

Formulation and Evaluation of Herbal Hand Sanitizer using Lemon, Tulsi and Aloe Vera

**Kartik Dongarkar, Mangesh Kolnure, Raj Tayade
Vivek Rathod, Ankosh Wanole**

Satyajeet College of Pharmacy, Mehkar, Buldhana. Maharashtra

Corresponding Authors : Kartik Ashok Dongarkar

kartikdongarkar1@gmail.com

Abstract: *Hand hygiene plays a crucial role in preventing the spread of infectious diseases. Although alcoholbased hand sanitizers are widely used, their frequent application may cause skin irritation, dryness, and dermatitis. Herbal hand sanitizers provide a safer and skin-friendly alternative due to the presence of natural antimicrobial and moisturizing agents.*

The present study aims to formulate and evaluate a herbal hand sanitizer containing Lemon (Citrus limon), Tulsi (Ocimum sanctum), and Aloe vera (Aloe barbadensis Miller). These medicinal plants are known for their antimicrobial, antioxidant, anti-inflammatory, and skin-protective properties. The formulation was prepared using Carbopol 940 as a gelling agent and evaluated for physicochemical parameters such as pH, viscosity, spreadability, antimicrobial activity, stability, and skin irritation.

The results showed that the formulated herbal hand sanitizer exhibited good antimicrobial activity, acceptable physicochemical characteristics, and excellent skin compatibility, indicating its potential as a natural alternative to synthetic hand sanitizers.

Keywords: Herbal hand sanitizer, Lemon, Tulsi, Aloe vera, Antimicrobial activity, Natural formulation

I. INTRODUCTION

1.1 Hand Hygiene and Disease Prevention

Hands are a critical vector for transmitting harmful microorganisms. Inadequate hand hygiene practices are directly linked to a range of infections, including diarrheal illnesses, respiratory infections, and infections acquired within healthcare settings. The World Health Organization (WHO) emphasizes hand hygiene as a cornerstone in preventing healthcare-associated infections, highlighting its costeffectiveness and ease of implementation. Regular and proper handwashing, particularly with soap and water or an alcohol-based hand sanitizer, can significantly reduce the spread of pathogens and protect individuals and communities from infectious diseases. This simple yet powerful practice is a fundamental component of public health strategies worldwide. [1].

1.2 Limitations of Alcohol-Based Hand Sanitizers

Alcohol-based hand sanitizers containing ethanol or isopropyl alcohol (60–95%) are highly effective antimicrobial agents and are recommended by global health authorities for routine hand hygiene. However, frequent application is associated with adverse effects such as skin dryness, irritation, and barrier disruption. Repeated use also alters the natural skin microflora, potentially affecting skin immunity. In addition, alcohol-based sanitizers are flammable and may leave an unpleasant odor after repeated use, reducing user acceptability. These limitations have driven increasing interest in herbal and natural formulations that can provide antimicrobial activity with better skin compatibility. [2].

1.3 Need for Herbal Hand Sanitizers

Herbal formulations utilize plant-derived bioactive compounds that exhibit potent antimicrobial properties while boasting minimal side effects. These formulations are increasingly recognized for their biodegradable nature, eco-



friendliness, cost-effectiveness, and safety for long-term use. Lemon, Tulsi, and Aloe vera stand out as prominent examples of medicinal plants deeply rooted in traditional practices for skin care and infection control.

The utilization of herbal formulations in modern healthcare has gained considerable traction due to the diverse array of benefits they offer. These formulations are derived from natural sources, such as plants, and harness the bioactive compounds present in these botanicals to combat microbial threats effectively. One of the key advantages of herbal formulations is their antimicrobial properties, which enable them to inhibit the growth and proliferation of various pathogens, including bacteria, viruses, and fungi. Unlike conventional antimicrobial agents, herbal formulations tend to exhibit minimal side effects, making them a safer alternative for long-term use.

Moreover, the biodegradability of herbal formulations is a significant factor contributing to their sustainability and environmental friendliness. Unlike synthetic antimicrobial agents that can persist in the environment and contribute to pollution, herbal formulations undergo natural decomposition processes, minimizing their impact on ecosystems. This eco-friendly characteristic aligns with the growing global emphasis on sustainable practices in healthcare and pharmaceutical industries.

In addition to their environmental benefits, herbal formulations are also valued for their cost-effectiveness. The availability of plant-derived bioactive compounds in abundance makes herbal formulations a more affordable option compared to synthetic drugs. This cost-effectiveness not only benefits consumers but also healthcare systems seeking to optimize resource allocation and reduce financial burdens associated with treatment.[1,2]

The safety profile of herbal formulations further enhances their appeal for long-term use. Lemon, Tulsi, and Aloe vera are renowned for their medicinal properties and have been traditionally used for skin care and infection control. These plants contain a rich array of bioactive compounds that contribute to their antimicrobial efficacy while being gentle on the skin. The safety and long-standing use of these herbal ingredients underscore their suitability for incorporation into formulations designed for sustained therapeutic applications.

Lemon, scientifically known as *Citrus limon*, is a citrus fruit widely recognized for its refreshing scent and culinary uses. Beyond its culinary applications, lemon possesses antimicrobial properties attributed to compounds such as citric acid and vitamin C. Citric acid exhibits antimicrobial activity against a broad spectrum of pathogens, including bacteria and fungi, making lemon a valuable ingredient in herbal formulations for skin care and infection control. Furthermore, the high vitamin C content in lemon contributes to its antioxidant properties, which play a role in protecting the skin from oxidative damage and promoting overall skin health.

Tulsi, or Holy Basil (*Ocimum sanctum*), is an aromatic herb revered in Ayurveda for its diverse medicinal benefits. Tulsi is known for its adaptogenic, anti-inflammatory, and antimicrobial properties, making it a versatile ingredient in herbal formulations targeting skin ailments and infections. The essential oils present in Tulsi, such as eugenol and linalool, exhibit antimicrobial activity against various pathogens, including bacteria and fungi. Additionally, Tulsi's anti-inflammatory properties help soothe skin irritations and promote healing, making it a valuable component in herbal formulations for dermatological conditions.[2]

Aloe vera, a succulent plant with fleshy leaves containing a gel-like substance, is widely utilized for its therapeutic properties in skincare and wound healing. The gel extracted from Aloe vera leaves contains bioactive compounds, including polysaccharides, phenolic compounds, and vitamins, which contribute to its antimicrobial and anti-inflammatory effects. Aloe vera gel has been traditionally used to treat burns, wounds, and skin infections due to its ability to promote tissue repair and inhibit microbial growth. The soothing and hydrating properties of Aloe vera make it a popular ingredient in herbal formulations designed for moisturizing, soothing, and protecting the skin.

The synergistic combination of Lemon, Tulsi, and Aloe vera in herbal formulations results in potent antimicrobial effects with enhanced therapeutic benefits. These medicinal plants not only offer antimicrobial protection but also provide nourishment, hydration, and skin-rejuvenating properties, making them ideal ingredients for holistic skincare solutions. By harnessing the natural bioactive compounds present in these plants, herbal formulations can address a wide range of skin concerns while ensuring minimal side effects and long-term safety for users.[1,2]

In conclusion, the use of herbal formulations incorporating plant-derived bioactive compounds such as Lemon, Tulsi, and Aloe vera represents a sustainable, cost-effective, and safe approach to skin care and infection control. These formulations offer antimicrobial protection with minimal side effects, making them suitable for long-term use. The



biodegradability and eco-friendliness of herbal formulations align with global sustainability goals, while their affordability and safety profile make them accessible and beneficial for a wide range of consumers. Incorporating traditional medicinal plants like Lemon, Tulsi, and Aloe vera into herbal formulations underscores the rich heritage and therapeutic potential of natural remedies in modern healthcare practices.

II. LITERATURE REVIEW

2.1 Lemon (*Citrus limon*)

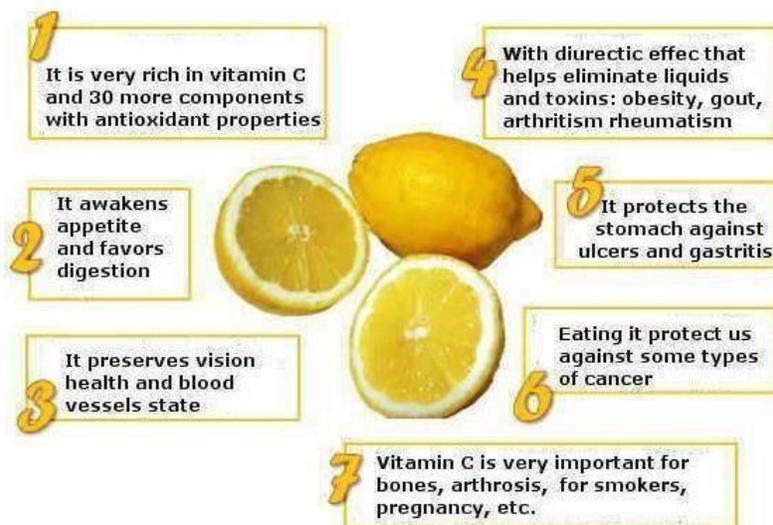
Lemon contains essential oil rich in **limonene, citral, and β -pinene**, which exhibit strong antibacterial, antifungal, and antiviral activities. Lemon extracts are effective against *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans* [3].

Lemon, scientifically known as *Citrus limon*, is a citrus fruit renowned for its various health benefits due to its rich content of essential oils. Among these oils, limonene, citral, and β -pinene stand out as key components that contribute to the fruit's potent antibacterial, antifungal, and antiviral properties. These bioactive compounds have been extensively studied for their effectiveness in combating a wide range of harmful microorganisms, making lemon a valuable natural resource in promoting health and wellness.

One of the primary components found in lemon essential oil is limonene, a monoterpene known for its powerful antimicrobial properties. Limonene has been shown to exhibit strong antibacterial activity against a variety of pathogens, including *Staphylococcus aureus*, a common bacterium responsible for a range of infections in humans. Research has demonstrated that limonene disrupts the cell membranes of bacteria, leading to their destruction and inhibiting their growth. This mechanism of action makes lemon an effective natural remedy for combating bacterial infections and promoting overall hygiene.

In addition to limonene, lemon essential oil also contains citral, a compound known for its antifungal properties. Citral has been shown to be particularly effective against fungal pathogens such as *Candida albicans*, a common yeast species that can cause infections in humans. Studies have revealed that citral disrupts the cell walls of fungi, leading to their death and inhibiting their ability to spread. By targeting fungal pathogens, lemon extracts can be used to treat a variety of fungal infections, offering a natural alternative to conventional antifungal medications.

PROPERTIES OF LEMON



Furthermore, β -pinene, another key component of lemon essential oil, contributes to the fruit's antiviral activity. β -pinene has been shown to possess potent antiviral properties, making it effective against a range of viral infections.



Research has indicated that β -pinene can inhibit the replication of viruses by interfering with their ability to infect host cells. This antiviral mechanism of action highlights the potential of lemon extracts in combating viral illnesses and strengthening the body's immune response against viral pathogens.

Studies have also demonstrated the broad-spectrum antimicrobial activity of lemon extracts against pathogens such as *Escherichia coli*, a common bacterial species known for causing foodborne illnesses. Lemon essential oil has been shown to effectively inhibit the growth of *E. coli* by disrupting its cellular functions and preventing its proliferation. This antimicrobial action underscores the potential of lemon as a natural sanitizer and disinfectant, offering a safe and eco-friendly alternative to chemical-based antimicrobial agents.[3,4]

In addition to its antimicrobial properties, lemon is also rich in antioxidants, such as vitamin C and flavonoids, which play a crucial role in supporting the immune system and protecting the body against oxidative stress. These antioxidants help to neutralize harmful free radicals in the body, reducing inflammation and promoting overall health. The combination of antimicrobial compounds and antioxidants in lemon makes it a versatile fruit with diverse health-promoting benefits.

2.2 Tulsi (*Ocimum sanctum*)

Tulsi, also known as holy basil, has been used in Ayurveda for centuries. It contains eugenol, ursolic acid, rosmarinic acid, and flavonoids. These compounds provide antibacterial, antifungal, antiinflammatory, and immunomodulatory effects [4].

Ocimum sanctum (Tulsi)



- ✓ Commonly known as **holy basil, tulasi or tulsi.**
- ✓ Aromatic perennial plant.
- ✓ Belongs to family **Lamiaceae.**
- ✓ Holy basil is an erect, many-branched subshrub.
- ✓ 30–60 cm tall with hairy stems.
- ✓ Leaves are green or purple.
- ✓ The three main morphotypes cultivated in India and Nepal are **Ram tulsi, Krishna tulsi, vana tulsi.**

Tulsi, scientifically known as *Ocimum sanctum* and commonly referred to as holy basil, holds a revered place in traditional Ayurvedic medicine with a history spanning centuries. This aromatic herb is enriched with a remarkable array of bioactive compounds, including eugenol, ursolic acid, rosmarinic acid, and various flavonoids, which contribute to its diverse therapeutic properties.

Eugenol, a key component of Tulsi, exhibits potent antibacterial properties, making it effective against a wide range of harmful bacteria. Research has shown that eugenol can inhibit the growth of bacterial strains responsible for infections, thereby highlighting Tulsi's role as a natural antibacterial agent. Furthermore, the presence of ursolic acid in Tulsi offers anti-inflammatory benefits by reducing inflammation in the body. This property is particularly valuable in managing conditions characterized by chronic inflammation, such as arthritis and certain skin disorders.

Rosmarinic acid, another significant compound in Tulsi, boasts antifungal properties that combat fungal infections. Studies have demonstrated the effectiveness of rosmarinic acid in inhibiting the growth of common fungi, underscoring Tulsi's potential as a natural antifungal remedy. Additionally, the flavonoids found in Tulsi play a crucial role in modulating the immune system, enhancing its ability to defend against pathogens and maintain overall health.



The combined actions of these bioactive compounds in Tulsi create a holistic approach to well-being, offering not only immediate relief from ailments but also long-term health benefits. Whether consumed as an herbal tea, included in culinary dishes, or applied topically, Tulsi continues to be a versatile herb with a rich pharmacological profile that aligns with the principles of Ayurveda.

2.3 Aloe vera (Aloe barbadensis Miller)

Aloe vera (*Aloe barbadensis* Miller) is a succulent plant known for its numerous health and skincare benefits. The gel extracted from its leaves is a rich source of polysaccharides, amino acids, vitamins, enzymes, and glycoproteins, making it a versatile natural remedy that has been used for centuries.

Polysaccharides found in aloe vera gel play a crucial role in promoting skin regeneration and wound healing. These compounds stimulate the production of collagen, which helps repair damaged tissues and accelerate the healing process. Additionally, amino acids such as alanine, proline, and serine present in aloe vera contribute to the synthesis of new skin cells, aiding in the restoration of healthy skin.

The vitamins present in aloe vera gel, including vitamin A, C, and E, provide antioxidant protection against free radicals that can damage skin cells and accelerate aging. These vitamins also help to nourish and rejuvenate the skin, promoting a more youthful and radiant complexion. Furthermore, enzymes like bradykinase help reduce inflammation and soothe irritated skin, making aloe vera gel a gentle and effective solution for various skin conditions.

One of the notable benefits of aloe vera gel is its antibacterial properties, which help prevent infections and promote overall skin health. By creating a protective barrier on the skin, aloe vera inhibits the growth of harmful bacteria and reduces the risk of skin infections. This makes it an ideal natural remedy for treating minor cuts, burns, and insect bites. Moreover, aloe vera gel is highly effective in moisturizing the skin and preventing dryness, especially for individuals who frequently use sanitizers or experience skin irritation due to environmental factors. Its hydrating properties help maintain the skin's natural moisture balance, leaving it soft, supple, and nourished [5].

2.4 Previous Studies on Herbal Hand Sanitizers

Several published studies indicate that herbal hand sanitizers formulated with plant extracts such as *Ocimum sanctum* (tulsi), *Aloe vera*, *Azadirachta indica* (neem), and citrus oils possess significant antimicrobial activity against common pathogens including *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*. These herbal formulations have been shown to exhibit antimicrobial effects comparable to alcohol-based hand sanitizers through *in vitro* evaluations using agar well diffusion and broth dilution methods. The bioactive phytoconstituents present in these herbal sanitizers, including flavonoids, tannins, saponins, essential oils, and phenolic compounds, play a crucial role in disrupting microbial cell membranes and inhibiting enzyme systems.

In addition to their antimicrobial efficacy, studies have highlighted the enhanced skin compatibility of herbal hand sanitizers compared to alcohol-based counterparts. Alcohol-based sanitizers are known to cause adverse skin effects such as dryness and irritation with frequent use, whereas herbal formulations containing humectants like *Aloe vera* gel and glycerin help maintain skin hydration and barrier function. This results in improved user acceptability and skin tolerance, with reports of better moisturization, reduced irritation, and increased compliance with regular use.

Despite these advantages, existing research on herbal hand sanitizers does have limitations. Many studies primarily rely on laboratory-based antimicrobial assays rather than standardized *in vivo* hand hygiene models, leading to variability in outcomes. Differences in extraction methods, plant concentrations, and formulation techniques further contribute to this variability. While herbal sanitizers demonstrate comparable antibacterial activity in controlled conditions and improved dermatological safety, alcohol-based hand rubs remain the preferred choice for rapid, broad-spectrum antimicrobial action, especially in healthcare settings.

To establish herbal hand sanitizers as viable alternatives to alcohol-based products, further well-designed clinical studies are necessary to validate their real-world efficacy and safety. These studies should address the limitations of current research by incorporating standardized *in vivo* hand hygiene models and considering factors like extraction methods and formulation techniques to provide comprehensive evidence of the benefits of herbal sanitizers in practical settings. [6].



III. AIM AND OBJECTIVES

3.1 Aim

The aim of the present study is to formulate and evaluate a herbal hand sanitizer using Lemon (*Citrus limon*), Tulsi (*Ocimum sanctum*), and Aloe vera (*Aloe barbadensis*). This study focuses on developing an effective hand hygiene product that provides antimicrobial protection while maintaining skin safety and user comfort. The selected herbal ingredients are well known for their antibacterial, antifungal, antiviral, antioxidant, and skin-soothing properties. The formulation is intended to serve as a safer and more skin-friendly alternative to conventional alcohol-based hand sanitizers, especially for frequent use.

3.2 Objectives

1. To prepare a stable herbal hand sanitizer formulation

This objective involves selecting suitable herbal extracts and excipients to formulate a physically and chemically stable hand sanitizer. The formulation process includes optimizing the concentration of Lemon, Tulsi, and Aloe vera to achieve maximum antimicrobial activity without causing skin irritation. Stability in terms of phase separation, color change, odor, and consistency is crucial to ensure product quality during storage and use.

2. To evaluate physicochemical properties of the formulation

Physicochemical evaluation is essential to determine the quality, safety, and acceptability of the herbal hand sanitizer. Parameters such as pH are evaluated to ensure skin compatibility, as extreme pH may cause irritation. Viscosity is measured to assess ease of application and spreadability on the hands. Other parameters like appearance, clarity, homogeneity, drying time, and consistency are examined to ensure good user experience and product performance.

3. To assess antimicrobial activity

The antimicrobial efficacy of the formulated herbal hand sanitizer is evaluated against selected pathogenic microorganisms commonly found on human hands, such as *Staphylococcus aureus* and *Escherichia coli*. Standard microbiological techniques like agar well diffusion or disc diffusion methods are employed to determine zones of inhibition. This objective helps to confirm the effectiveness of Lemon, Tulsi, and Aloe vera extracts in reducing or inhibiting microbial growth.

4. To study skin irritation and stability

Skin irritation studies are conducted to ensure the safety of the formulation upon topical application. Patch tests or observational studies are performed to detect any signs of redness, itching, or inflammation. Additionally, stability studies are carried out by storing the formulation under different environmental conditions and periodically evaluating its physicochemical and antimicrobial properties. This ensures the formulation remains safe, effective, and stable throughout its shelf life..

IV. PLANT PROFILE

4.1 Lemon

Biological name: *Citrus limon*

Family: Rutaceae

Parts used: Peel, juice

Uses: Antimicrobial, antioxidant, fragrance

Lemon (*Citrus limon*) is a versatile citrus fruit known for its numerous health benefits and wide array of applications in various industries. The peel and juice of lemon are the most utilized parts, each offering unique properties that make lemon a valuable ingredient.[7]

The peel of lemon is a treasure trove of essential oils, with limonene being the predominant component. These essential oils, coupled with flavonoids and phenolic compounds, give the lemon peel its potent antimicrobial and antioxidant characteristics. Studies have shown that the antimicrobial properties of lemon peel can help combat various bacteria and fungi, making it a popular choice in natural health remedies and herbal formulations.[8]





On the other hand, lemon juice is rich in organic acids like citric acid and ascorbic acid (vitamin C), which not only contribute to its distinct tart flavor but also play a crucial role in its antimicrobial and preservative effects. The presence of vitamin C in lemon juice makes it a powerful antioxidant, capable of neutralizing free radicals that can damage cells and contribute to aging and disease.

In the realm of skincare, lemon is often incorporated into herbal hand sanitizer formulations for its natural antimicrobial properties. By inhibiting the growth of harmful microorganisms on the skin, lemon helps maintain hygiene and prevent infections. Furthermore, the antioxidant constituents found in lemon provide an added layer of protection, helping to keep the skin healthy and radiant.

Moreover, the inclusion of lemon essential oil in hand sanitizers not only enhances the overall antimicrobial efficacy of the product but also imparts a refreshing and invigorating citrus scent. This natural fragrance not only elevates the user experience but also serves as a distinguishing feature of lemon-based sanitizers. [9]

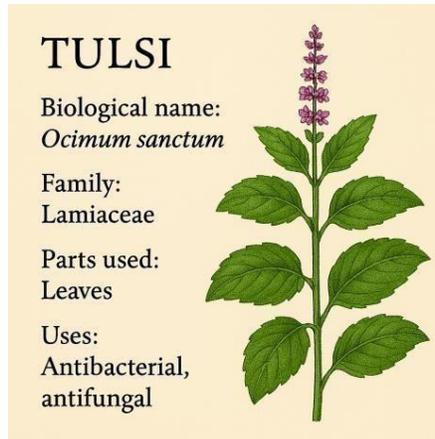
4.2 Tulsi

Biological name: *Ocimum sanctum*

Family: Lamiaceae

- Parts used: **Leaves**
- **Uses:** Antibacterial, antifungal

Tulsi (*Ocimum sanctum*), also known as holy basil, belongs to the Lamiaceae family and is primarily valued for its medicinal properties. This revered herb has been a cornerstone of traditional Indian medicine for centuries due to its diverse therapeutic benefits. The leaves of Tulsi are the most commonly utilized part of the plant, containing a rich array of bioactive compounds that contribute to its remarkable healing properties. [10]



The bioactive constituents found in Tulsi leaves, such as eugenol, ursolic acid, rosmarinic acid, flavonoids, and essential oils, are responsible for its powerful antibacterial, antifungal, anti-inflammatory, and antioxidant activities. These compounds work synergistically to combat various pathogens, making Tulsi a potent natural remedy for a wide range of health issues.

One of the key benefits of Tulsi is its significant antimicrobial action, which has been harnessed in herbal hand sanitizer formulations. By incorporating Tulsi leaf extract into sanitizers, the growth of harmful microorganisms, including both Gram-positive and Gram-negative bacteria, as well as certain fungi, can be effectively inhibited. This action not only helps in reducing the microbial load on the skin but also aids in preventing the transmission of infections.[11]

Tulsi's anti-inflammatory properties make it beneficial for soothing skin irritations and promoting overall skin health. Its antioxidant properties further contribute to skin protection by neutralizing harmful free radicals and reducing oxidative stress. These qualities make Tulsi an ideal ingredient for topical applications, as it can be used frequently without causing irritation.[12]

4.3 Aloe vera

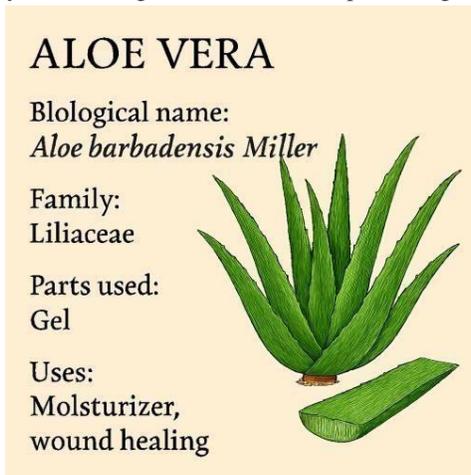
Biological name: *Aloe barbadensis* Miller

Family: Liliaceae

- **Parts used:** Gel
- **Uses:** Moisturizer, wound healing

Aloe vera, scientifically known as *Aloe barbadensis* Miller and belonging to the Liliaceae family, is a renowned medicinal plant coveted for its exceptional healing and therapeutic properties. The gel derived from the inner parenchymatous tissue of its leaves is a treasure trove of beneficial bioactive compounds, including polysaccharides like acemannan, glycoproteins, essential vitamins, amino acids, enzymes, and minerals. These constituents work synergistically to bestow upon Aloe vera its remarkable benefits for both health and beauty.[13]

The polysaccharides present in Aloe vera gel, notably acemannan, play a pivotal role in its therapeutic effects. Acemannan has been extensively studied for its immunomodulatory properties, aiding in bolstering the immune system and promoting overall health. Moreover, the glycoproteins found in Aloe vera exhibit anti-inflammatory characteristics, making it an excellent natural remedy for soothing skin irritations and promoting healing.[14]



Aloe vera gel is a popular ingredient in herbal hand sanitizers due to its multifaceted benefits. Beyond its moisturizing properties that prevent skin dryness, Aloe vera's wound-healing attributes facilitate the regeneration of skin cells, making it particularly effective in treating minor cuts, abrasions, and irritations. The gel's anti-inflammatory properties further enhance its healing potential, reducing redness and swelling while promoting a speedy recovery.

Aloe vera gel also serves as a versatile cosmetic ingredient, enhancing the texture, spreadability, and overall compatibility of skincare formulations. Its cooling sensation provides instant relief, making it a preferred choice in



products designed to soothe sunburns, insect bites, and various skin conditions. The presence of essential vitamins and amino acids further nourishes the skin, helping to maintain its health and vitality.[15]

V. MATERIALS AND METHODS

5.1 Materials

The formulation of the herbal hand sanitizer is meticulously crafted to harness the synergistic effects of carefully selected active herbal ingredients and pharmaceutical excipients. This thoughtful combination is intricately balanced to ensure not only the efficacy of the product but also its stability and compatibility with the skin.

Aloe vera gel is a cornerstone of this formulation, chosen for its exceptional properties as a natural moisturizer and skin-soothing agent. Its role goes beyond mere hydration; aloe vera helps to maintain the skin's moisture levels, thereby preventing dryness and irritation that may arise from frequent use of the sanitizer. This botanical wonder acts as a guardian of skin health, ensuring that each application is a nurturing experience for the hands.[16]

Tulsi extract, with its potent antimicrobial properties, stands out as a star ingredient in the hand sanitizer. This herbal powerhouse exhibits remarkable antibacterial and antifungal activities, effectively reducing the microbial load on the hands and playing a crucial role in curbing the spread of infections. The inclusion of Tulsi extract not only enhances the sanitizing power of the product but also adds a touch of nature's prowess to the formula.

Lemon oil or extract brings a dual benefit to the hand sanitizer formulation. Not only does it serve as an antimicrobial agent, bolstering the product's germ-fighting capabilities, but it also imparts a delightful natural fragrance. The presence of bioactive compounds like limonene and citric acid not only enhances the antimicrobial efficacy but also leaves a refreshing aroma, elevating the user experience and making hand hygiene a pleasant ritual.[17]

The addition of Carbopol 940 as a gelling agent ensures that the hand sanitizer attains the desired viscosity and consistency. This ingredient facilitates easy spreading on the hands while maintaining stability over time. Glycerin's role as a humectant further enhances the formula by attracting and retaining moisture on the skin, promoting softness and preventing dryness. Triethanolamine, as a pH adjusting agent, ensures that the formulation maintains a skin-friendly pH level, crucial for preventing irritation.[18,17]

Ingredient	Role
Aloe vera gel	Moisturizer
Tulsi extract	Antimicrobial
Lemon oil/extract	Antimicrobial, fragrance
Carbopol 940	Gelling agent
Glycerin	Humectant
Triethanolamine	pH adjuster
Distilled water	Vehicle

5.2 Method of Preparation

Carbopol 940, a widely used polymer in pharmaceutical and cosmetic formulations for its thickening and gelling properties, was meticulously handled in the preparation of a specialized skincare gel. The process began with the precise weighing of Carbopol 940, which was then gently dispersed in a carefully measured amount of distilled water. The dispersion was left undisturbed overnight to allow the polymer to fully swell and ensure optimal gel formation. This extended hydration period is crucial in achieving the desired consistency and stability of the final product.[19]

Upon complete hydration of the Carbopol 940, a freshly prepared Aloe vera gel was methodically integrated into the dispersion. The addition was done gradually and with continuous stirring to guarantee a homogeneous blend. Aloe vera, known for its soothing and moisturizing properties, complements the Carbopol 940 to create a synergistic formulation that promotes skin health and hydration.

Following the incorporation of Aloe vera, extracts of Tulsi and lemon were introduced into the mixture. These herbal extracts were added gradually while maintaining constant stirring to evenly distribute their active constituents within



the gel. Tulsi extract, with its antioxidant and antimicrobial properties, and lemon extract, rich in vitamin C and citric acid, enhance the formulation with additional skin benefits.

To further enhance the skincare benefits of the gel, glycerin was carefully added as a moisturizing and humectant agent. Glycerin's ability to attract and retain moisture helps improve skin hydration and smoothness, making it a valuable addition to the formulation.

To ensure the formulation's compatibility with the skin's natural pH, triethanolamine was used to adjust the pH to a skin-friendly range of 6.0–6.5. This pH adjustment not only enhances the product's tolerance on the skin but also aids in neutralization and gel formation, contributing to the overall stability of the formulation.[19,20]

The meticulous process of mixing and blending continued until a clear, homogeneous gel with a smooth consistency was achieved. This attention to detail and careful consideration of each ingredient's role resulted in a high-quality skincare product that combines the benefits of Carbopol 940, Aloe vera, herbal extracts, glycerin, and pH-adjusting agents to deliver a nourishing and effective solution for skin health and hydration.

METHOD OF PREPARATION

1. Biological name: *Aloe barbadensis* Miller and allowed to hydrate overnight.
2. Aloe vera gel was incorporated with constant stirring.
3. Tulsi extract and lemon extract were added slowly.
4. Glycerin was added as a moisturizing agent.
5. pH was adjusted using triethanolamine (pH 6.0–6.5).



Carbopol 940 was dispersed in distilled water and allowed to hydrate overnight.

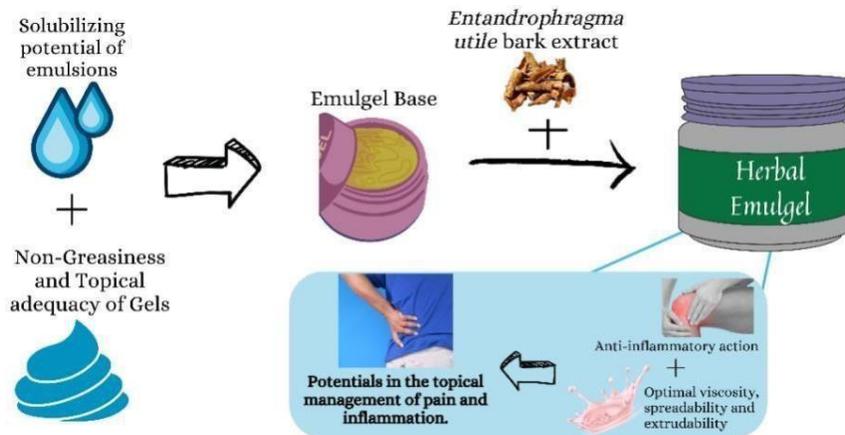
Aloe vera gel was incorporated with constant stirring.

Tulsi extract and lemon extract were added slowly.

Glycerin was added as a moisturizing agent.

pH was adjusted using triethanolamine (pH 6.0–6.5).

The formulation was mixed uniformly to obtain a clear gel.



VI. EVALUATION PARAMETERS

6.1. Evaluation of Herbal Hand Sanitizer

Physical Evaluation

In the physical evaluation of the formulated herbal hand sanitizer, various aspects were considered to ensure its quality and acceptability. The color of the formulation was noted to be uniform and visually appealing, reflecting the natural hues of the herbal ingredients used. The characteristic herbal scent was distinct, indicating the presence of quality botanical extracts. The appearance of the hand sanitizer was clear and smooth, with a homogeneous texture throughout, showcasing a well-blended formulation without any clumps or roughness. These observations collectively suggest that the hand sanitizer was carefully crafted with attention to detail, resulting in a visually pleasing and well-structured product.

6.2 pH Determination

The pH determination of the herbal hand sanitizer is crucial for its compatibility with the skin. The pH range of 6.0–6.5 falls within the acidic range, which is ideal for maintaining the skin's natural barrier function. This pH level is gentle on the skin, minimizing the likelihood of irritation or disruption to the skin's protective layers. By aligning with the skin's normal pH, the herbal hand sanitizer ensures a harmonious interaction with the skin, promoting comfort and safety during use.

6.3 Viscosity

The viscosity of the hand sanitizer plays a key role in its application and effectiveness. Through viscosity testing, it was determined that the formulation exhibited an optimal thickness, striking a balance between being easy to dispense and providing adequate coverage. The appropriate viscosity contributes to the hand sanitizer's ability to spread smoothly over the skin, ensuring thorough application and maximizing its efficacy in cleansing and disinfecting the hands.

6.4 Spreadability

The spreadability of the herbal hand sanitizer was assessed to evaluate its application convenience and effectiveness. The formulation's ability to spread evenly without leaving a sticky or oily residue on the skin is essential for user satisfaction and compliance with hand hygiene practices. The smooth and nongreasy texture allows for effortless application, enabling the hand sanitizer to cover the skin surface uniformly for comprehensive protection against germs.

6.5 Antimicrobial Activity

To validate the effectiveness of the herbal hand sanitizer in combating harmful microorganisms, antimicrobial activity testing was conducted. The formulation was subjected to evaluation against common pathogens like *Staphylococcus aureus* and *Escherichia coli*, both of which are known to cause infections. The presence of distinct zones of inhibition around the testing wells indicated that the hand sanitizer successfully inhibited the growth of these bacteria, underscoring its potent antimicrobial properties and ability to safeguard against microbial threats effectively.

6.6 Stability Study

Stability studies are essential to assess the durability and shelf-life of the hand sanitizer under various conditions. By subjecting the formulation to room temperature storage over a month-long period, its resilience to environmental factors was evaluated. The consistent color, odor, pH level, and overall appearance of the hand sanitizer throughout the study duration signify its robust physical and chemical stability. This ensures that the product maintains its quality and efficacy over time, providing users with a reliable and long-lasting solution for hand hygiene.

6.7 Skin Irritation Test

A critical aspect of evaluating the herbal hand sanitizer's safety profile is conducting a skin irritation test. The absence of any adverse reactions such as redness, itching, or inflammation upon topical application indicates that the hand sanitizer is gentle on the skin and does not trigger sensitivities or allergic responses. This test reaffirms the



formulation's safety for regular use, reassuring consumers of its skin-friendly nature and suitability for daily hand sanitization practices.[21,22,23]

VII. RESULTS AND DISCUSSION

The formulated herbal hand sanitizer exhibited exceptional physicochemical characteristics and robust antimicrobial activity, underscoring the efficacy of the formulation strategy. The meticulous physical assessment unveiled a pleasing color profile, a delightful herbal fragrance, a transparent appearance, and optimal homogeneity, affirming the consistent dispersion of all constituents. The formulation's pH level was meticulously controlled within the narrow range of 6.0–6.5, mirroring the natural pH of the human skin and mitigating the likelihood of irritations with repeated use. The viscosity and spreadability assessments showcased an ideal gel texture, facilitating effortless application and even coverage across the hands sans any tackiness.

The antimicrobial appraisal, conducted through the agar well diffusion method, showcased substantial inhibition zones against notorious pathogens like *Staphylococcus aureus* and *Escherichia coli*. This remarkable antimicrobial prowess can be largely ascribed to the potent lemon extract and tulsi extract, teeming with bioactive compounds like flavonoids, essential oils, and phenolic constituents renowned for their antibacterial prowess. These findings corroborate prior studies suggesting that herbal components can deliver microbial suppression akin to traditional sanitizing agents in controlled settings.

The integration of Aloe vera gel emerged as pivotal in enhancing the dermatological compatibility of the formulation. Its hydrating and soothing attributes effectively countered skin dryness and irritation, common repercussions of frequent hand sanitizer usage. The stability assay detected no substantial alterations in physical attributes, scent, or pH throughout the storage duration, validating the formulation's resilience under standard conditions. Moreover, the absence of irritations, redness, or itching during the skin irritation examination attests to the safety of the herbal hand sanitizer for topical use. Collectively, these outcomes underscore the effectiveness, durability, and user-centric nature of the formulated herbal hand sanitizer, rendering it an optimal choice for routine hand hygiene practices.

VIII. CONCLUSION

The formulated herbal hand sanitizer containing lemon, tulsi, and aloe vera was found to be safe, effective, and stable based on physicochemical evaluation, antimicrobial studies, stability testing, and skin irritation assessment. The presence of lemon and tulsi provided significant antimicrobial activity against common pathogenic microorganisms, while aloe vera contributed to skin hydration and reduced dryness, enhancing user comfort during frequent use. The formulation exhibited suitable pH, good viscosity, uniform spreadability, and no signs of irritation, indicating excellent skin compatibility.

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