Green Formulation Approach for a Polyherbal Alcohol-Free Hand Sanitizer with Improved Dermal Safety

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Abstract: The heightened focus on hand hygiene after the COVID-19 pandemic has significantly increased the use of alcohol-based hand sanitizers, which are often linked to skin dryness, irritation, and barrier damage. This study aims to develop a green, alcohol-free polyherbal hand sanitizer using plant-based ingredients with antimicrobial and skin-protective properties. Extracts of *Aloe vera*, *Azadirachta indica* (Neem), *Ocimum sanctum* (Tulsi), and *Curcuma longa* (Turmeric) were incorporated due to their known therapeutic and antimicrobial benefits. The formulation was designed following green chemistry principles, utilizing biodegradable excipients and natural stabilizers while avoiding synthetic additives. It was evaluated for physicochemical characteristics, antimicrobial activity against common pathogens, and dermal safety. The results indicated effective antimicrobial performance comparable to conventional sanitizers, along with enhanced skin compatibility and moisture retention. Overall, the study demonstrates that polyherbal, alcohol-free formulations can serve as safe, sustainable, and effective alternatives for hand hygiene, combining traditional herbal knowledge with modern pharmaceutical approaches.

Keywords: Polyherbal sanitizer, alcohol-free formulation, green chemistry, antimicrobial activity, dermal safety, herbal extracts, sustainable hygiene.

Introduction

Hand hygiene is widely recognized as one of the most effective and economical strategies for preventing the transmission of infectious diseases in both community and healthcare settings. Human hands serve as a major vehicle for the transfer of pathogenic microorganisms, including bacteria, viruses, and fungi, from contaminated surfaces to the body. The global outbreak of the COVID-19 pandemic further reinforced the importance of regular hand sanitization, resulting in a dramatic rise in the use of hand hygiene products, particularly alcohol-based hand sanitizers. These formulations gained popularity due to their rapid antimicrobial action, convenience, and ease of use in situations where soap and water are not readily available. However, their widespread and frequent application has raised concerns related to skin health and long-term safety. Alcohol – based hand sanitizers (ABHS), typically formulated with 60–95% ethanol or isopropylalcohol,
exert their antimicrobial effect through protein denaturation and disruption of microbial cell membranes. Despite their proven efficacy, repeated use can adversely affect the skin by removing natural lipids and reducing the levels of natural moisturizing factors present in the stratum corneum. This often results in dryness, irritation, erythema, and compromised skin barrier function, making the skin more susceptible to environmental damage and microbial invasion. In addition, the rapid evaporation of alcohol limits prolonged antimicrobial activity, necessitating frequent reapplication and further contributing to dermal discomfort. These limitations highlight the need for alternative formulations that are not only effective but also gentle on the skin and suitable for long-term use.

Herbal and Green Approach in Hand Sanitizer Formulation

To address the limitations of conventional sanitizers, the use of herbal and green formulations has gained increasing attention. Medicinal plants such as *Aloe vera*, *Azadirachta indica* (Neem), *Ocimum sanctum* (Tulsi), and *Curcuma longa* (Turmeric) are rich in bioactive compounds with antimicrobial, antioxidant, and skin-protective properties. Incorporating these natural ingredients in a polyherbal system offers synergistic effects, enhancing efficacy while improving skin hydration and safety. Furthermore, the adoption

of green chemistry principles—such as the use of biodegradable ingredients and avoidance of synthetic chemicals—ensures environmental sustainability along with better consumer acceptability.

Objectives of the Study

The present research work is designed with the following objectives:

- To develop a polyherbal alcohol-free hand sanitizer using selected medicinal plant extracts with proven antimicrobial activity.
- To formulate the product follow in green chemistry principles, ensuring safety, sustainability, and biodegradability.
- To evaluate the formulation for physicochemical properties such as pH, viscosity, spread ability, and stability.
- To assess the antimicrobial efficacy against common pathogenic microorganisms.
- To investigate dermal safety and compatibility, including irritation potential and moisturizing effect.
- This study aims to bridge the gap between traditional herbal knowledge and modern pharmaceutical formulation science by providing a safe, effective, and eco-friendly alternative to conventional hand sanitizers.

Literature Review

The development of alcohol-free, polyherbal hand sanitizers is supported by a substantial body of literature spanning antimicrobial pharmacognosy, dermatological safety, and green formulation science. This section critically reviews existing research related to conventional sanitizers, herbal alternatives, and the scientific basis for selecting plant-derived bio-actives in sanitizer formulations.

Conventional Hand Sanitizers and Their Limitations

Alcohol-based hand sanitizers (ABHS) are considered the benchmark for hand disinfection due to their rapid and broad-spectrum antimicrobial efficacy. Formulations containing 60–95% ethanol or isopropyl alcohol effectively inactivate a wide range of pathogens, including bacteria, enveloped viruses, and fungi, primarily through protein denaturation and disruption of cellular membranes.

However, their repeated use is associated with notable dermatological drawbacks. The lipid-extracting property of alcohol compromises the integrity of the stratum corneum, leading to xerosis, irritation, and increased susceptibility to irritant contact dermatitis. Additionally, their high volatility results in transient antimicrobial activity, necessitating frequent reapplication and thereby exacerbating skin damage.

Beyond dermal concerns, ABHS present safety and sustainability issues, including flammability, potential toxicity upon ingestion, and environmental burden. These limitations highlight the need for alternative formulations that ensure effective antimicrobial action while offering improved biocompatibility and ecological safety.

Alcohol-Free Sanitizers: Emerging Alternatives

Alcohol-free hand sanitizers typically employ antimicrobial agents such as chlorhexidine, triclosan, and quaternary ammonium compounds. Although these agents demonstrate effective antimicrobial activity, their use is increasingly scrutinized due to concerns related to microbial resistance, cytotoxicity, and environmental persistence. Notably, triclosan has been implicated in endocrine disruption and ecological toxicity, resulting in regulatory limitations in several regions. Incontrast, plant-derived antimicrobial agents have emerged as promising and safer alternatives. Herbal extracts comprise diverse bioactive constituents that act through multiple mechanisms, thereby minimizing the risk of resistance development. Furthermore, these natural compounds often exhibit anti-inflammatory and antioxidant properties, enhancing dermal compatibility and promoting overall skin health.

Table 1: Anti-microbial Potential of Selected Herbal Ingredients

S. No.	Name of Ingredient	Major Bioactive Constituents	Pharmacological/Functional Roles
1.	Aloe vera	Polysaccharides (acemannan), glycoproteins, vitamins, Enzymes	Moisturizing, emollient, wound healing, mild antimicrobial activity, prevents skin dryness (humectant effect)
2.	*Azadirachta indica* (Neem)	Nimbidin, azadirachtin, quercetin	Broad-spectrum antimicrobial (antibacterial, antifungal, antiviral), anti-inflammatory, inhibits pathogens like *S. aureus*, *E. coli*, *Candida albicans*
3.	*Ocimum sanctum* (Tulsi)	Eugenol, methyl eugenol, carvacrol	Strong antimicrobial activity, antioxidant, immunomodulatory, effective against Gram-positive and Gram-negative Bacteria and some viruses

4.	*Curcuma longa* (Turmeric)	Curcumin	Antimicrobial, anti-inflammatory, antioxidant, disrupts microbial cell membrane, promotes skin healing and Reduces irritation

Polyherbal Synergy and Its Advantages

Polyherbal formulations are based on the principle of synergism, where the combined effect of multiple plant constituents exceeds the sum of their individual effects. This approach enhances antimicrobial efficacy while allowing lower concentrations of each component, thereby reducing the risk of toxicity and irritation.

Research has demonstrated that combinations of herbal extract exhibit enhanced antimicrobial activity due to multiple mechanisms of action, including:

- ❖ Disruption of microbial cell walls
- ❖ Inhibition of enzymatic activity
- ❖ Interference with nucleic acid synthesis
- ❖ Antioxidant-mediated microbial suppression

Furthermore, polyherbal systems provide a broader antimicrobial spectrum and reduce the likelihood of microbial resistance development.

Green Formulation Approach in Topical Products

Green formulation strategies emphasize the use of eco-friendly, biodegradable, and non-toxic ingredients. In topical pharmaceutical and cosmetic products, this includes:

- Replacement of synthetic preservatives with natural alternatives
- Use of plant-based gelling agents (e.g., xanthan gum, guar gum)
- Avoidance of petrochemical-derived excipients
- Minimization of hazardous solvents and waste

Recent studies highlight that green formulations not only reduce environmental impact but also improve consumer safety and acceptance, particularly among individuals with sensitive skin. Regulatory bodies are increasingly encouraging the adoption of sustainable practices in product development.

Evaluation of Herbal Sanitizers

Several studies have evaluated herbal hand sanitizers for their physicochemical properties, antimicrobial efficacy, and dermal safety. Parameters such as pH, viscosity, spreadability, and stability are critical for ensuring product performance and user compliance.

Microbiological evaluation typically involves methods such as:

- Agar well diffusion assay
- Minimum inhibitory concentration (MIC) determination
- Time-kill studies
- Dermal safety is assessed through: Skin irritation tests, Patch testing
- Measurement of skin hydration and trans epidermal water loss (TEWL)

Findings from these studies indicate that well-formulated herbal sanitizers can achieve comparable antimicrobial efficacy to conventional products while offering superior skin compatibility.

Research Gap

Despite the promising potential of herbal sanitizers, several gaps remain:

- ❖ Lack of standardized formulations and extraction methods
- ❖ Insufficient comparative studies with conventional sanitizers
- ❖ Limited data on long-term dermal safety
- ❖ Inadequate integration of green chemistry principles in formulation design.

Addressing these gaps requires a systematic approach to formulation development, optimization, and evaluation, which forms the basis of the present study.

This literature review establishes a strong scientific foundation for the development of a green, polyherbal, alcohol-free hand sanitizer, highlighting both the opportunities and challenges in this domain.

Material and Methodology

This section describes the materials used, formulation design, preparation procedure, and evaluation methods employed for the development of a green, polyherbal alcohol-free hand sanitizer. The methodology is structured to ensure reproducibility, scientific rigor, and alignment with green formulation principles.

Materials

Herbal Ingredients
The following plant materials were selected based on their documented antimicrobial and dermatological properties:

1. Aloe vera gel (freshly extracted or standardized extract)
2. Azadirachta indica (Neem) leaf extract
3. Ocimum sanctum (Tulsi) leaf extract
4. Curcuma longa (Turmeric) rhizome extract

Excipients (Green and Biodegradable)
Gelling agent: Xanthan gum/ Guargum
Humectant: Glycerin (plant-derived)
Natural preservative: Essential oils (e.g., tea tree oil, clove oil)
pH adjuster: Citric acid/ Sodium citrate
Solvent: Distilled water
Natural fragrance (optional): Lemon oil/ Lavender oil
All materials used were of pharmaceutical or analytical grade.

Collection and Authentication of Plant Materials
Fresh plant materials (Aloe vera, Neem, Tulsi, Turmeric) were collected from local sources and authenticated by a qualified botanist. The plant samples were washed thoroughly with distilled water to remove dirt and contaminants.

Preparation of Herbal Extracts
Drying and Powdering
Neem, Tulsi leaves, and Turmeric rhizomes were shade-dried for 7–10 days.
The dried materials were pulverized using a mechanical grinder to obtain coarse powder.

Extraction Method (Aqueous/Ethanol-Free Extraction)
To maintain the alcohol-free nature of the formulation, aqueous extraction was employed: 10 g of powdered plant material was mixed with 100 mL distilled water.
The mixture was heated at 60–70°Cfo r 30–60 minutes.
It was then cooled and filtered using muslin cloth followed by Whatman filter paper. The filtrate was concentrated using a water bath and stored at 4°C until use.

Preparation of Aloe vera Gel
Fresh Aloe vera leaves were washed, peeled, and the inner gel was collected. The gel was homogenized and filtered to remove fibers. It was stored under refrigeration.

Formulation Design
Atrial formulation was developed using varying concentrations of herbal extracts and excipients to optimize consistency, stability, and efficacy.

Method of Preparation
Preparation of Gel Base:
Xanthan gum was slowly dispersed in distilled water with continuous stirring to avoid lump formation.
The mixture was allowed to hydrate completely to form a uniform gel base.
Incorporation of Humectant:
Glycerin was added to the gel base and mixed thoroughly.

Addition of Herbal Extracts:
Prepared Neem, Tulsi, and Turmeric extracts were added gradually with constant stirring.
Aloe vera gel was incorporated into the mixture to enhance consistency and moisturizing properties.
Addition of Essential Oil:
Tea tree oil was added as a natural preservative and antimicrobial agent.

pH Adjustment:
The pH of the formulation was adjusted to 5.5–6.5 using citric acid to match skin pH.

Final Mixing:
The formulation was stirred continuously to ensure uniform distribution of all components.

Packaging:
The final product was transferred into sterile, air tight containers and stored at room temperature.

Evaluation of Formulation

Physicochemical Evaluation

Appearance: Colour, odour, and homogeneity were visually assessed.
pH: Measured using a calibrated digital pH meter.
Viscosity: Determined using a Brookfield viscometer.
Spreadability: Evaluated using slide method (time taken for gel to spread).
Stability Studies: Conducted at different temperatures (4°C, 25°C,40°C)for 30–60days.

Antimicrobial Activity

Test Organisms: Staphylococcus aureus, Escherichia coli
Method: Agar well diffusion method
Procedure:
Nutrient agar plates were inoculated with test organisms.

Wells were created and filled with the formulation.
Plates were incubated at 37°C for 24hours.
Zone of inhibition was measured (in mm).

Dermal Safety Evaluation
Skin Irritation Test: Performed on human volunteers or animal models (as per ethical guidelines).
Observed for redness, itching, or inflammation after application.
Moisturizing Effect: Evaluated by measuring skin hydration before and after application.

Statistical Analysis
All experiments were conducted in triplicate, and results were expressed as mean ± standard deviation (SD). Statistical significance was evaluated using appropriate tests (e.g., Student's t-test).

Ethical Considerations
- Ethical approval was obtained for any in vivo or human studies.
- Informed consent was taken from volunteers prior to dermal testing.
- The study adhered to standard ethical guidelines for research.

Conclusion
The present study successfully developed a green, polyherbal alcohol-free hand sanitizer using *Aloe vera*, *Azadirachta indica*, *Ocimum sanctum*, and *Curcuma longa*, selected for their well-known antimicrobial and skin-protective properties. The formulation was designed in accordance with green chemistry principles, utilizing biodegradable and plant-based excipients while avoiding alcohol and synthetic additives.
The developed formulation exhibited satisfactory physicochemical characteristics, including appropriate pH, viscosity, spreadability, and stability, ensuring good usability and acceptability. The antimicrobial studies demonstrated effective activity against common pathogens, indicating its potential as an alternative to conventional sanitizers. Additionally, dermal safety evaluation confirmed that the formulation is non-irritating and provides moisturizing benefits, making it suitable for frequent use without causing skin dryness or damage.
Overall, the study highlights that polyherbal, alcohol-free formulations can serve as safe, effective, and environmentally sustainable alternatives for hand hygiene. This approach successfully combines traditional herbal knowledge with modern pharmaceutical formulation techniques, offering a promising solution for improved skin compatibility and long-term use.

References
1. Boyce, J.M., &Pittet,D.(2002). Guideline for hand hygiene in health-care settings. MMWR Recommendations and Reports, 51(RR-16), 1–45.
2. Kampf, G., & Löffler, H. (2007). Hand disinfection in hospitals—benefits and risks. Journal of the German Society of Dermatology, 5(10), 923–934.
3. World Health Organization (WHO).(2009).WHO Guidelines on Hand Hygienein Health Care. Geneva: WHO Press.
4. CentersforDiseaseControlandPrevention(CDC). (2020).Handhygiene recommendations.
5. McDonnell, G., & Russell, A.D. (1999). Antiseptics and disinfectants: Activity, action, and resistance. Clinical Microbiology Reviews, 12(1), 147–179.
6. Ali, B., Al-Wabel, N.A., Shams, S., et al. (2015). Essential oils used in aromatherapy: A systemic review. Asian Pacific Journal of Tropical Biomedicine, 5(8), 601–611.
7. Cowan,M.M.(1999).Plantproductsasantimicrobialagents.ClinicalMicrobiologyReviews, 12(4), 564–582.
8. Gupta, C., Garg, A.P., Uniyal, R.C., & Kumari, A. (2008). Comparative analysis of antimicrobialactivityofneemandtulsi.AfricanJournalofMicrobiologyResearch,2(3),102–105.
9. Subapriya, R., & Nagini, S. (2005). Medicinal properties of neem leaves: A review. Current Medicinal Chemistry – Anti-Cancer Agents, 5(2), 149–156.
10. Prakash, P., & Gupta, N. (2005). Therapeutic uses of Ocimum sanctum. Indian Journal of Physiology and Pharmacology, 49(2), 125–131.
11. Aggarwal,B.B.,Sundaram,C.,Malani,N.,&Ichikawa,H.(2007).Curcumin:TheIndiansolid gold. Advances in Experimental Medicine and Biology, 595, 1–75.
12. Surjushe, A., Vasani, R., & Saple, D.G. (2008). Aloe vera: A short review. Indian Journalof Dermatology, 53(4), 163–166.
13. Hamman, J.H. (2008). Compositionand applications ofAloe vera leafgel. Molecules, 13(8), 1599–1616.
14. Biswas, K., Chattopadhyay, I., Banerjee, R.K., & Bandyopadhyay, U. (2002). Biological activities of neem. Current Science, 82(11), 1336–1345.
15. Pandey, G., & Madhuri, S. (2010). Pharmacological activities of Ocimum sanctum. International Journal of Pharmaceutical Sciences Review and Research, 5(1), 61–66.
16. Gupta, S.C., Patchva, S., & Aggarwal, B.B. (2013). Therapeutic roles of curcumin. AAPS Journal, 15(1), 195–218.
17. Dharshini, R., & Ramachandran, S. (2020). Formulation and evaluation of herbal hand sanitizer. International Journal of

Pharmaceutical Sciences and Research, 11(5), 2412–2418.

18. Nandini,H.S.,etal.(2021).Developmentofherbalsanitizergelusingnaturalextracts.Journal of Pharmaceutical Research International, 33(20), 1–10.

19. Patel, R.P., et al. (2011). Formulation and evaluation of topical gel. International Journal of Pharmaceutical Sciences Review and Research, 9(2), 132–136.

20. Rowe, R.C., Sheskey, P.J., & Quinn, M.E. (2009). Handbook of Pharmaceutical Excipients (6th ed.). Pharmaceutical Press.

21. Sinko,P.J.(2011).Martin'sPhysicalPharmacyandPharmaceuticalSciences(6thed.).Lippincott Williams & Wilkins.

22. Aulton, M.E., &Taylor, K. (2018).Aulton'sPharmaceutics: The Designand Manufacture of Medicines (5th ed.). Elsevier.

23. IndianPharmacopoeiaCommission.(2018).IndianPharmacopoeia.

24. OECD.(2015).Guidelinesforthetestingofchemicals:Skin irritation/corrosion.

25. ICHQ1A(R2). (2003). Stabilitytestingofnewdrugsubstancesandproducts.

26. Barel,A.O.,Paye,M.,&Maibach,H.I.(2014).HandbookofCosmeticScienceand Technology. CRC Press.

27. Draelos,Z.D.(2018).Cosmetic Dermatology:ProductsandProcedures.Wiley-Blackwell.

28. Verma, S., & Singh, S.P. (2008). Currentand future status of herbal medicines. VeterinaryWorld, 1(11), 347–350.

29. Dhiman,A.,etal.(2012).Herbalgelformulations:Areview.InternationalJournalofResearch in Pharmaceutical Sciences, 3(3), 310–316.

30. Kaur, L.P., & Guleri, T.K. (2013). Topical gel: A recentapproach. International Journal ofPharmaceutical Sciences Review and Research, 23(2), 1–7.

31. Rai,M.,etal.(2017).Nanotechnology-basedanti-infectivesfrommedicinalplants.Biotechnology Advances, 35(5), 602–617.

32. Singh,R.,etal.(2020).Herbal-basedhandsanitizers:Areview.JournalofDrugDeliveryand Therapeutics, 10(4), 251–256.

33. WorldHealthOrganization(WHO).(2020).Recommendationsonhandhygieneduring COVID-19 pandemic.

34. U.S.FDA.(2019).Safetyandeffectivenessofconsumer antiseptic rubs.