

*Original Article*

# Natural Hand Sanitizers: A Systematic Review on the Effectiveness and Antimicrobial Potential Against Pathogens

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## Abstract

**Background:** Microbes are mostly transferred through the hands and the nosocomial infections are extremely common. To combat the harmful effects of microbial burden in health care facilities, hand sanitizers are recommended for hand disinfection.

**Objective:** The goal of this research is to conduct a systematic review of studies on the effectiveness of natural hand sanitizers.

**Methods:** Under the PRISMA criteria, a systematic search was carried out (Recommended Reporting Items for Systematic Reviews and Meta Analyses) three databases were used to conduct the search: PubMed, Google Scholar, and Science Direct. Published from 2002 to 2024. The Key words for the survey were 'Natural hand sanitizers, Hand hygiene, Disinfectant, Antibacterial activity. Following the finding of relevant papers, a critical appraisal was carried out in order to select those that would be appropriate for the systematic review. The study's inclusion criteria were surveys, clinical studies, no sample size limits, and only English literature.

**Result:** The keywords led to the discovery of 65 relevant publications, 14 of which were suitable for the systematic review. Hand sanitizers of several kinds were investigated. It's used to stop the spread of infection and sickness.

**Conclusion:** In this systematic review, it was concluded that the efficacy and the broad spectrum of natural hand sanitizers were significantly efficient which is important to boost the formulation's effectiveness as well as safety.

## 1 Introduction

The COVID-19 (Coronavirus Disease-2019) has emerged given that pandemics are contagious, they have become a major global public health concern and have led to widespread consumption of hand disinfectants. Several experts have suggested employing hand sanitizers as a preventative measure against COVID-19 given the significance of the global health emergency it has caused. The WHO declared the COVID-19 pandemic, also known as the severe acute respiratory syndrome coronavirus 2 to be taking place in early 2020. Despite the authority's best efforts, there has been an exponential rise in the cases (1). The practice of hand washing before eating is one of the most significant scientific and religious doctrines. This prevents harmful bacteria from entering the body and causing contagious illnesses. Most hospital-acquired infections are caused by unclean hands, both on the part of the patient and hospital staff. Hand hygiene is the primary cause of most nosocomial infections, such as respiratory and gastrointestinal infections. Wearing gloves or thoroughly cleaning your hands with clean water is consequently essential (2). In recent years, safe-to-use hand sanitizers with high bactericidal activity have been available on the market. There are hand sanitizers on the market with and without alcohol. The hand sanitizer with alcohol base professes to eradicate 99.99% of bacteria, even the most resilient type. Hand sanitizers are available in liquid, foam, and convenient gel formulations that can be rubbed over the palm of the hand and all the fingers and hands until they are dry (3). In addition to restaurants, toiletries, and other businesses, the product is widely used by doctors, surgeons, pathologists, and researchers both before and after surgery.

The effectiveness of herbal hand sanitizer in reducing the number of germs on hands was demonstrated by comparison with commercial synthetic hand sanitizer (4). Plants are rich in a wide range of secondary metabolites, such as tannins, terpenoids, alkaloids, and flavonoids, among others, which have been found to possess in vitro antimicrobial properties. Individuals with sensitive skin experience a multitude of issues when they use alcohol-based hand sanitizer excessively. The disadvantages include ocular irritation, harshness on the skin, dryness of the skin, and irritation. Alcohol may occasionally remove the outermost protective layer of oil, which could impair the skin's

ability to function as a barrier. Traditional hand sanitizers often contain harsh chemicals that cannot only cause skin irritation, allergies but also responsible for antibiotic resistance. As a result, there is an increasing demand for natural hand sanitizers because they are safe, effective and eco friendly (5). Nonetheless, the frequent and excessive use of chemical surface disinfectants, hand sanitizers, and soaps releases tones of non-biodegradable bio contaminants that pose a risk to human health and the environment. These natural extracts hold promise for treating a wide range of additional viruses, including those found in veterinary products and antiseptic surface disinfectants. When hand sanitizers are used for extended periods of time, the presence of chemicals such as: phthalates, synthetic fragrances, benzalkonium, and triclosan in excess poses serious health and environmental risks (6). It is therefore extremely important to replace these harmful chemical additives, synthetic fragrances, and additives in the formulations of hand sanitizers with natural and sustainable ingredients that have clear safety and efficacy against pathogens. The majority of plants that exhibit high potential for antimicrobial activity do so because they contain phytochemicals that prevent the growth of microorganisms, particularly bacteria. The Myrtaceous family of plants includes the guava, or *Psidium guajava*, leaf, which is referred to as "bayabas" locally. Studies have revealed that practically every part of it has therapeutic properties (7). Therefore, objective of this article is to conduct a systematic review of selected studies regarding the association between natural hand sanitizers and pathogenic microorganisms according to PICO criteria.

## 2 Material and Methods

The study employed a systematic review methodology, guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a comprehensive and structured approach. A detailed literature search was conducted using three major electronic databases: PubMed, Google Scholar, and Science Direct. The search spanned articles published from 2002 to 2024, with keywords including "natural hand sanitizers," "hand hygiene," "disinfectant," "antibacterial activity," "antifungal," "antiviral," and "efficacy." Boolean operators (AND, OR, NOT) were utilized to refine and expand the search parameters, ensuring the inclusion of all relevant studies (8).

The selection criteria for this review were rigorous. Articles had to be original research published in English, detailing the formulation and testing of natural hand sanitizers. Only studies focusing on the effectiveness of these sanitizers against pathogens were considered. The inclusion criteria encompassed surveys and clinical studies without any restriction on sample size, provided they met the language and publication year requirements. Articles such as systematic reviews, meta-analyses, editorials, and case reports were excluded from the review to maintain a focus on primary research findings (8).

Data extraction was performed meticulously from the selected studies to capture essential information such as the primary authors, publication year, study objectives, methodology, key findings, and conclusions. The extracted data were used to construct a summary table that highlighted the characteristics of each study, including the types of natural hand sanitizers used and their tested efficacy against various pathogens. Indicator organisms such as *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* were commonly assessed across the studies (9).

Ethical considerations were duly noted in adherence to the Declaration of Helsinki, although this systematic review did not involve direct human or animal subjects. As such, ethical approval was not required, but the researchers ensured that all included studies had obtained necessary ethical clearances as reported in their respective publications.

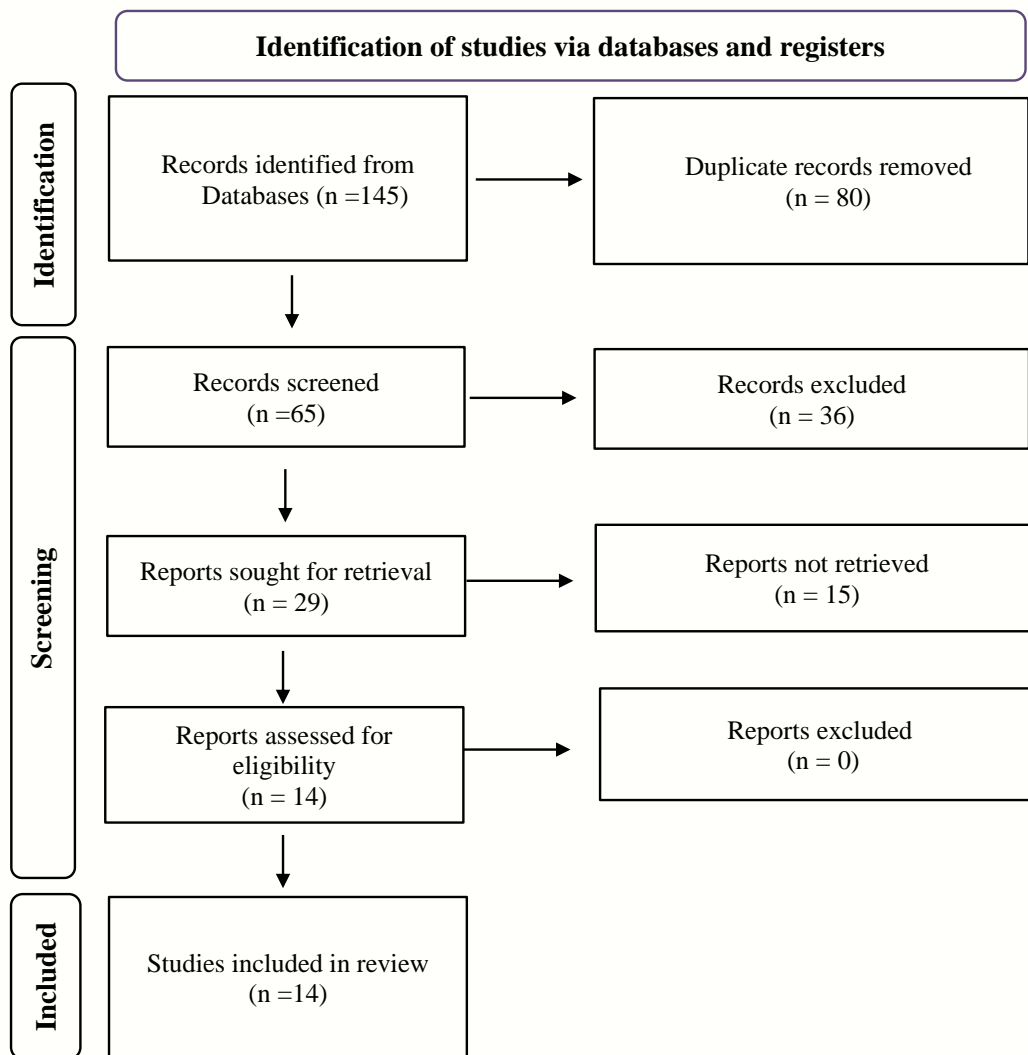
The quality of the studies was critically appraised using predefined criteria to assess the validity and reliability of their findings. The assessment focused on the study design, sample size, statistical analyses, and the transparency of reporting the results. Data analysis for this review was conducted using SPSS software version 25. Descriptive statistics were utilized to synthesize the findings from the included studies, while comparative analyses were performed to determine the relative effectiveness of natural hand sanitizers against various pathogens.

Through this systematic review, the research aimed to consolidate evidence on the efficacy of natural hand sanitizers and identify gaps in the current literature that could inform future research directions. The comprehensive approach ensured that only studies with robust methodologies and clear outcomes were included, thereby providing reliable insights into the potential of natural hand sanitizers in infection control.

## 3 Results

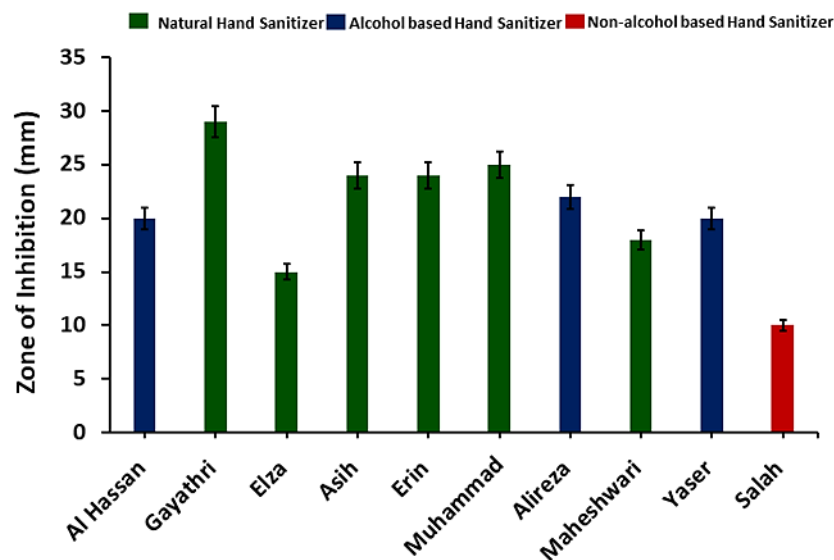
The Google Scholar database yielded 145 publications. Articles were directly excluded from PubMed Science due to various phases. It entailed eliminating article duplication. A total of 65 articles were taken from this location. The final stage of this systematic review paper's article selection. Only 14 relevant articles were selected after reviewing. The flow diagram of the search results is represented in fig. 1. Moreover, after reviewing the 14 relevant articles (title, abstracts and the full articles pdfs) their characteristics, description and the

potential results are summarized in Table 1. The focus of the systematic review is on the effectiveness of natural hand sanitizers to combat pathogenic microorganisms that causes serious illness.



**Figure 1.** Prisma flow diagram showing the results of literature review and the review studies retrieved

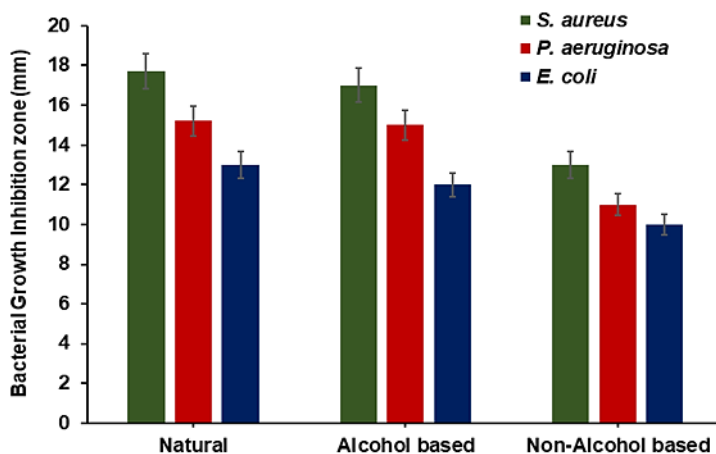
Moreover, the comparison of alcohol based and non-alcohol-based sanitizers were done to ensure the use of right sensitizer. In the current systematic review, 14 relevant studies were observed that natural extract hand sanitizers gave a significant inhibition against disease related pathogens. Chemically based and natural extract hand sanitizers both kills the microorganisms but herbal hand sanitizers have less side effects. The results showed that growth inhibition of three different types of hand sanitizers: Natural Hand Sanitizer, Alcohol-based Hand Sanitizer, and Non-alcohol-based Hand Sanitizers against various pathogens. Each sanitizer's antimicrobial efficacy is reflected in its zone of inhibition. Interestingly, the zones of inhibition for the Natural Hand Sanitizer are consistently larger, especially in the Gayathri sample, reaching approximately 30 mm, indicating a strong antimicrobial effect. The Alcohol-based Hand Sanitizer is also very effective, showing zones of 20–25 mm in most samples (Eliza and Yaser are the exception, where it is a little less effective). In contrast, the Salah sample, which lacks a zone of inhibition indicates that the non-alcohol-based hand sanitizer is noticeably less effective. Several other studies also reported the efficacy of natural hand sanitizer over alcohol and non-alcohol-based hand sanitizers (22, 23). This demonstrates how differently the various sanitizer types perform from one another. The graph shows that alcohol-based hand sanitizers are generally the most effective, followed by non-alcohol-based hand sanitizers, which are the least effective overall. The data were representative in Fig 2.



**Figure 2.** Different studies showing the activity of all of the three types of hand sanitizers

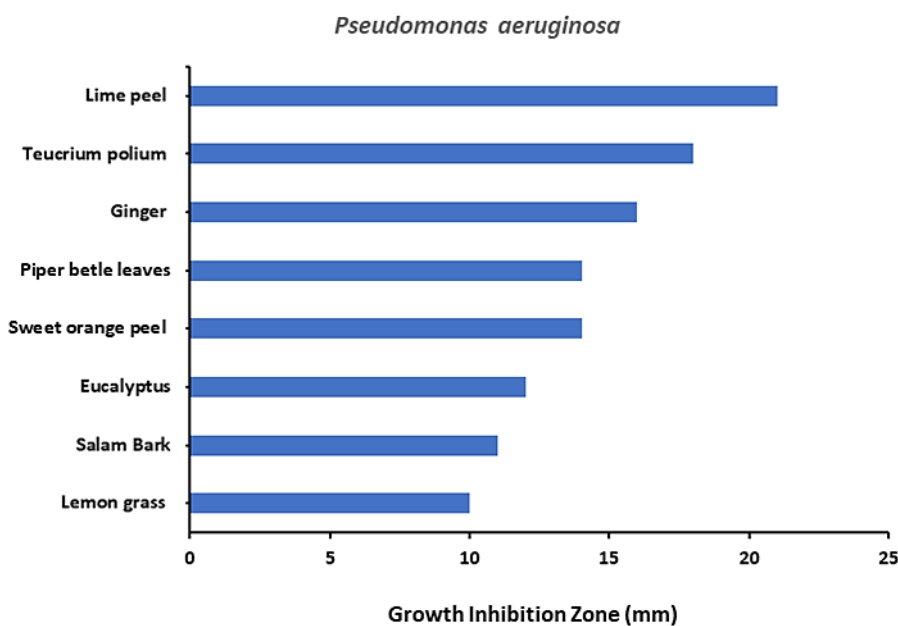
Moreover, the antibacterial activity of the sanitizers (natural, alcohol and non-alcohol-based) was also observed against three different bacterial species such as: *Pseudomonas aeruginosa*, *Escherichia coli*, and *Staphylococcus aureus*. The most significant bacterial growth inhibition is shown by natural sanitizers among all tested bacteria. *S. aureus*, *P. aeruginosa*, and *E. coli*. They exhibit inhibition zones that measure approximately 17.5 mm, 15 mm, and 14 mm, respectively. According to this, out of all the sanitizers that have been tested, natural hand sanitizers have the most effective antibacterial properties. Inhibition zones for based on alcohol agents are approximately 16 mm for *S. aureus*, 14.5 mm for *P. aeruginosa*, and 14 mm for *E. coli*. These zones are still quite effective, but significantly less than those of natural sanitizers. According to this, natural agents are more effective than alcohol-based ones at reducing the growth of bacteria. Considering the lowest inhibition zones across all three bacteria, non-alcohol-based agents are the most effective. The inhibition zone for *S. aureus* is approximately 15 mm, for *P. aeruginosa* it is approximately 13.5 mm, and for *E. coli* it is approximately 13 mm compared to both natural and alcohol-based agents, this data emphasises the comparatively lower efficacy of non-alcohol-based agents (Fig. 3). With respect to these treatments, *S. aureus* consistently exhibits the largest inhibition zones across all three types of agents, followed by *P. aeruginosa* and *E. coli*, which exhibits the smallest inhibition zones. It is due to the different levels of susceptibility to distinct kinds of antibacterial agents. The results revealed that observed the natural sanitizer significantly reduced the count of pathogenic microorganisms. On the other hand, various alcoholic and non-alcoholic hand sanitizers also reduces the bacterial count therefore it is evident from this result the alcohol-based hand sanitizers can easily be replaced by natural hand sanitizers. Benzalkonium chloride, one of the active components Isopropyl alcohol and ethyl alcohol are two different kinds of alcohol. It is reported on the efficacy of hand sanitizers.

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**Figure 3.** The growth inhibition pattern of sanitizers against *S. aureus*, *P. aeruginosa* and *E. coli*.

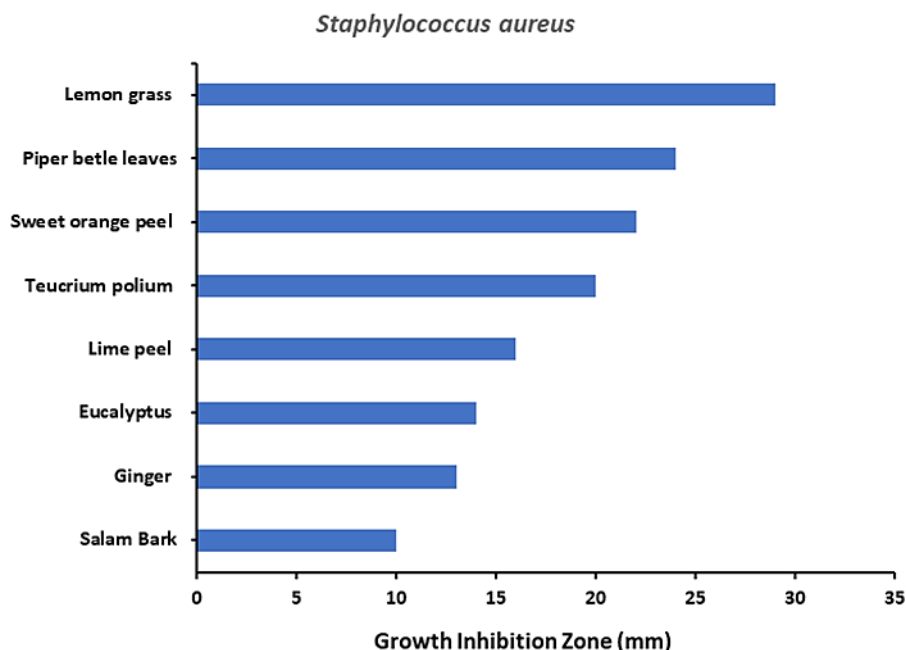
In this systematic review, it was evident that the natural hand sanitizers made up of herbal ingredients have higher antimicrobial potential. Therefore, the activity of different herbs and natural fruit peels extracts were also examined against three bacterial strains i.e. *S. aureus*, *P. aeruginosa* and *E. coli*. The result revealed that the antibacterial efficacy of different natural extracts and essential oils against pathogens is strongly dependent on the composition of natural compounds. For instance, lime peel has the strongest antibacterial activity, closely followed by *Teucrium polium* and ginger extract. The results also indicated that lemon grass extract has the least antibacterial activity against *p. aeruginosa*. Other natural substances such as: piper betle, sweet orange peel, eucalyptus oil, and salam bark showed moderate inhibitory effects (Fig. 4).



**Figure 4.** The antibacterial potential of various natural herbs and fruit peel extracts against *P. aeruginosa*.

Out of the three types, hand sanitizers without alcohol have the least effectiveness. Several other studies also reported the antimicrobial properties of various herbs, such as lemon, ginger, Salam bark, neem, aloe vera, *Teucrium polium*, Eucalyptus oil, tulsi, sweet orange peel, lemongrass, and lime peel, can make them effective against a variety of microorganisms (24, 25, 26). These sanitizers are not only gentle on the skin but also effective in killing germs due to Tulsi's antioxidant properties that aid in skin protection. Similarly, the effectiveness of several distinct natural substances was examined in reducing the growth of *Staphylococcus aureus*. In these results it was found that

the lemon grass oil exhibits the highest zone of inhibition, trailed by sweet orange peel and essential oil of piper betle where as, the salam bark has the least inhibitory effect (Fig. 5).



**Figure 5.** The antibacterial potential of various natural herbs and fruit peel extracts against *S. aureus*.

**Table 1: Characteristics of Selected Studies on Natural Hand Sanitizers**

Authors & Year	Objective	Methods	Types of Hand Sanitizer	Indicator Organisms	Results	Conclusion
<b>Aodah, 2021 (8)</b>	Evaluate the antimicrobial activity of BKC-based sanitizers	Formulated with Benzoylkonium chloride (BKC) 0.1%	Non-alcoholic	<i>E. coli</i> , <i>P. aeruginosa</i>	Showed effectiveness comparable to alcohol-based sanitizers	Suggested non-alcoholic sanitizers as viable alternatives
<b>Bondurant, 2021 (9)</b>	Assess BKC and ethanol's efficacy against <i>S. aureus</i>	Use of BKC 0.12%, ethanol 70%	Alcohol-based	<i>S. aureus</i>	BKC reduced bacterial colonies effectively	BKC and ethanol are highly effective
<b>Ramesh, 2016 (10)</b>	Study antimicrobial activity of herbal oils	Lemongrass, eucalyptus oils	Herbal	<i>S. aureus</i> , <i>Pseudomonas</i> , <i>Klebsiella</i>	Lemongrass oil showed superior antimicrobial efficacy	Lemongrass is more effective than eucalyptus oil
<b>Djima, 2021 (11)</b>	Test lime peel and lemongrass extracts	Ethyl acetate extraction	Herbal	<i>S. aureus</i>	Inhibition of <i>S. aureus</i> growth	Lime peel is more potent than lemongrass
<b>Triastuti, 2021 (12)</b>	Formulate with piper betel oil	Extraction and formulation	Herbal	<i>S. aureus</i>	Effective against <i>S. aureus</i>	Betel oil enhances sanitizer effectiveness

Authors & Year	Objective	Methods	Types of Hand Sanitizer	Indicator Organisms	Results	Conclusion
<b>Budianti, 2021 (13)</b>	Combine Carbopol and sweet orange peel	Maceration and evaporation	Herbal (Gel)	-	Effective formulation with stable properties	Combination enhances gel stability
<b>Abed, 2021 (14)</b>	Formulate herbal extracts with alcohol	Various plant extracts	Alcohol and Non-alcohol	E. coli, P. aeruginosa, Klebsiella	Alcoholic formulations more potent	Combined extracts enhance efficacy
<b>Balkrishna, 2021 (15)</b>	Compare semi-herbal and commercial sanitizers	Neem, Aloe, Tulsi	Semi-herbal	S. aureus	Semi-herbal formulations less effective than alcohol-based	Alcohol-based more potent
<b>Goodarzi, 2020 (16)</b>	Estimate antimicrobial efficacy	Various formulations	Alcohol-based, Herbal	S. aureus, E. coli, Pseudomonas	Group A (alcohol-based) most effective	Alcohol-based show strong inhibition
<b>Surini, 2018 (17)</b>	Test Salam bark extract gel	Gel formulation testing	Herbal (Gel)	S. aureus	Formulation 2 more effective	Higher Salam bark concentration enhances efficacy
<b>Wani, 2012 (18)</b>	Compare alcoholic and non-alcoholic gels	Various commercial brands	Alcoholic and Non-alcoholic	S. aureus, E. coli	Alcohol-based most effective	Alcohol-based preferred for antimicrobial activity
<b>Karimie, 2021 (19)</b>	Compare BKC and ethanol sanitizers	BKC, ethanol 80%	Foaming and concentrated	SARS-CoV-2	Similar performance for both	BKC and ethanol both effective
<b>Al-Zahrani, 2020 (20)</b>	Formulate herbal sanitizers	Maceration, triethanolamine	Herbal	-	Effective antibacterial testing	Herbal ingredients effective
<b>Herdt, 2021 (21)</b>	Analyze sanitizer advantages and disadvantages	Various commercial formulations	Alcohol-based	-	Highlighted both benefits and drawbacks	Alcohol-based control infections effectively

The results indicated that natural hand sanitizers exhibit significant antimicrobial efficacy, with many formulations demonstrating zones of inhibition comparable to or greater than those of traditional alcohol-based hand sanitizers. For instance, formulations containing lime peel, lemongrass, and essential oils such as piper betel and sweet orange peel showed considerable effectiveness against common bacterial strains like *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Escherichia coli*.

#### 4 Discussion

The systematic review provided significant insights into the effectiveness of natural hand sanitizers, highlighting their potential as viable alternatives to alcohol-based formulations in the prevention of microbial transmission. The review of the selected studies demonstrated that natural sanitizers formulated with plant-based extracts and essential oils exhibited considerable antimicrobial activity, often

comparable to or exceeding that of traditional alcohol-based sanitizers. This was particularly evident in formulations using potent natural extracts such as lime peel and *Teucrium polium*, which showed strong antibacterial properties against common pathogens like *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Escherichia coli*. These findings are consistent with previous studies that have reported the efficacy of natural compounds in inhibiting microbial growth due to the presence of bioactive phytochemicals such as tannins, flavonoids, and terpenoids (8, 9).

The study's results aligned with earlier research, confirming the antimicrobial potential of various natural extracts. For instance, the efficacy of lime peel and lemongrass was supported by Djima (2021), who found these extracts capable of inhibiting *S. aureus* growth significantly (11). Similarly, the strong antimicrobial activity of essential oils, such as those from piper betel and sweet orange peel, was consistent with the findings of Triastuti (2021) and Budianti (2021), further validating the role of volatile compounds in enhancing the effectiveness of natural sanitizers (12, 13). The review also corroborated the findings of other studies that have highlighted the advantages of natural hand sanitizers, including their reduced skin irritation and environmental impact compared to synthetic products (14, 15).

The strengths of this systematic review included its comprehensive approach, adhering to PRISMA guidelines and encompassing a broad range of studies from reputable databases. This allowed for a robust comparison of natural and alcohol-based hand sanitizers across various formulations and test conditions. The inclusion of diverse natural ingredients provided valuable insights into the potential of these substances in combating pathogens. However, several limitations were identified. The review was restricted to English-language studies, which might have excluded relevant research published in other languages. Additionally, the variability in study designs, formulations, and test methods across the included articles presented challenges in directly comparing results. Some studies lacked detailed descriptions of the formulation processes and specific concentrations of active ingredients, which are critical factors influencing efficacy (16).

Further research is recommended to address these limitations by standardizing methodologies and expanding the range of natural compounds evaluated. Longitudinal studies assessing the long-term effects of natural hand sanitizers on skin health and environmental safety are needed. Moreover, exploring the synergistic effects of combining multiple natural extracts could enhance antimicrobial efficacy and broaden the spectrum of action against various pathogens. As the demand for sustainable and skin-friendly hygiene products grows, the development of standardized guidelines for formulating and testing natural hand sanitizers will be essential in advancing their use in both healthcare and community settings.

Overall, the findings of this systematic review support the potential of natural hand sanitizers as effective alternatives to alcohol-based products. By leveraging the antimicrobial properties of plant-derived compounds, these sanitizers offer a promising approach to maintaining hand hygiene while minimizing the adverse effects associated with chemical disinfectants. The continued exploration and optimization of natural formulations will contribute to more sustainable and effective strategies for infection control and public health promotion (17, 18).

## 5 Conclusion

In recent years, due to the emergence of Covid, Severe Acute Respiratory Syndrome (SARS) and other food borne illnesses, the people are more attracted towards an efficient and potent hand sanitizers which gives a good hand hygiene and kill pathogenic microorganism. Hands are the most common prevalent manner that infections are spread to the people. Practicing good hand hygiene may prevent the spread of various infections and illness associated with medical care. Thus, there is a great deal of potential to control multidrug resistant bacteria and prevent their spread through surfaces from one part of the globe to another by promoting the application of antimicrobial herbal hand sanitizers. Herbal hand sanitizers offer an alternative to commercial Alcoholic-based hand sanitizers, which are usually made of synthetic compounds. The chemicals used in alcoholic hand sanitizers pose several health risks, such as skin irritation and dehydration. Additionally, ABHS causes hands to become dry, which can exacerbate skin peeling or cracking. Therefore, Herbal sanitizers are safer for the environment and gentler on the skin often made with natural ingredients like aloe vera, Tulsi, fruits peel extracts, a wide variety of medicinal plants and various other natural essential oils.

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**Disclaimers**

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<b>Author Contributions</b>	Nighat Perveen and Fariha Ibrahim conceived and designed the study. Asma Ansari and co-authors conducted the literature review and data analysis. Fariha Ibrahim and Asma Ansari prepared the manuscript.
<b>Conflict of Interest</b>	The authors declare that there are no conflicts of interest.
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<b>Trial Registration</b>	NA
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