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Development of the composition and technology of an alcohol-free hand sanitiser

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Abstract. Effective hand hygiene is a key factor in the prevention of infectious diseases, which creates a need for safe and highly effective antiseptic products and underscores the relevance of developing formulations with optimal antimicrobial, dermatological, and technological properties. The objective of the study was to develop an alcohol-free hand antiseptic with high antimicrobial activity, skin safety, and compatibility with sensor-based dispensers. The analysis of the hand antiseptic market was conducted using analytical and statistical methods, while the determination of quality parameters of the hand antiseptic was carried out using organoleptic, physicochemical, and microbiological control methods. It was established that alcohol-based products – ethanol, propanol, and isopropanol – dominate the antiseptic market (over 70%), and their main limitations were identified, including the potential to cause skin dryness, risk of irritation with prolonged use, and increased flammability. Based on the conducted analysis, an alcohol-free composition was proposed, in which benzalkonium chloride (0.1-0.15%) was identified as the optimal active ingredient. Four formulation variants with different essential oils were studied; it was determined that the samples had a pH ranging from 4.8 to 5.3 and a viscosity of 22-24 mPa·s. The sample containing demonstrated the best overall parameters, with a pH of 5.3 ± 0.2, viscosity of 23 ± 0.3 mPa·s, transparency and stability, as well as improved organoleptic properties. All samples met microbiological requirements, and the content of benzalkonium chloride was 0.12 ± 0.02%, confirming accurate dosing. A technological process for obtaining the antiseptic through the preparation of two phases followed by

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their combination was proposed, ensuring the stability and homogeneity of the final product. The results of this study can be utilised by manufacturers of cosmetic and disinfectant products to create alcohol-free hand antiseptics suitable for use in medical, educational, and social institutions, as well as in household settings, including applications with sensor-based hand sanitiser dispensers

Keywords: hygienic agent; benzalkonium chloride; essential oil; dissolution; hand hygiene; sensor dispenser

Introduction

There is a growing trend toward the replacement of alcohol-based antiseptics with products containing natural-origin components. Increasingly, formulations include essential oils (tea tree, eucalyptus, lavender), plant extracts (chamomile, calendula, green tea), and biopolymers (hyaluronic acid, aloe vera). These substances provide mild antimicrobial activity and contribute to the preservation of the natural skin microbiome, which aligns with the modern concept of "skin microbiome-friendly cosmetics". Accordingly, alcohol-free antiseptics are becoming particularly relevant when combined with sensor-based dispensers, which ensure contactless application and significantly reduce the risk of cross-contamination. The development of an effective alcohol-free product allows for the combination of pronounced antimicrobial activity with skin safety and user comfort, which is important both for healthcare facilities and for public spaces, offices, and educational institutions.

Alcohol-based hand sanitisers (ABHS) have become especially valued for their fast-acting properties, versatility, and proven effectiveness in reducing microbial and viral loads in hands. C. Villa & E. Russo (2021) reported that the essential formulation components of ABHS comprise an alcohol base, typically ethanol or propanol, combined with water, supplemented with minor quantities of hydrogen peroxide and glycerin. These constituents collectively contribute to the sanitiser's antimicrobial effectiveness while maintaining skin tolerability. However, the standard formulation has certain limitations related to its delivery and distribution properties, which has prompted the inclusion of thickeners to prevent leakage and improve overall efficacy. O. Atolani *et al.* (2020) emphasised that the main consumer-level safety concerns associated with alcohol-based hand antiseptics include their flammability, accidental or intentional ingestion, and potential adverse local effects. The study by S. Dalasile *et al.* (2024) confirmed that ethanol from disinfectants can cause intoxication, hypoglycemia, and impaired consciousness. In addition to toxicological risks, such products were characterised by increased fire hazard due to volatile alcohol vapors, which create a risk of ignition when exposed to open flame or heat sources. D. Gupta & A. More (2021) reported cases of skin burns among staff due to non-compliance with safety measures. Dermatological complications (dryness, irritation, contact dermatitis) are typically listed separately in the "Contraindications" section, which is especially important when alcohol concentration is high or the product is used improperly. A. Rafizadeh *et al*. (2023) demonstrated the presence of substandard alcohol-based hand hygiene products on the market, revealing insufficient alcohol concentrations (<60%) and the occurrence of unacceptable toxic contaminants, including methanol, which compromises both antiseptic efficacy and consumer safety.

To enhance consumer properties, dermatological safety, and efficacy of hand antiseptics, in addition to alcohol, excipients may be included in their composition, such as humectants, gelling agents, fragrances, as well as plant extracts or silver nanoparticles (Perveen *et al.,* 2024). K. Abuga & N. Nyamweya (2021) also emphasised the importance of considering various formulation factors, including the type and concentration of alcohol, as well as inactive ingredients, when determining the overall efficacy and safety of alcohol-based hand sanitisers. The study T. Saha *et al.* (2021) highlighted that, alongside the high demand for ABHS, significant challenges emerged regarding formulation standardisation and safety. The authors reported risks associated with improper use, including burns and toxic reactions, emphasising the need for effective labeling and regulatory control to minimise consumer harm. These findings underscored the importance of ensuring both efficacy and safety in ABHS. The research O.V. Pokryshko & T.I. Pyatkovskyy (2025) demonstrated that ethanol-based formulations exhibited higher antimicrobial activity compared to isopropanol-based products. However, the study also revealed the presence of ineffective or contaminated products on the market, highlighting the urgent need for strengthened regulatory oversight and quality assurance in Ukraine. These results emphasised the variability of product quality and the importance of monitoring local markets. Innovations in ABHS formulation have been explored by L. Večerková *et al.* (2024), who proposed a novel powdered hand sanitiser with controlled release of active ingredients. This approach may reduce the frequency of reapplication and potentially decrease skin irritation associated with conventional alcohol gels. The study illustrated a promising direction for improving consumer compliance, safety, and overall product performance.

Research into the development of hand antiseptics has highlighted the importance of balancing high antimicrobial efficacy, user safety and innovative formulation strategies. Although alcohol-based products are effective, their limitations, such as skin irritation and unsuitability for sensitive populations, have highlighted the need to find alternative solutions. In response to these issues, the present study aimed to develop an alcohol-free antiseptic formulation that provides robust antimicrobial activity, ensures safety and tolerability, and is compatible with sensor dispenser systems.

Materials and Methods

The analysis of the hand antiseptic market was conducted using a set of analytical and statistical methods aimed at achieving a comprehensive and objective characterisation of its structural features. The study relied on data retrieved from the State Register of Disinfectants (Resolution of the Cabinet of Ministers of Ukraine No. 863, 2023), which served as a reliable and authoritative source for assessing the current market environment. Analysis of the disinfectants register data allowed for the assessment of the current state of the disinfectants market, its diversity in terms of composition and intended use, and underscores the importance of state control over product quality and safety. The analytical framework included the following criteria: systematic classification of products according to the chemical nature of their active ingredients; differentiation of antiseptics by their intended use; examination of dosage forms and technological characteristics; and statistical assessment of the proportional distribution of products across the identified categories. Formulation optimisation was carried out by varying the concentrations of active ingredients and excipients to achieve the desired viscosity, stability, and uniform distribution of the active components, thereby ensuring high antimicrobial efficacy and dermatological safety of the developed antiseptic. Table 1 presented the composition of the developed alcohol-free hand antiseptic, along with the functional purpose and mechanism of action of each component.

***Table 1**. Composition and functional purpose of components in the alcohol-free hand antiseptic*

Component	Content (mass %)	Function	Mechanism of action	Justification for inclusion in the formula
Benzalkonium Chloride (Merck KGaA, Germany)	0.1-0.15	Antimicrobial agent.	Disrupts bacterial membranes and viral envelopes, causing microbial death.	Effective against Gram-positive and Gram-negative bacteria and enveloped viruses; allows safe use without alcohol.
Cocamidopropyl PGDimonium Chloride Phosphate (M.C. Biotec Inc., China)	1.0-3.0	Gentle skin cleansing; improves product distribution.	Reduces surface tension, ensures uniform application of antimicrobial components.	Amphoteric surfactant that minimises irritation, improves cosmetic properties and efficacy of the antiseptic.
Propylene glycol (Hedinger GmbH, Germany)	3.0-6.0	Humectant; improves glide.	Retains water in the upper layers of the skin; reduces formula viscosity.	Moisturising component that supports skin hydration and compatibility with sensor dispensers.
Triethylene Glycol (Dow Chemical Company, USA)	1.0-2.0	Additional antimicrobial agent; stabiliser.	Suppresses growth of bacteria and viruses; reduces evaporation of active components.	Enhances formula stability and the effectiveness of the alcohol-free antiseptic.
Polysorbate20 (CDH Fine Chemical, India)	0.2-0.5	Emulsifier; aroma stabilisation.	Forms stable colloidal systems, prevents phase separation.	Ensures organoleptic stability and no adverse impact on antimicrobial activity.
Essential oils of *Citrus limon* (HBNO® Bulk Essential Oils, Germany), *Citrus sinensis* (Isope Provence, France), *Lavandula angustifolia* (Visagenics, Bulgaria), and *Melaleuca alternifolia* (NatureInBottle, India)	0.01-0.08	Fragrancer; antiseptic and antiinflammatory action.	Disrupts membranes of bacteria and viral envelopes; enhances skin barrier function.	Boosts antiseptic activity, improves organoleptic properties of the solution.
Water	up to 100	Main solvent; provides liquid consistency.	Dissolves the active components and ensures uniform application on skin.	Ensures physicochemical stability and correct concentration of active components.

***Source:** developed by the authors of this study*

The technological process for the production of the antiseptic involved the preparation of two phases – an aqueous phase and an antimicrobial phase – in two separate reactors. In the first reactor, at a temperature of 25-30°C, the aqueous phase was prepared by dissolving Cocamidopropyl PG-Dimonium Chloride Phosphate in purified water obtained by reverse osmosis. This component reduced surface tension and ensured uniform distribution of the antimicrobial ingredients. Propylene glycol was then added as a humectant, and triethylene glycol was incorporated as an additional antimicrobial agent and stabiliser. Simultaneously, in the second reactor, benzalkonium chloride was dissolved in purified water at 25-30°C to reduce system viscosity and facilitate dissolution of the active ingredient, while maintaining solution homogeneity within a pH range of 4.5-6.0. After stabilising both phases, they were combined under moderate stirring to obtain a homogeneous, transparent solution. Essential oils (*Citrus limon*, *Citrus sinensis*, *Lavandula angustifolia*, *Melaleuca alternifolia*), previously dissolved in a small amount of Polysorbate-20 to ensure colloidal stability and uniform distribution of the antiseptic and aromatic components, were then added.

The final solution was filtered through a membrane (0.45-1 μm) to remove mechanical impurities and subsequently filled into bottles. After bottling, organoleptic evaluation and assessment of the physicochemical parameters of the product were conducted according to the quality specifications for the finished product. To evaluate the influence of essential oils on the quality of the alcohol-free antiseptic solution, four variants were prepared with active components: Benzalkonium Chloride (0.1-0.15%) and essential oils of *Citrus limon* (Sample 1), *Citrus sinensis* (Sample 2), *Lavandula angustifolia* (Sample 3), and *Melaleuca alternifolia* (Sample 4). The pH was determined using a 949 pH Meter (Metrohm, Switzerland). Measurements were carried out within a controlled temperature range of 23-25°C, which was maintained throughout the entire experiment. The viscosity was measured using a DVPlus-II viscometer (Brookfield, USA).

Results and Discussion

During state registration with the authorised regulatory authorities, difficulties may arise in correctly determining the legal status of products labelled as “antiseptic” or “antibacterial”. Such products may fall under various regulatory categories – biocidal products, cosmetic products, medicinal products, or medical devices – depending on their declared purpose and functional characteristics. The distinction between cosmetic products and medicinal products is particularly debatable, as classification is determined by the therapeutic intent of the product. According to the recommendations of the Oder of the Ministry of Health of Ukraine No. 1247 (2024), if a product claims therapeutic or prophylactic properties against infectious processes or skin lesions, it is most likely regulated as a medicinal product. In certain cases, such products may also be subject to regulation under the Technical Regulation on Medical Devices (Resolution of the Cabinet of Ministers of Ukraine No. 753, 2013).

Based on an analysis of available sources and official data, it was established that, as of September 11, 2025, approximately 1,130 Ukrainian and imported products are registered in the State Register of Disinfectants (Ministry of Health of Ukraine, 2025). These products have either received state registration or undergone re-registration following the examination of registration materials conducted by the expert institution – the State Enterprise “Committee on Hygienic Regulation of the Ministry of Health of Ukraine”. The data analysis revealed that, among all registered disinfectants, only 37 products (3.27%) are intended for prophylactic disinfection and decontamination of personnel hands in healthcare, educational, childcare, sports, social, and penitentiary facilities, military units, enterprises of various industries, and establishments in the hospitality, retail, entertainment sectors, and communal services. These products were presented in Figure 1, which illustrated the distribution of various types of hand disinfectants in the market.

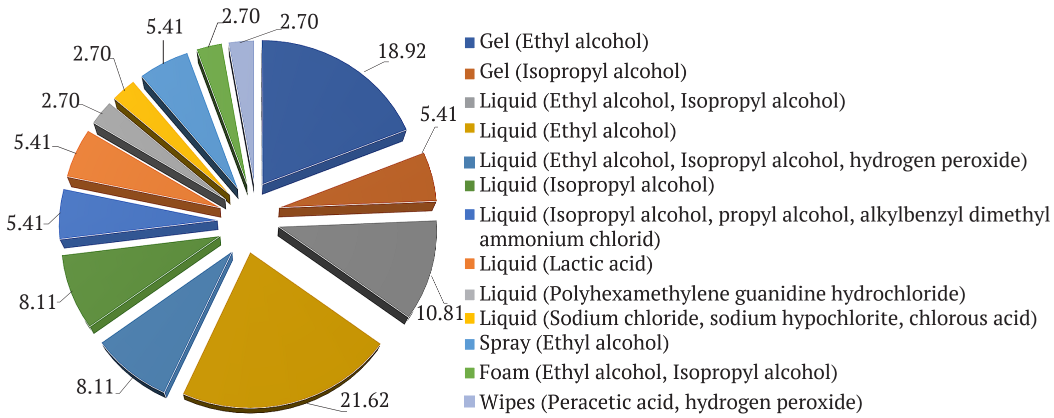

Figure 1*. Products for preventive hand disinfection and decontamination (%)*
Source: *developed by the authors of this study*

The pie chart illustrated the distribution of different types of hand disinfectants available in the market. The largest share is occupied by liquid formulations containing ethyl chloride, sodium hypochlorite, or chlorous acid, accounting for 21.62% of the total. This is followed by gel formulations with ethyl alcohol (18.92%) and liquid formulations containing a combination of ethyl alcohol and isopropyl alcohol (10.81%). Smaller portions are represented by foams containing ethyl and isopropyl alcohol (8.11%), sprays with ethyl alcohol (8.11%), and liquids with isopropyl alcohol alone (5.41%). Other minor categories, each comprising between 2.70% and 5.41%, include gels with isopropyl alcohol, liquids with ethyl alcohol only, liquids with a combination of ethyl alcohol, isopropyl alcohol, and hydrogen peroxide, liquids with isopropyl alcohol and propyl alcohol plus alkylbenzyl dimethyl ammonium chloride, liquids with polyhexamethylene guanidine hydrochloride, and wipes containing peracetic acid and hydrogen peroxide. Overall, the chart highlighted that alcohol-based gels and liquids dominate the disinfectant market, with alternative forms such as sprays, foams, and wipes representing smaller segments.

It was established that the Ukrainian retail pharmacy and supermarket sectors feature a segment of compact, pocket-sized hand antiseptics (Table 2), produced by Ukrainian pharmaceutical and cosmetic companies. These products combine high antimicrobial efficacy with dermatological safety and ease of use due to their compact bottle design. The antiseptics are intended not only to eliminate pathogenic microorganisms but also to support the natural barrier functions of the skin. A comparison of the formulations revealed that these products contain moisturising, emollient, and antioxidant components such as glycerin, panthenol, aloe vera, and vitamin E. The inclusion of these ingredients minimises the risk of dryness, irritation, and allergic reactions, ensuring comfortable and prolonged use of the products in both domestic and professional settings. By supporting the barrier functions of the skin, these formulations reduce the risk of skin dryness, irritation, and hypersensitivity, providing a comfortable and safe experience for extended use in everyday and occupational environments.

Table 2*. Hand antiseptics in the Ukrainian retail pharmacy and supermarket*

Manufacturer / Country	Name	Form	Composition
LLC "Medical Scientific and Production Association BIOKON", Ukraine	Antiseptic Hand Spray "Aloe Vera and Sage"	Spray	Isopropanol (70%), water, aloe vera extract, sage oil, tea tree oil.
	Antiseptic Hand Gel	Gel	Isopropanol, water, PEG 8, DEC, triclocarban, bisabolol, panthenol, fragrance composition.
LLC Lysoform Medical, Ukraine	Hand / Skin Antiseptics	Gel / Liquid	Mixture of isopropyl alcohol and 1-propanol (>70%).
LLC LekoPro, Ukraine	Hand Antiseptic Spray "Chlorhexidine Bigluconate 0.05%"	Spray	Purified water, chlorhexidine bigluconate 0.05%.
	Antiseptic Lotion	Liquid	Isopropyl alcohol, water, glycerin, benzalkonium chloride, benzyl alcohol, benzyl salicylate, fragrance.
LLC "UNIKS", Ukraine	Universal Antiseptic Spray for Hands / Surfaces	Liquid	Isopropyl alcohol (⩾65%), chlorhexidine bigluconate (⩾0.02%).
Shelly™, Ukraine	Universal Disinfectant Spray	Liquid	Propanol, organic solvent, purified water, glycerin, alkyl dimethyl benzyl ammonium chloride, fragrance, vitamin E.
LLC "Petrokos", Ukraine	Antiseptic for Hands	Liquid	Ethyl alcohol, water, lavender extract, glycerin, vitamin E.
MDM GROUP, Ukraine	Hand Antiseptic "Manorm"	Liquid	Isopropyl alcohol 60%, quaternary ammonium compounds 0.11%, excipients: water, glycerin, panthenol, fragrance, dye.
LLC "Ales", Ukraine	Universal Antiseptic "Sani Silver"	Liquid	Alcohol-based compounds 70%, water, glycerin, fragrance composition, aloe extract.
Company "Pharmacom", Ukraine	Antiseptic Hand Lotion	Liquid	Isopropyl alcohol, purified water, glycerin, panthenol.

Source: *developed by the authors of this study*

As a result of the study, an alcohol-free hand sanitiser was developed, which demonstrated high antimicrobial activity and skin safety. This was an important step towards finding alternatives to widely used alcohol-based antiseptics, which have several significant limitations, such as the ability to cause skin dryness and irritation with frequent use, as well as increased fire hazard (Aodah *et al.*, 2021). The study noted that the use of benzalkonium chloride as the main active ingredient made it possible to create an alcohol-free product that was not only effective in combating microorganisms but also provided a more comfortable experience compared to traditional ethanol gels due to the reduced likelihood of skin irritation. A comparison with other alcohol-free antiseptics developed, for example, by P. Egner *et al*. (2023), showed that the addition of mandelic acid and essential oils (cinnamon, clove, lemon, thyme) to the gels helped to maintain optimal physicochemical characteristics, such as pH and viscosity. At the same time, these additives also improved the antimicrobial activity of the product and ensured the stability of the solution. Similarly, B.-H. Youn *et al.* (2021) demonstrated that essential oils, such as tea tree oil, can also enhance antimicrobial properties and are effective alternatives to alcohol-based antiseptics. This made it possible to create a product that meets the requirements of dermatological safety and ease of use. It was noted that the mixture of essential oils with mandelic acid additionally provided a milder effect on the skin, reducing the risk of allergic reactions with prolonged use.

Given this context, it is important to highlight the issues associated with the use of traditional thickeners, particularly carbomer. S. Sommatis *et al.* (2023) and A. Berardi *et al.* (2020) identified carbomers – also referred to as carboxypolymethylene or Carbopol – as the primary viscosity-enhancing excipients employed in ABHS. These cross-linked polyacrylic acid polymers create a three-dimensional network within their polymer chains, and upon hydration, they expand and uncoil to produce clear, stable, and thick hydroalcoholic formulations with a favorable tactile quality. Nevertheless, M. Marchetti *et al.* (2024) highlighted that the environmental sustainability of these synthetic polymers is a growing concern, prompting investigation into greener alternatives. Studies by S. Bom *et al.* (2020) and A.M. Martins & J.M. Marto (2023) emphasised issues related to the petrochemical origin of carbomers, their resistance to biodegradation, adverse effects on aquatic ecosystems, and potential residual monomer contaminants. Considering the possible risks associated with the use of carbomer, in order to reduce the likelihood of skin irritation and dryness, moisturising and softening components, in particular propylene glycol, triethylene glycol and cocamidopropyl PG-dimonium chloride phosphate, were included in the development of the product within the framework of this study. The results of organoleptic testing and the determination of physicochemical properties were presented in Table 3.

Table 3. *Organoleptic and physicochemical characteristics of the tested samples*

Parameter	Sample 1	Sample 2	Sample 3	Sample 4
Appearance	Transparent, homogeneous	Transparent, homogeneous	Transparent, homogeneous	Transparent, homogeneous
pH	4.8 ± 0.2	5.0 ± 0.2	5.2 ± 0.2	5.3 ± 0.2
Viscosity (mPa·s)	22 ± 0.3	23 ± 0.4	24 ± 0.3	23 ± 0.3
Transparency	Transparent	Transparent	Transparent	Transparent
Organoleptic properties	Strong citrus aroma	Mild orange aroma	Lavender aroma, calming	Light woody aroma

Source: *developed by the authors of this study*

Research by L. Dascalu (Rusu) *et al.* (2020) revealed a strong correlation between the chemical composition of essential oils and their antimicrobial activity. The main active components of lemon, cinnamon, clove and thyme essential oils are limonene, cinnamaldehyde, eugenol and thymol, respectively. They have the ability to disrupt the integrity of microbial cell membranes, leading to the loss of cell contents and cell death. These results are consistent with a study by A. Orchard & S. van Vuuren (2017), which confirmed the antibacterial properties of cinnamaldehyde, the main component of cinnamon oil. Cinnamaldehyde effectively destroys bacterial membranes, making cinnamon oil a promising ingredient for antiseptic agents. Additionally, a study by J. Sedlaříková *et al.* (2019) showed that thymol, the main component of thyme oil, has similar antimicrobial activity by disrupting the membranes of microorganisms. This makes essential oils, particularly thyme oil, important in the fight against bacteria due to their antimicrobial activity and skin safety.

The conducted studies revealed that the addition of *Citrus limon* resulted in a slight decrease in pH to 4.8, while viscosity and transparency remained within the established limits. For Sample 2 (*Citrus sinensis*), the pH was approximately 5.0, with viscosity and transparency remaining within the permissible range. For Sample 3 (*Lavandula angustifolia*), the pH was around 5.2, but an increase in solution viscosity to 24 mPa·s was observed, which may lead to uneven dosing when using a sensor-based dispenser. For Sample 4 (*Melaleuca alternifolia*), the pH was 5.3, and viscosity was 23 mPa·s. All samples were transparent and passed microbiological testing for the absence of pathogenic microorganisms. The quality specification for the finished product of Sample 4 was presented in Table 4. The results indicated that the choice of essential oil significantly affects both the physicochemical properties and the antimicrobial efficacy of the formulations. The inclusion of *Melaleuca alternifolia* provided an optimal balance between pH, viscosity, and transparency, ensuring uniform dosing and compliance with microbiological safety standards. Slight variations in pH observed with other essential oils did not compromise product stability but may influence skin compatibility and sensory perception. The findings highlighted the importance of carefully selecting essential oils not only for their antimicrobial activity but also for their impact on formulation stability, user safety, and application convenience, supporting the development of effective and consumer-friendly alcohol-free hand antiseptics.

Table 4. *Finished product specification (Sample 4)*

Parameter	Control method	Acceptance criteria	Result	Note
Appearance	Organoleptic	Transparent, homogeneous	Transparent, homogeneous	Complies
pH	pH meter	4.5-6.0	5.3 ± 0.2	Complies
Viscosity (mPa·s)	Rotational viscometer	15-35	23 ± 0.3	Complies
Transparency	Visual inspection	No turbidity	Transparent	Complies
Benzalkonium chloride (%)	Titrimetric, HPLC	0.1-0.15	0.12 ± 0.02	Complies
Microbiological purity	Microbiological analysis	Absence of pathogens	Absence of pathogens	Complies

Source: *developed by the authors of this study*

The analysis of the results presented in Table 4 demonstrated that the addition of *Melaleuca alternifolia* essential oil provided additional antimicrobial activity and improved the organoleptic properties of the product without affecting solution stability. The developed model alcohol-free hand antiseptic based on benzalkonium chloride meets the established regulatory requirements for physicochemical and microbiological parameters (World Health Organization, 2009). The transparent and homogeneous appearance confirmed system stability, while a pH of 5.3 ± 0.2 corresponds to the established norm. The solution viscosity of 23 ± 0.3 mPa·s ensures convenient and uniform dispensing using a sensor-based dispenser. Transparency met the regulatory requirements, the concentration of benzalkonium chloride at 0.12% confirmed the accuracy of active ingredient incorporation, and microbiological purity indicated the absence of pathogenic microorganisms. These findings indicated that the incorporation of *Melaleuca alternifolia* not only enhances the antimicrobial efficiency of the formulation but also contributes positively to the sensory characteristics of the product, making it more acceptable for regular use. The pH value within the skin-friendly range suggests minimal risk of irritation, while the observed viscosity ensures precise and reproducible dosing, which is particularly important when using sensor-based dispensers. The compliance with transparency and microbiological standards confirmed the formulation's stability and safety. Overall, the results supported the feasibility of developing alcohol-free hand antiseptics that are both effective against microorganisms and gentle on the skin, aligning with consumer demand for safer, non-alcoholic alternatives.

Conclusions

The conducted studies demonstrated that the developed formulation and technological process for obtaining an alcohol-free antiseptic solution based on benzalkonium chloride and essential oils with antimicrobial properties – involving the preparation of aqueous and antimicrobial phases, their subsequent combination, and incorporation of essential oils – allow the production of a stable and safe product. All four model samples containing different essential oils (*Citrus limon*, *Citrus sinensis*, *Lavandula angustifolia*, and *Melaleuca alternifolia*) met physicochemical and microbiological requirements, exhibiting a transparent and homogeneous structure, skin-friendly pH, and comfortable viscosity. The inclusion of essential oils enabled modulation of organoleptic properties (aroma) without negatively affecting solution stability or antimicrobial efficacy. The pH values ranged from 4.8 for *Citrus limon* to 5.3 for *Melaleuca alternifolia*, remaining within the skin-safe range. Solution viscosities varied between 22 mPa·s (*Citrus limon*) and 24 mPa·s (*Lavandula angustifolia*), ensuring uniform dosing and compatibility with sensor-based dispensers. Transparency measurements confirmed a clear and homogeneous appearance for all samples, while microbiological analysis demonstrated the absence of pathogenic microorganisms, confirming the formulations' safety and antimicrobial efficacy.

The most optimal formulation was the Sample 4 containing *Melaleuca alternifolia*, which combined effective antimicrobial action, pleasant aroma, skin-safe pH (5.3 ± 0.2), and appropriate viscosity (23 ± 0.3 mPa·s) for use with sensor-based dispensers. The benzalkonium chloride concentration of 0.12% in all samples ensured consistent antimicrobial activity while minimising skin irritation, and the addition of humectants and emollients (propylene glycol, triethylene glycol, Cocamidopropyl PG-Dimonium Chloride Phosphate) supported skin hydration and comfort. Further research could focus on expanding the spectrum of tested essential oils, optimising the formulation for enhanced antiviral activity, and conducting long-term stability and sensory studies to evaluate consumer acceptance and practical usability under various environmental conditions. Such studies would contribute to the development of safer, highly effective, and consumer-friendly alcohol-free hand antiseptics suitable for both domestic and professional use.

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Conflict of Interest

None.

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Розробка складу та технології безспиртового антисептичного засобу для рук

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Анотація. Ефективна гігієна рук є ключовою умовою профілактики інфекційних захворювань, що зумовлює потребу у безпечних та високоефективних антисептичних засобах і підкреслює актуальність розробки формул з оптимальними антимікробними, дерматологічними та технологічними властивостями. Метою дослідження була розробка безспиртового антисептичного засобу для рук із високою антимікробною активністю, безпечністю для шкіри та можливістю застосування сумісністю з сенсорними дозаторами. Аналіз ринку антисептичних засобів здійснювали з використанням аналітично-статистичних методів, а визначення показників якості антисептичного засобу проводили із застосуванням органолептичних, фізико-хімічних та мікробіологічних методів контролю. Встановлено, що на ринку антисептичних засобів домінують препарати на основі етилового, пропілового та ізопропілового (понад 70 %), а також визначено їхні основні обмеження, зокрема здатність викликати сухість шкіри та ризик подразнення при постійному застосуванні, а також їх підвищену пожежонебезпечність. На основі проведеного аналізу запропоновано безспиртову композицію, у якій бензалконію хлорид (0,1-0,15 %) визначено оптимальним активним компонентом. Досліджено чотири варіанти складу з різними ефірними оліями; встановлено, що зразки мали pH у межах 4,8-5,3 та в'язкість 22-24 мПа•с. Зразок з *Melaleuca alternifolia* продемонстрував найкраще співвідношення показників – pH 5,3 ± 0,2, в'язкість 23 ± 0,3 мПа•с, прозорість та стабільність, а також покращені органолептичні властивості. Усі зразки відповідали мікробіологічним вимогам, а вміст бензалконію хлориду становив 0,12 ± 0,02 %, що підтверджує точність дозування. Запропоновано технологічний процес одержання засобу шляхом приготування двох фаз із подальшим їх об'єднанням, що забезпечило стабільність та однорідність готового продукту. Результати роботи можуть бути використані виробниками косметичних і дезінфекційних засобів для створення безспиртових антисептиків, придатних до застосування у медичних, освітніх, соціальних установах та побутових умовах, зокрема в приладах для антисептичної обробки рук з сенсорними дозаторами

Ключові слова: гігієнічний засіб; бензалконію хлорид; ефірна олія; розчинення; гігієнічна обробка рук; сенсорний дозатор