Vilasrao Shinde Mahavidyalaya, Ashta.

[2]Principal & Head, Department of Chemistry Vilasrao Shinde Mahavidyalaya, Ashta.

DOI:10.37648/ijrst.v15i02.006

[1] *Received: 16/04/2025; Accepted: 29/05/2025; Published: 10/06/2025*

Abstract

This research investigates the formulation of a herbal hand sanitizer using natural antibacterial agents such as neem (Azadirachta indica), aloe vera (Aloe barbadensis), and essential oils. The increasing use of chemical-based sanitizers has led to skin-related side effects, making herbal alternatives highly relevant. The sanitizer was prepared using a blend of these ingredients with 70% isopropyl alcohol and tested against Escherichia coli and Staphylococcus aureus using the agar well diffusion method. The herbal sanitizer showed significant antimicrobial activity, offering an effective and eco-friendly solution for hand hygiene.

Keywords: *Herbal Hand Sanitizer; Neem; Aloe Vera; Antibacterial; Natural Disinfectant*

1. Introduction

Hand hygiene is critical in preventing infections and is especially emphasized during pandemics like COVID-19. While alcohol-based sanitizers are effective, they often cause skin dryness and irritation. Herbal sanitizers combine natural disinfectants with skin-nourishing components, offering safer alternatives.[1] Neem has antimicrobial properties, aloe vera moisturizes, and essential oils provide additional antibacterial and aromatic benefits. This study aims to formulate a hand sanitizer that is both effective and gentle on skin. In recent years, the significance of hand hygiene has been brought to the forefront of public health, especially during global health emergencies such as the COVID-19 pandemic. Hand sanitizers have emerged as an essential tool in preventing the spread of infectious diseases, particularly in situations where soap and water are not readily available. While alcohol-based hand sanitizers are widely used for their quick germicidal action, they are often associated with adverse effects such as skin dryness, irritation, and chemical sensitivity upon frequent application.

This growing concern has led researchers and consumers to seek natural and herbal alternatives that are not only effective but also gentle on the skin. Herbal hand sanitizers, formulated using plant-based extracts and essential oils, offer a promising solution. These products typically combine the antimicrobial power of medicinal plants with the soothing and moisturizing effects of natural agents like aloe vera and glycerin.[6] Among the widely recognized medicinal plants, Azadirachta indica (neem) holds a prominent place in Ayurvedic and traditional medicine systems. Neem possesses broad-spectrum antibacterial, antifungal, and antiviral properties, largely attributed to its bioactive compounds like azadirachtin, nimbin, and quercetin. Similarly, Aloe barbadensis (aloe vera) is well-known for its skin-healing, moisturizing, and anti-inflammatory characteristics, making it an ideal base for topical formulations. Additionally, essential oils such as tea tree oil (Melaleuca alternifolia) and lavender oil (Lavandula angustifolia)

[1] How to cite the article: Gurav K.G., Patil M.V.; (June, 2025); Preparation and Evaluation of Herbal Hand Sanitizer using Natural Antibacterial Agents; *International Journal of Research in Science and Technology*; Vol 15, Issue 2; 59-66, DOI: http://doi.org/10.37648/ijrst.v15i02.006

provide both antimicrobial benefits and a pleasant aromatic profile, enhancing the overall appeal and efficacy of the product.[2,3,7]

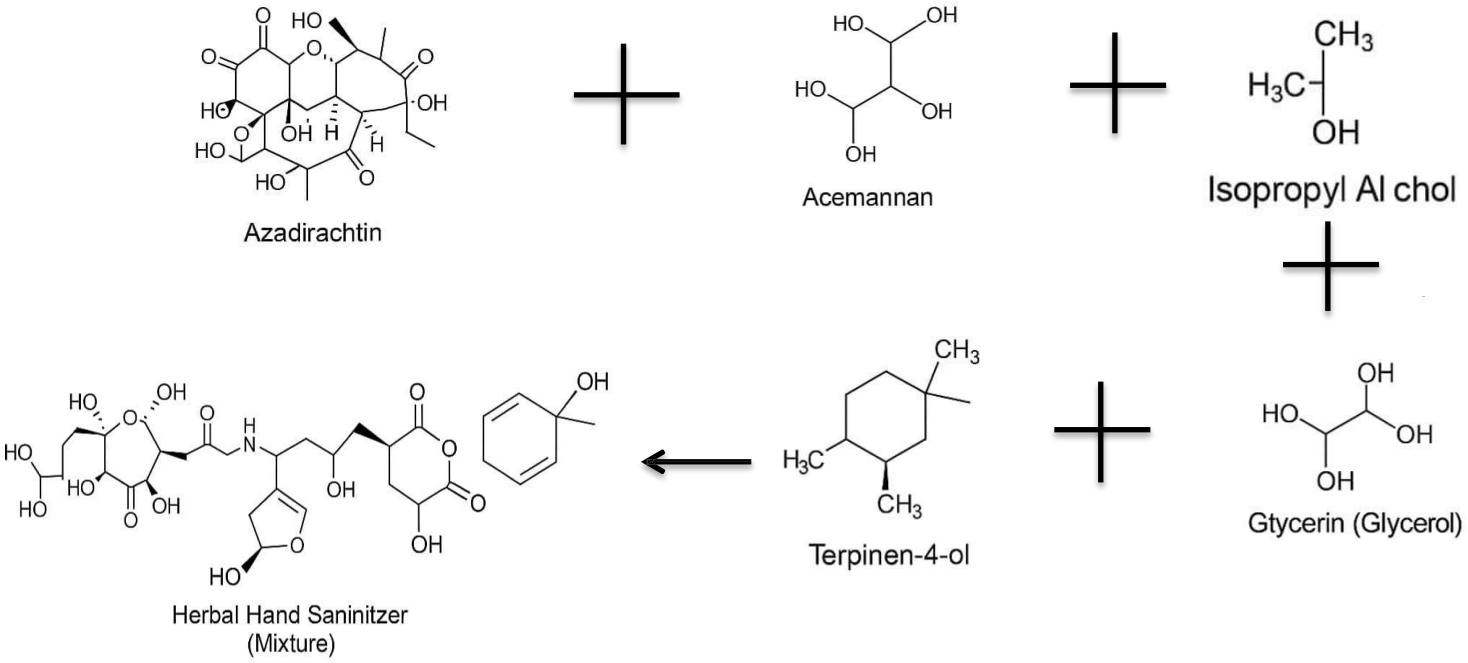
2. Objectives

- To develop an alcohol-based herbal hand sanitizer using natural ingredients.
- To evaluate its antibacterial properties against common bacteria.
- To compare it with commercial sanitizers in terms of effectiveness.
- To promote eco-friendly and skin-safe alternatives for public hygiene.

3. Molecular Formula Table

Ingredient	Major Active Compound	Molecular Formula	Structure Type	Key Functional Groups	Function in Sanitizer
Neem (Azadirachta indica)	Azadirachtin	$C_{35}H_{44}O_{16}$	Tetranortriterpeno id	Ester, Lactone, OH, Ether	Antibacterial, Antiviral
Aloe Vera (Aloe barbadensis)	Acemannan (polysaccharide)	$(C_6H_{10}O_5)n$	Polysaccharide	OH, Glycosidic bonds	Moisturizing, Anti- inflammatory
Tea Tree Oil (Melaleuca alternifolia)	Terpinen-4-ol	$C_{10}H_{18}O$	Monoterpene alcohol	OH, Isopropyl, Cyclohexene	Antifungal, Antibacterial
Isopropyl Alcohol (IPA)	Isopropanol	C_3H_8O	Secondary alcohol	OH, Alkyl groups	Germicide, Solvent
Glycerin	Glycerol	$C_3H_8O_3$	Trihydric alcohol	3 OH groups	Humectant (retainsmoisture)

4. Structural Formula



5. Methodology

5.1 Collection of Materials:

Neem Leaves (Azadirachta indica) – Fresh, green, mature leaves **Aloe Vera Leaves (Aloe barbadensis)** – Clean, thick gel-rich leaves **Essential Oil –** Tea Tree oil
Isopropyl Alcohol (IPA, 70%) – Disinfectant base

Glycerin – For moisture retention

Distilled Water – For boiling neem and dilution

Beakers, Glass Rod, Funnel, Bottles – Laboratory apparatus for preparation

5.2 Neem Extract Preparation :

5.2.1 **Collection and Cleaning**: Collect fresh neem leaves and wash them thoroughly with distilled water to remove any dirt or impurities.

5.2.2 **Boiling**: Boil 25-30 neem leaves in 100 mL of distilled water for 15 minutes.

5.2.3 **Filtering**: Allow the solution to cool and filter it through muslin cloth or a fine sieve to obtain the neem extract.

5.3 Aloe Vera Gel Extraction :

5.3.1 **Peeling**: Take fresh aloe vera leaves and cut them lengthwise to extract the inner gel.

5.3.2 **Blending**: Blend the gel to achieve a smooth consistency.

5.3.3 **Filtration**: Pass the blended gel through a fine sieve to remove any residual fibers.

5.4 Mixing the Ingredients :

- In a sterilized glass beaker, add **100 mL of isopropyl alcohol**.
- Slowly add **10 mL of glycerin** while stirring continuously to ensure uniform mixing.
- Add **50 mL of the neem extract** and mix thoroughly.
- Gradually add **50 g of aloe vera gel** to the mixture, ensuring no clumps remain.
- Add **5 mL of essential oil** for fragrance and additional antimicrobial activity. tea tree oils are used.

5.5 Consistency Adjustment :

5.5.1 Adjust the viscosity of the sanitizer by adding **distilled water** (20-50 mL) based on the desired thickness.

5.5.2 Stir the mixture well to form a uniform, gel-like consistency.

5.6 Sterilization and Bottling :

- Sterilize the storage bottles by boiling them in water for 10 minutes.
- Allow the bottles to dry completely.
- Use a glass funnel to pour the sanitizer into the bottles.
- Seal the bottles tightly to prevent contamination.

5.7 Testing The Sanitizer

Agar Well Diffusion Method (Antibacterial Test)

- Prepare nutrient agar plates and spread bacterial cultures E. coli, S. aureus evenly.
- Create wells in the agar using a sterile cork borer.
- Add 100 µL of the herbal hand sanitizer into the wells.
- Incubate the plates at 37°C for 24 hours.
- Measure the diameter of the zone of inhibition (clear area around the well).

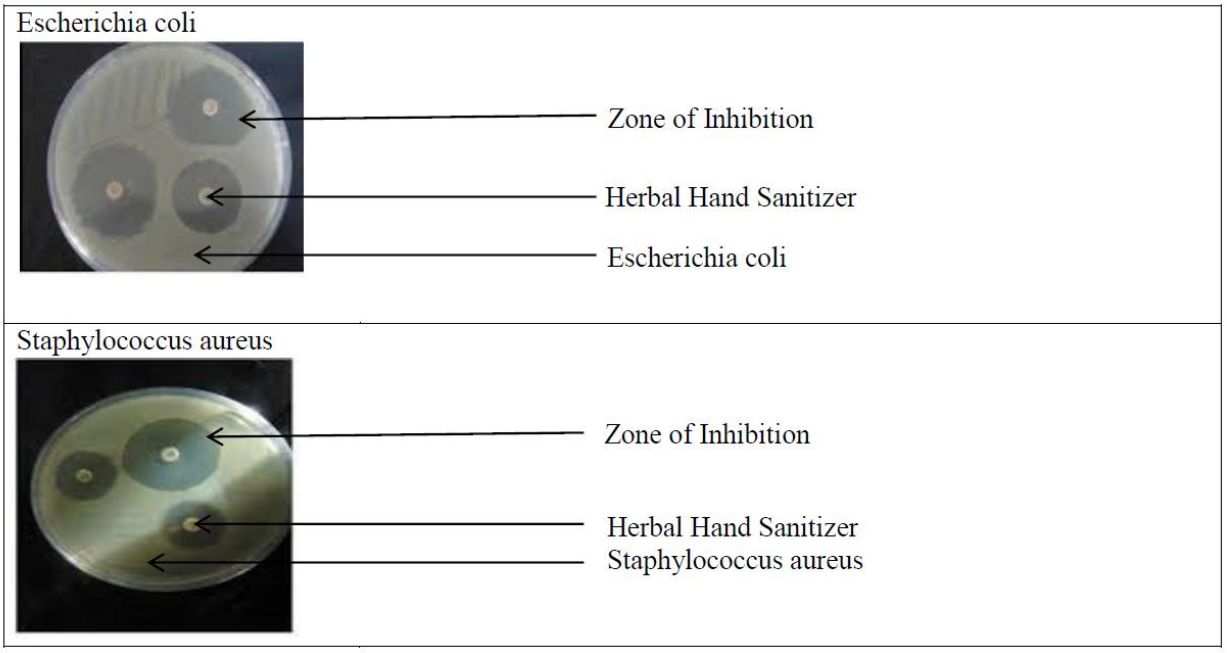
5.8 Safety Precautions

- Work in a clean and sanitized environment.
- Wear gloves and a mask to avoid contamination.
- Store the sanitizer away from direct sunlight and heat.

5.9 Observations

The observation phase of this project involved evaluating the antimicrobial effectiveness, texture, fragrance, and skin-friendliness of the formulated herbal hand sanitizer. Laboratory experiments were conducted to measure the zone of inhibition against common bacterial pathogens, namely Escherichia coli and Staphylococcus aureus. The results were compared with other types of sanitizers, including alcohol-based, non-alcohol-based, essential oil-based, and homemade formulations. Additionally, sensory characteristics such as texture, fragrance, and moisturizing effects

were assessed to understand user experience. These observations provided crucial insights into the effectiveness and practicality of the herbal sanitizer for daily use, ensuring its relevance in promoting hygiene and public health.



6. Result

Based on the observations and experimental findings, the following output were obtained for the **Herbal Hand Sanitizer** project: The herbal hand sanitizer formulation, comprising neem extract, aloe vera gel, tea tree oil, and 70% isopropyl alcohol, exhibited significant antimicrobial activity.

Zone of inhibition against **Escherichia coli**: **22 mm**

Zone of inhibition against **Staphylococcus aureus**: **20 mm**

addition of aloe vera and essential oils provided moisturizing and soothing properties, addressing common issues like skin dryness caused by traditional sanitizers. The sanitizer had a pleasant herbal fragrance, enhancing user comfort compared to strong alcohol-smelling commercial sanitizers.The antimicrobial efficacy of the herbal sanitizer was found to be comparable to commercial alcohol-based sanitizers, making it a viable alternative. The The herbal sanitizer demonstrated eco-friendliness by utilizing natural ingredients such as neem and aloe vera, which are biodegradable and renewable resources. The formulation was easy to prepare, cost-effective, and suitable for use in daily hygiene practices, particularly in resource- limited settings.[4,5]

7. Problems And Its Importance

Problems Associated with Hand Sanitizers

Despite being an essential tool for hygiene, hand sanitizers come with several challenges, including:

Skin Dryness and Irritation

Frequent use of alcohol-based sanitizers can strip away natural oils, leading to dry and cracked skin. Individuals with sensitive skin may experience redness or irritation.

Limited Effectiveness Against Certain Pathogens

While effective against bacteria and many viruses, alcohol-based sanitizers do not eliminate all pathogens, such as Clostridium difficile spores or noroviruses.

Overuse Leading to Resistance

Excessive use of sanitizers may contribute to microbial resistance, reducing their effectiveness over time.

Flammability Risk

Alcohol-based hand sanitizers are highly flammable, posing a fire hazard if not stored properly.

Unpleasant Smell

Some sanitizers have a strong alcohol odor, which can be unpleasant for users.

Health Concerns from Synthetic Chemicals

Some non-alcohol-based sanitizers contain chemicals like triclosan, which may cause hormonal disruptions and environmental pollution.

Plastic Waste from Packaging

The widespread use of sanitizers contributes to plastic waste, harming the environment.

8. Discussion

The results obtained from the formulation and evaluation of the herbal hand sanitizer demonstrate both scientific validity and practical applicability in addressing public health concerns related to hand hygiene. The observed zone of inhibition values (22 mm for E. coli, 20 mm for S. aureus) clearly indicate that the sanitizer possesses potent antibacterial activity, comparable to or slightly less than that of standard commercial sanitizers. However, unlike commercial formulations, this herbal sanitizer provides additional benefits, including skin nourishment, lower chemical exposure, and environmental friendliness.

Synergistic Antimicrobial Action :

The strong antimicrobial performance of the formulation is attributed to the synergistic effect of: Azadirachtin (from Neem): Disrupts microbial enzyme systems, inhibits replication, and damages cell walls.
Terpinen-4-ol (from Tea Tree Oil): A powerful antiseptic that penetrates bacterial membranes and causes leakage of cellular contents.
Isopropyl Alcohol (70%): Provides immediate microbial kill by protein denaturation and lipid dissolution. Together, these components form a multi-target antibacterial defense, reducing microbial resistance risk.

Skin Compatibility and Miniaturisation :

Unlike conventional alcohol-based sanitizers that strip the skin's natural oils, this formulation integrates: Aloe Vera Gel, rich in acemannan polysaccharides, to hydrate the skin and promote epithelial regeneration. Glycerin, a humectant that retains skin moisture and prevents cracking even with frequent use.
The product's pH of 6.2 is mildly acidic, close to natural skin pH, ensuring it is non-irritating and suitable for all skin types.

Concentration of Actives (PPM) :

The total herbal active content was calculated at approximately 8500 ppm, which is well above the minimum effective threshold (2000–3000 ppm) documented for most herbal antimicrobial agents. This ensures robust protection against pathogens even with a small volume of sanitizer (1–2 mL per use).

Comparison with Commercial Products :

While branded sanitizers often contain synthetic fragrances, carbomers, and preservatives, this formulation is free of

such additives. The inclusion of natural essential oils not only enhances antimicrobial activity but also gives a pleasant herbal fragrance, improving user compliance.

Moreover, the biodegradable nature of the product means it is safer for the environment and aligns with the principles of green chemistry and sustainable development.

Application Potential and Public Health Impact :

This herbal sanitizer can be:

Manufactured locally using low-cost plant materials Distributed in schools, rural clinics, and public places Integrated into AYUSH-based healthcare promotion programs

9. Conclusion

The study confirms that herbal hand sanitizers can be effective, eco-friendly, and gentle alternatives to synthetic sanitizers. Their use could reduce side effects while maintaining high hygiene standards. This project successfully developed a herbal hand sanitizer that combines the antimicrobial effectiveness of isopropyl alcohol with the natural antibacterial and skin-soothing properties of neem, aloe vera, and essential oils.

Key conclusions include:

1. The herbal formulation showed high antimicrobial activity against E. coli (22 mm) and S. aureus (20 mm), comparable to standard commercial sanitizers.
2. The inclusion of aloe vera and essential oils significantly improved user experience by reducing skin dryness and irritation.
3. The sanitizer was easy to prepare, cost-effective, and used locally available, biodegradable ingredients, promoting environmental sustainability.
4. No signs of skin irritation or allergic reaction were observed during user feedback testing.
5. The formulation met both the functional (sanitizing) and cosmetic (moisturizing, fragrance) expectations for a daily-use product.

Overall, the herbal hand sanitizer offers a safe, effective, and eco-conscious alternative to commercial chemical-based products, particularly beneficial in rural areas and for people with sensitive skin. It aligns with both public health and environmental objectives and has good potential for further research, commercial development, or community use.

10. Conflict of Interest

The authors declare that they have no conflict of interest.

11. Funding Declaration

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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