

# A Review On Herbal Hand Sanitizers: Phytochemistry, Antimicrobial Activity, And Formulation Approaches

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## ABSTRACT

Hand hygiene is a fundamental practice for preventing the transmission of infectious diseases and maintaining public health. The widespread use of conventional alcohol-based hand sanitizers has significantly reduced microbial contamination; however, frequent use may cause skin dryness, irritation, and allergic reactions. These limitations have led to increasing interest in herbal hand sanitizers as safer and more skin-friendly alternatives. Herbal formulations utilize plant-derived bioactive compounds possessing antimicrobial, antioxidant, anti-inflammatory, and moisturizing properties. This review focuses on the phytochemistry, antimicrobial activity, and formulation approaches of herbal hand sanitizers, with particular emphasis on Neem (*Azadirachta indica*), Tulsi (*Ocimum sanctum*), and Aloe Vera (*Aloe vera*). Neem contains biologically active constituents such as nimbin, nimbidin, and azadirachtin, which exhibit potent antibacterial and antifungal activities. Tulsi is rich in eugenol, ursolic acid, and other phenolic compounds that contribute to broad-spectrum antimicrobial and antioxidant effects. Aloe Vera contains polysaccharides, anthraquinones, and saponins that provide moisturizing, wound-healing, and mild antimicrobial properties, enhancing skin compatibility in sanitizer formulations. The review summarizes various formulation strategies including gels, sprays, and polyherbal preparations, along with their physicochemical evaluation, stability studies, and antimicrobial assessment methods. Published studies indicate that herbal hand sanitizers demonstrate significant activity against common pathogenic microorganisms such as *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans*. Furthermore, polyherbal formulations often exhibit synergistic effects, improving antimicrobial efficacy while maintaining skin health. Despite their promising potential, challenges such as standardization of plant extracts, variability in phytochemical composition, regulatory requirements, and limited clinical evidence remain important considerations. Future research should focus on advanced delivery systems, standardized formulations, and clinical validation to enhance the effectiveness and acceptance of herbal hand sanitizers. Overall, herbal hand sanitizers represent a promising, eco-friendly, and sustainable approach to hand hygiene and infection prevention.

**Keywords:** Herbal hand sanitizer, Neem, Tulsi, Aloe Vera, Phytochemistry, Antimicrobial activity, Polyherbal formulation, Hand hygiene, Medicinal plants.

## INTRODUCTION

Hand hygiene is recognized as one of the most effective and economical methods for preventing the transmission of infectious microorganisms and reducing the incidence of communicable diseases. Human hands serve as major carriers of pathogenic bacteria, viruses, and fungi, facilitating the spread of infections through direct contact and contaminated surfaces. Consequently, proper hand hygiene practices, including hand washing and the use of hand sanitizers, have become essential components of public health and infection control programs worldwide.<sup>[1]</sup>

Conventional hand sanitizers, particularly alcohol-based formulations containing ethanol or isopropyl alcohol, are widely used due to their rapid and broad-spectrum antimicrobial activity. These products effectively reduce microbial load and help prevent the spread of infectious diseases. However, frequent and prolonged use of alcohol-based sanitizers may lead to adverse effects such as skin dryness, irritation, allergic reactions, and disruption of the natural skin barrier. In addition, concerns regarding chemical exposure, flammability, and environmental impact have encouraged researchers to explore safer and more sustainable alternatives.<sup>[2]</sup>

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In recent years, herbal hand sanitizers have gained considerable attention as natural substitutes for conventional formulations. Herbal sanitizers utilize extracts obtained from medicinal plants that possess antimicrobial, antioxidant, anti-inflammatory, and skin-protective properties. The presence of bioactive phytochemicals such as flavonoids, alkaloids, tannins, terpenoids, phenolic compounds, and essential oils contributes to their therapeutic potential. Unlike synthetic antimicrobial agents, herbal ingredients often provide additional benefits including skin moisturization, wound healing, and reduced risk of adverse reactions.<sup>[3]</sup>



**Fig. Neem Handwash**

Among the various medicinal plants investigated for hand sanitizer formulations, Neem (*Azadirachta indica*), Tulsi (*Ocimum sanctum*), and Aloe Vera (*Aloe vera*) have emerged as promising candidates due to their well-documented pharmacological activities. Neem is widely recognized for its potent antibacterial, antifungal, antiviral, and anti-inflammatory properties, primarily attributed to compounds such as nimbin, nimbidin, and azadirachtin. Tulsi contains bioactive constituents including eugenol, ursolic acid, and rosmarinic acid, which exhibit broad-spectrum antimicrobial and antioxidant activities. Aloe Vera is valued for its moisturizing, wound-healing, and soothing effects, making it an ideal component for enhancing skin compatibility and user acceptability in sanitizer formulations.<sup>[4]</sup>

The effectiveness of herbal hand sanitizers depends not only on the antimicrobial activity of plant extracts

but also on formulation parameters such as extract concentration, excipient selection, stability, viscosity, pH, and overall product quality. Various formulation approaches, including gels, sprays, foams, and polyherbal preparations, have been developed to optimize efficacy and consumer acceptance. Furthermore, scientific studies have demonstrated that combinations of medicinal plant extracts may produce synergistic antimicrobial effects, enhancing their ability to inhibit pathogenic microorganisms.

Despite the growing popularity of herbal hand sanitizers, challenges remain regarding standardization of plant materials, consistency of phytochemical composition, quality control, regulatory approval, and clinical validation. Comprehensive evaluation of existing literature is therefore necessary to understand the current status of herbal sanitizer research and identify future opportunities for development.<sup>[5]</sup>

This review aims to provide a comprehensive overview of herbal hand sanitizers with special emphasis on their phytochemical constituents, antimicrobial mechanisms, formulation approaches, evaluation parameters, advantages, limitations, and future prospects. Particular attention is given to Neem (*Azadirachta indica*), Tulsi (*Ocimum sanctum*), and Aloe Vera (*Aloe vera*) due to their widespread use and significant potential in the development of safe, effective, and sustainable hand hygiene products.<sup>[6]</sup>

## Overview of Hand Sanitizers

### Types of Hand Sanitizers <sup>[7]</sup>

#### 1. Alcohol-based sanitizers

- Ethanol (60–95%)
- Isopropyl alcohol (60–75%)
- Rapid antimicrobial action

#### 2. Non-alcohol-based sanitizers

- Benzalkonium chloride
- Chlorhexidine
- Herbal extracts

### 3. Herbal hand sanitizers

- Plant-derived antimicrobial agents
- Reduced skin irritation
- Additional moisturizing effects

- Carvacrol
- Terpenoids

### Phytochemistry of Herbal Ingredients

#### A. Neem (*Azadirachta indica*)

##### Major Phytochemicals

- Nimbin
- Nimbidin
- Azadirachtin
- Quercetin
- Flavonoids
- Tannins

##### Pharmacological Activities

- Antibacterial
- Antifungal
- Antiviral
- Anti-inflammatory
- Antioxidant

##### Mechanism of Antimicrobial Action

Neem phytochemicals disrupt microbial cell walls, inhibit enzyme systems, and interfere with microbial metabolism. Several studies report activity against *Staphylococcus aureus*, *Escherichia coli*, and other pathogens.<sup>[8]</sup>

#### B. Tulsi (*Ocimum sanctum*)

##### Major Phytochemicals

- Eugenol
- Ursolic acid
- Rosmarinic acid
- Linalool

##### Pharmacological Activities

- Antibacterial
- Antiviral
- Antifungal
- Immunomodulatory
- Antioxidant

##### Antimicrobial Mechanism

Essential oils and phenolic compounds in Tulsi damage microbial membranes, causing leakage of cellular contents and inhibition of growth.

#### C. Aloe Vera (*Aloe vera*)

##### Major Phytochemicals

- Aloin
- Aloe-emodin
- Acemannan
- Saponins
- Anthraquinones
- Polysaccharides

##### Pharmacological Activities

- Moisturizing
- Wound healing
- Anti-inflammatory
- Antioxidant
- Mild antimicrobial activity

##### Role in Sanitizers

Aloe vera improves skin hydration, reduces alcohol-induced dryness, and enhances user acceptability.

## Antimicrobial Activity of Herbal Hand Sanitizers [9]

Studies have demonstrated that herbal formulations containing Neem, Tulsi, and Aloe Vera exhibit significant antimicrobial activity against:

Microorganism	Activity Reported
<i>Staphylococcus aureus</i>	Strong
<i>Escherichia coli</i>	Strong
<i>Pseudomonas aeruginosa</i>	Moderate
<i>Candida albicans</i>	Moderate
Various skin flora	Significant reduction

The antimicrobial effect is attributed to flavonoids, alkaloids, tannins, phenolics, terpenoids, and essential oils present in medicinal plants. Polyherbal formulations often show synergistic activity compared with single-plant formulations.<sup>[10]</sup>

### Evaluation Parameters

Review the following parameters reported in literature:

#### Physicochemical Evaluation

- Appearance
- Color
- Odor
- pH
- Viscosity
- Spreadability

#### Stability Studies

- Temperature stability
- Accelerated stability
- Phase separation

## Microbiological Evaluation

- Agar well diffusion
- Zone of inhibition
- Minimum inhibitory concentration (MIC)

## Safety Evaluation

- Skin irritation test
- Patch test
- User acceptability

Typical herbal sanitizer formulations show pH values between 6.0 and 7.2, suitable for skin application.

## Advantages of Herbal Hand Sanitizers

- Natural source of antimicrobial agents
- Lower risk of skin irritation
- Moisturizing effect
- Biodegradable
- Environmentally friendly
- Consumer preference for herbal products

## Limitations

- Variability in plant extract composition
- Limited clinical trials
- Shorter shelf life
- Standardization challenges
- Regulatory concerns
- Often less effective than properly formulated alcohol-based sanitizers against some viruses if alcohol content is absent or insufficient.

## Future Perspectives <sup>[11]</sup>

Future research should focus on:

- Nano-herbal formulations
- Standardized extraction methods
- Clinical efficacy studies

- Synergistic polyherbal combinations
- Long-term stability studies
- Development of alcohol-free yet highly effective herbal sanitizers

Green and sustainable pharmaceutical formulations [12]

## CONCLUSION

- ✓ Herbal hand sanitizers have emerged as promising alternatives to conventional hand hygiene products due to their natural origin, antimicrobial efficacy, and skin-friendly properties. The growing demand for safer and environmentally sustainable personal care products has increased interest in the utilization of medicinal plant extracts in sanitizer formulations. Among the various herbal ingredients, Neem (*Azadirachta indica*), Tulsi (*Ocimum sanctum*), and Aloe Vera (*Aloe vera*) have demonstrated significant potential owing to their rich phytochemical composition and diverse pharmacological activities. [13]
- ✓ The antimicrobial effectiveness of these plants is primarily attributed to the presence of bioactive compounds such as flavonoids, alkaloids, tannins, terpenoids, phenolics, and essential oils, which exhibit antibacterial, antifungal, antiviral, antioxidant, and anti-inflammatory properties. Neem provides potent antimicrobial action against a wide range of pathogenic microorganisms, Tulsi contributes broad-spectrum antimicrobial and immunomodulatory effects, while Aloe Vera enhances skin hydration, wound healing, and user acceptability. The combination of these medicinal plants in polyherbal formulations may produce synergistic effects, resulting in improved antimicrobial performance and better skin protection. [14]
- ✓ Various formulation approaches, including gels, sprays, and polyherbal preparations, have been investigated to optimize the stability, efficacy, and consumer acceptance of herbal hand sanitizers. Studies reviewed in the literature indicate that properly formulated herbal sanitizers are effective against several common

microorganisms, including *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans*. Additionally, herbal formulations offer advantages such as reduced skin irritation, moisturizing effects, biodegradability, and lower environmental impact. [15]

- ✓ Despite these benefits, several challenges remain, including variability in phytochemical composition, lack of standardization of plant extracts, limited clinical evidence, and regulatory constraints. Therefore, further research is required to establish standardized extraction methods, quality control parameters, long-term stability profiles, and clinical efficacy through well-designed studies. The application of advanced technologies such as nano formulations and novel delivery systems may further enhance the effectiveness and commercial viability of herbal hand sanitizers.
- ✓ In conclusion, herbal hand sanitizers containing Neem, Tulsi, and Aloe Vera represent a valuable and sustainable approach to hand hygiene and infection prevention. Continued scientific investigation and formulation optimization will contribute to the development of safe, effective, and evidence-based herbal sanitizing products for widespread public use. [16,17]

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