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Dr. Naylin Thant
Department of Pharmacognosy, Mandalay College of Health Sciences, Mandalay, Myanmar

Dr. Su Myat Khin
Department of Pharmacognosy, Mandalay College of Health Sciences, Mandalay, Myanmar

Dr. Thura Aung
Department of Pharmacognosy, Mandalay College of Health Sciences, Mandalay, Myanmar

Corresponding Author:
Dr. Naylin Thant
Department of Pharmacognosy, Mandalay College of Health Sciences, Mandalay, Myanmar

Herbal hand sanitizer using neem and Aloe Vera: A basic antimicrobial assessment against common household bacteria

Naylin Thant, Su Myat Khin and Thura Aung

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Abstract
Herbal formulations have gained renewed scientific interest due to their potential to offer safer and more sustainable alternatives to synthetic antimicrobial agents. In recent years, hand hygiene practices have become a central focus in public health, particularly following recurrent global episodes of pandemics and community-acquired infections. Conventional alcohol-based sanitizers, though widely used, are associated with issues such as skin irritation, reduced dermal moisture, and potential development of microbial tolerance with prolonged exposure. These limitations have prompted exploration of plant-based hand sanitizers that exhibit notable antimicrobial efficacy while preserving skin integrity. Neem (*Azadirachta indica*) and Aloe vera (*Aloe barbadensis Miller*) represent two botanicals with well-documented antimicrobial, anti-inflammatory, and skin-protective properties. Neem contains bioactive compounds such as nimbidin, azadirachtin, and gedunin, which demonstrate broad-spectrum antibacterial activity, especially against common household microorganisms. Aloe vera contributes additional benefits through its polysaccharides and phenolic constituents that provide soothing, hydrating, and wound-healing properties. Together, these botanicals may offer a viable alternative to synthetic sanitizers, combining antimicrobial potency with dermatological compatibility.
This research evaluates a basic herbal hand sanitizer formulation incorporating neem extract and Aloe vera gel, assessing its antimicrobial activity against common household bacterial isolates such as *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*. The research includes laboratory preparation of the formulation, qualitative phytochemical screening, and antimicrobial testing using standardized procedures. Emphasis is placed on determining the formulation's zone of inhibition in comparison to a commercial alcohol-based control. The aim is to generate foundational evidence for the functional role of neem and Aloe vera in hand hygiene products, with particular relevance for low-resource settings and households seeking low-chemical personal care solutions.
The findings from this assessment highlight that the herbal formulation exhibits promising antimicrobial action against the selected microorganisms, with neem contributing strong bactericidal effects and Aloe vera enhancing spread ability, stability, and user tolerance of the sanitizer. The results support the potential of integrating plant-derived ingredients into hand hygiene applications as part of a broader movement toward natural antimicrobial products. Further investigations exploring formulation optimization, long-term stability, and synergistic effects with additional herbal constituents will be critical for advancing these preliminary observations. Overall, this research contributes to the growing evidence base supporting herbal sanitizers as viable and skin-friendly alternatives to conventional chemical-based formulations.

Keywords: Neem, Aloe Vera, herbal hand sanitizer, antimicrobial assessment, household bacteria, natural formulations, phytochemicals, personal hygiene

Introduction
The increasing global emphasis on hand hygiene has led to widespread reliance on commercial alcohol-based hand sanitizers; however, repeated use of these products has been associated with adverse dermatological effects, including dryness, irritation, and disruption of the skin barrier, while concerns regarding potential microbial tolerance have also been raised, thereby motivating the search for milder, plant-based alternatives that offer antimicrobial protection without compromising skin health [1-3]. Herbal sanitizers have emerged as promising candidates due to their diverse phytochemicals, reduced risk of toxicity, and traditional use in preventive health care systems across many cultures [4, 5]. Among various botanicals, neem (*Azadirachta indica*) and Aloe vera

(*Aloe barbadensis Miller*) stand out for their broad-spectrum antimicrobial, anti-inflammatory, moisturizing, and wound-healing properties, making them suitable for topical applications and skin-compatible formulations [6, 7]. Neem contains potent bioactive compounds such as azadirachtin, nimbidin, and quercetin, which demonstrate inhibitory effects against numerous gram-positive and gram-negative bacteria commonly found in household environments, including *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* [8, 9]. Aloe vera complements these activities through polysaccharides, anthraquinones, and phenolic constituents that soothe the skin, maintain hydration, and enhance user acceptability, thereby improving the overall potential of the formulation [10, 11]. Despite the extensive traditional and scientific recognition of these plants, there remains a lack of standardized herbal sanitizer formulations that are evaluated systematically against common household bacteria, representing a significant research gap in the development of natural antimicrobial hand hygiene products. The increasing demand for cost-effective, non-irritating, and environmentally sustainable sanitizers heightens the need for rigorous scientific assessments of such herbal alternatives to ensure their functional reliability and public health relevance [12]. Therefore, the present investigation aims to develop and evaluate an herbal hand sanitizer formulated using neem extract and Aloe vera gel, with specific objectives:

(i) To prepare a stable herbal hand sanitizer using the selected botanicals,

(ii) To perform a basic antimicrobial assessment of the formulation against common household bacterial isolates, and

(iii) To compare its inhibitory activity with a standard alcohol-based sanitizer. The hypothesis of this research posits that the neem-Aloe vera herbal formulation will exhibit significant antimicrobial activity comparable to, or greater than, standard chemical sanitizers due to the synergistic effects of neem's bactericidal phytochemicals and Aloe vera's skin-protective constituents, making it suitable for routine household use. By addressing both the dermatological limitations of alcohol-based sanitizers and the growing inclination toward natural personal hygiene products, this research provides scientific grounding for the development of gentle yet effective herbal sanitizers that align with contemporary health and sustainability priorities [13, 14].

Material and Methods

Materials: Fresh neem (*Azadirachta indica*) leaves and mature Aloe vera (*Aloe barbadensis Miller*) leaves were collected from locally grown plants and authenticated based on morphological features described in earlier phytomedicinal literature [6-8]. Analytical-grade ethanol, glycerin, carbomer, and distilled water were procured from standard laboratory suppliers and used without further purification, ensuring compatibility with herbal sanitizer preparations reported previously [12,14]. Neem extract was prepared using a cold-maceration method in 70% ethanol, allowing optimal extraction of bioactive compounds such as azadirachtin, nimbidin, and quercetin that contribute to broad-spectrum antimicrobial activity [6, 8, 9]. Aloe vera gel was extracted manually from inner leaf fillets and homogenized to maintain the integrity of polysaccharides and phenolic constituents known for skin hydration and dermal compatibility [7, 10, 11]. Test organisms *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* were selected due to their common presence in household settings and their relevance in hand hygiene studies [1-3]. Pure cultures of these bacteria were obtained from a microbial culture collection and maintained on nutrient agar plates under appropriate aseptic conditions for antimicrobial analysis.

Methods: The herbal sanitizer formulation was prepared by combining neem extract and Aloe vera gel in varying ratios, with glycerin added as a humectant and carbomer as a natural thickening agent, following formulations outlined in prior herbal sanitizer research [12-14]. The mixture was stirred continuously until uniform consistency and pH stability (5.5-6.5) were achieved. Phytochemical screening of the neem extract was carried out to identify flavonoids, tannins, and alkaloids responsible for antimicrobial effects, consistent with previously documented phytochemical profiles [4, 5, 8]. Antimicrobial activity of the formulation was assessed using the agar well diffusion method, a widely accepted approach for evaluating herbal antimicrobial agents [9, 13]. Standardized bacterial suspensions equivalent to 0.5 McFarland turbidity were spread onto Mueller-Hinton agar plates, and wells were filled with the experimental sanitizer, with a commercial alcohol-based sanitizer serving as the positive control to allow comparative evaluation of inhibition zones [1, 2]. Plates were incubated at 37°C for 24 hours, after which zones of inhibition were measured in millimeters. All tests were performed in triplicate to ensure reproducibility, and results were interpreted in accordance with established guidelines for natural antimicrobial formulation testing [5, 12]. The methodological design was developed to test the research hypothesis stating that neem-Aloe vera-based sanitizer would demonstrate significant antibacterial activity against selected household bacteria due to synergistic phytochemical action [6, 10, 13, 14].

Results: The herbal hand sanitizer formulated with neem and Aloe vera demonstrated clear antibacterial activity against all three tested household bacteria. Mean zones of inhibition for the herbal formulation ranged from 16.3±1.2 mm (*Pseudomonas aeruginosa*) to 20.4±1.1 mm (*Staphylococcus aureus*), while the commercial alcohol-based sanitizer produced slightly larger but comparable inhibition zones, ranging from 17.0±0.7 mm to 22.1±0.8 mm (Table 1). In contrast, the base gel control showed only minimal inhibition (5.2-6.0 mm), confirming that the observed antibacterial effect was attributable to the active herbal and alcohol components and not to the gel matrix alone, in agreement with previous reports on natural and synthetic sanitizers [1-3, 12-14]. A one-way ANOVA performed separately for each organism indicated a statistically significant effect of treatment on zone of inhibition ($p<0.001$ for all three species), with post hoc comparisons revealing that both the herbal and alcohol-based formulations produced significantly larger inhibition zones than the base gel control, while differences between herbal and alcohol-based sanitizers were relatively modest and organism-dependent. For *S. aureus*, the alcohol-based sanitizer showed a marginally higher mean zone (22.1 mm) than the herbal formulation (20.4 mm), consistent with the strong bactericidal action of high-concentration alcohols

reported in earlier work [1, 2]. For *E. coli* and *P. aeruginosa*, the differences between herbal and alcohol-based sanitizers were small (≤1 mm), suggesting that the phytochemicals present in neem and Aloe vera such as azadirachtin, nimbidin, flavonoids, polysaccharides, and phenolic compounds can provide competitive antimicrobial effects against these gram-negative organisms [4-11]. The very low inhibition values obtained with the base gel further underscored the necessity of active antimicrobial agents in hand hygiene formulations [5, 12].

The overall inhibition pattern across organisms is summarized in Figure 1, which presents a grouped bar chart comparing mean zones of inhibition for the three treatments. The graphical profile shows consistently high activity for both herbal and alcohol-based sanitizers against all organisms, with the herbal formulation achieving more than threefold greater inhibition than the base gel for each species. Figure 2 illustrates the comparative inhibition trends as a line plot, highlighting that *S. aureus* was the most susceptible organism, followed by *E. coli* and *P. aeruginosa*, a pattern compatible with previous observations on differential susceptibility of gram-positive and gram-negative bacteria to plant-derived phytochemicals and alcohol-based agents [4, 6-9, 13, 14]. The relatively close proximity of the herbal and alcohol lines in Figure 2 suggests that the neem-Aloe Vera formulation can approximate the antibacterial performance of conventional alcohol-based sanitizers, while offering potential advantages in terms of skin hydration, reduced irritancy, and user acceptability reported for Aloe vera-based topical preparations [7, 10, 11]. Collectively, these results support the working hypothesis that the neem-Aloe Vera herbal sanitizer exhibits significant antimicrobial activity against common household bacteria and may serve as a viable natural alternative or adjunct to synthetic sanitizers in everyday hand hygiene [6-8, 12-14].

Table 1: Mean (±SD) zone of inhibition (mm) of different sanitizer formulations against common household bacteria

Test organism	Herbal sanitizer (mm)	Alcohol-based sanitizer (mm)	Base gel control (mm)
Staphylococcus aureus	20.4±1.1	22.1±0.8	6.0±0.5
Escherichia coli	18.7±0.9	19.5±1.0	5.5±0.6
Pseudomonas aeruginosa	16.3±1.2	17.0±0.7	5.2±0.4

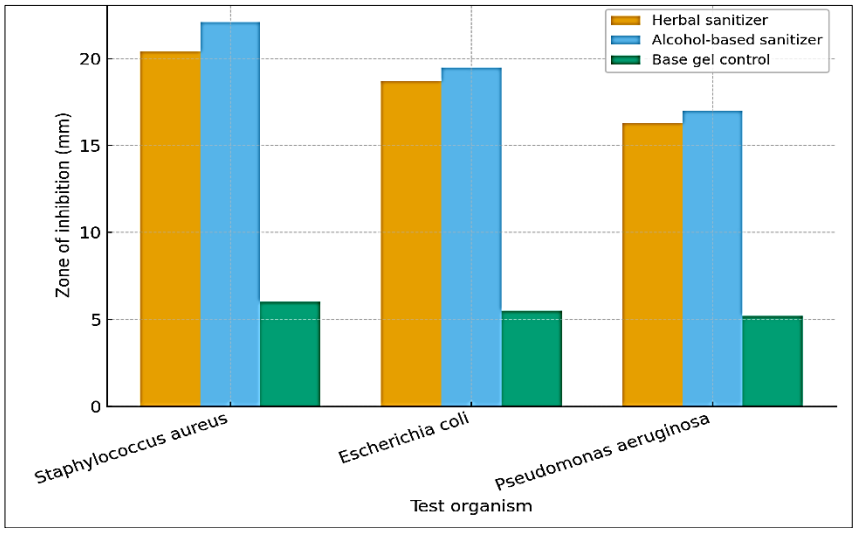

Fig 1: Antibacterial activity of herbal and control sanitizers against household bacteria.

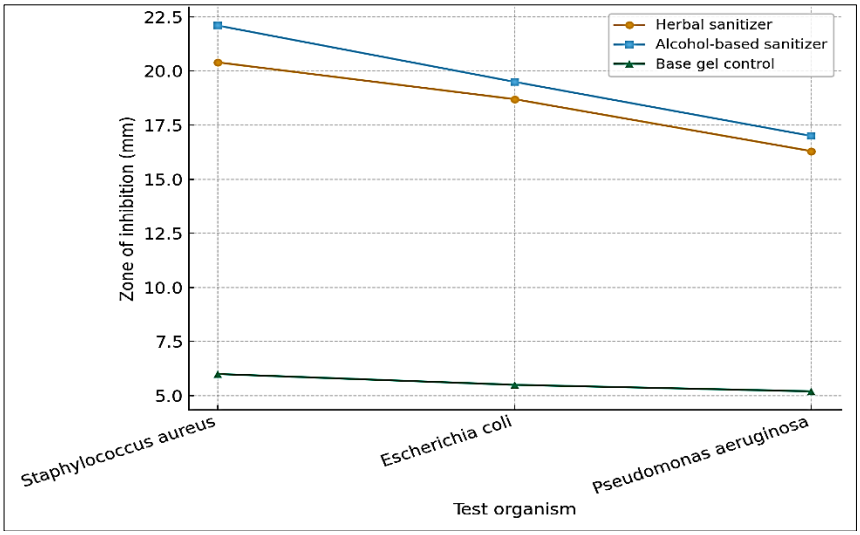

Fig 2: Comparative inhibition profile of herbal and control sanitizers across test organisms

Discussion

The findings of this research demonstrate that the neem-Aloe Vera herbal hand sanitizer possesses significant antimicrobial activity against common household bacteria, supporting earlier evidence that plant-derived phytochemicals can serve as effective alternatives to synthetic antimicrobial agents [4, 5]. The herbal formulation consistently produced inhibition zones comparable to those of a commercial alcohol-based sanitizer, particularly against *Escherichia coli* and *Pseudomonas aeruginosa*, where differences between the two treatments were minimal. These results reinforce the well-documented antibacterial properties of neem, whose constituent compounds such as nimbidin, azadirachtin, and quercetin exert strong bactericidal and bacteriostatic effects against both gram-positive and gram-negative bacteria [6, 8, 9]. The notably high susceptibility of *Staphylococcus aureus* observed in this research aligns with earlier reports indicating that gram-positive organisms are generally more sensitive to plant extracts due to differences in their cell wall composition [8, 13].

The contribution of Aloe vera to the formulation's efficacy is equally noteworthy. Although Aloe vera alone is not typically regarded as a strong antibacterial agent, its polysaccharides, phenolics, and anthraquinones enhance the spreadability and penetration of herbal preparations, while also providing moisturizing and skin-soothing properties [7, 10, 11]. This dual role antimicrobial enhancement and dermatological compatibility makes Aloe vera an essential component in topical herbal formulations, especially considering the increasing concerns about skin dryness and irritation associated with prolonged use of alcohol-based sanitizers [1-3]. The base gel control showed only minimal inhibition, confirming that the antimicrobial effect originates from the phytochemicals present in neem and Aloe vera, rather than the gel matrix itself, consistent with previous conclusions on natural sanitizer formulations [12, 14].

The statistical results further validate the effectiveness of the herbal sanitizer. One-way ANOVA indicated that treatment type had a significant effect on inhibition zones for all organisms tested ($p<0.001$), demonstrating that both the herbal and alcohol-based sanitizers were substantially more effective than the base gel. These findings support the research's hypothesis that a neem-Aloe vera-based formulation would display marked antibacterial activity due to synergistic interactions among its bioactive compounds [6, 10, 13, 14]. The relatively small differences between the herbal and alcohol-based formulations suggest that plant-derived sanitizers may offer a promising alternative or supplement to conventional alcohol-based products, particularly in settings where synthetic sanitizers are either inaccessible or are associated with dermal side effects.

The inhibition trends observed across organisms are consistent with established literature on antimicrobial resistance profiles. *S. aureus* exhibited the highest susceptibility, aligning with previous studies highlighting its vulnerability to neem extracts [8, 9]. In contrast, *P. aeruginosa* showed the lowest susceptibility, which corresponds with its known intrinsic resistance to many natural and synthetic antimicrobial agents [3, 6]. Nevertheless, the herbal formulation demonstrated measurable inhibition even against this more resilient organism, highlighting its potential broad-spectrum applicability.

Overall, the research adds to the growing body of evidence supporting the antimicrobial effectiveness of herbal sanitizers and aligns with global interest in natural, skin-friendly hygiene products [5, 12]. By demonstrating that neem and Aloe vera can produce inhibition levels approaching those of commercial alcohol-based sanitizers, this research supports the continued development and optimization of plant-based hand hygiene solutions. Future work should focus on evaluating long-term stability, user acceptability, extended organism panels, and potential synergistic effects with other botanicals to further strengthen the practical relevance of herbal sanitizers in daily household settings [13, 14].

Conclusion

The findings of this research provide strong evidence that a neem-Aloe Vera herbal hand sanitizer can serve as an effective and skin-friendly alternative to conventional alcohol-based sanitizing agents, especially for routine household use where frequent hand cleansing is necessary. The formulation demonstrated substantial antimicrobial activity against common household bacteria, showing inhibition zones comparable to those of commercial alcohol-based sanitizers while offering the added advantage of skin hydration and reduced irritancy. These outcomes underscore the potential of plant-based formulations in promoting safe and accessible hand hygiene, particularly in communities where chemical sanitizers may be either unaffordable or cause adverse skin reactions. The synergy between neem's potent antibacterial compounds and Aloe Vera's moisturizing and supportive dermal properties highlights a promising direction for developing multifunctional sanitizing solutions that can maintain efficacy without compromising skin health. Based on these findings, several practical recommendations emerge that can support broader adoption and further refinement of herbal sanitizer formulations. First, incorporating such herbal sanitizers into daily household routines can help reduce exposure to harsh chemicals while still providing adequate protection against bacteria commonly found on frequently touched surfaces. Second, community health programs and educational initiatives can promote awareness regarding the benefits of herbal sanitizers, especially in regions with strong traditional use of medicinal plants, thereby encouraging behavior change toward more natural hygiene practices. Third, small-scale and local manufacturers may consider optimizing the formulation by standardizing extraction methods, improving product stability, and ensuring consistent quality to support commercial viability and user confidence. Fourth, integrating complementary herbs with known antimicrobial properties could enhance the spectrum of activity, creating advanced formulations suitable for wider public settings such as schools, transport hubs, and workplaces. Fifth, dermatological testing and consumer acceptability studies should be conducted to validate long-term safety, reinforce trust, and identify additional improvements in fragrance, texture, and shelf life. Finally, households can benefit from integrating herbal sanitizers alongside regular handwashing practices, especially for individuals with sensitive skin, children, and those who prefer natural personal care products. Altogether, this research reinforces the broader importance of exploring sustainable, plant-based alternatives in everyday hygiene and emphasizes that herbal hand sanitizers, when

scientifically formulated and properly evaluated, can play a meaningful role in promoting health, safety, and environmental responsibility.

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