

# Green Alternatives in Personal Hygiene: Evaluating Bioalcohols in Wipes, Hand Sanitizers, and Sprays



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**Abstract:** The widespread use of petrochemical-derived alcohols in personal care and disinfectant products has raised growing concerns over environmental sustainability and human health safety. As the global demand for eco-friendly healthcare solutions intensifies, bioalcohols—notably bioethanol and biobutanol produced from renewable biomass—have emerged as compelling alternatives. This review systematically evaluates the integration of bioalcohols into personal care formulations, with a particular focus on wipes, hand sanitizers, and spray-based disinfectants. Drawing upon recent advances in green chemistry, toxicology, and industrial biotechnology, we assess the performance, safety profile, and environmental impact of bioalcohols relative to their fossil-based counterparts. While challenges persist—such as supply chain scalability, cost competitiveness, and formulation stability—our analysis reveals that bioalcohol adoption can significantly reduce carbon emissions and volatile organic compound (VOC) release in consumer products. The study concludes with strategic recommendations encompassing regulatory incentives, standardization frameworks, public education, and technological innovation, charting a pathway toward the mainstream deployment of bioalcohols in sustainable healthcare and hygiene applications.

**Keywords:** Bioalcohols; Personal Care Products; Green Disinfectants; Sustainable Nursing; Wipes; Hand Sanitizers; Sprays

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## 1 Introduction

In recent years, the global emphasis on environmental sustainability and public health has intensified scrutiny of the ingredients used in personal care products [1]. Traditional disinfectants, particularly those based on petrochemical-derived alcohols like isopropanol and synthetic ethanol, have been widely utilized for their effective antimicrobial properties [2]. However, concerns have arisen regarding their environmental impact, including issues related to non-renewable resource consumption, potential toxicity, and ecological degradation [3]. As a result, there is a growing demand for greener, more sustainable alternatives that can maintain efficacy while reducing envi-

ronmental footprints [4].

Bioalcohols, such as bioethanol and biobutanol, have emerged as promising substitutes [5–8]. Derived from renewable biomass sources through fermentation processes, these bio-based alcohols offer comparable antimicrobial effectiveness to their petrochemical counterparts [9–12]. Moreover, their production and use align with principles of green chemistry, aiming to minimize hazardous substances and promote environmental stewardship [13–15]. The integration of bioalcohols into personal care products represents a significant step toward sustainable hygiene practices [16–18].

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The application of bioalcohols in products like wipes, hand sanitizers, and sprays is particularly pertinent. These items are ubiquitous in both healthcare settings and daily personal use, especially in the wake of global health crises that have heightened awareness of hygiene and infection control [19, 20]. Traditional formulations often rely on petrochemical alcohols, which, while effective, pose challenges such as skin irritation, flammability, and environmental persistence. Bioalcohols, with their renewable origins and favorable biodegradability profiles, offer a compelling alternative that addresses these concerns [21–23].

Despite the advantages, the transition to bioalcohol-based formulations is not without challenges [24, 25]. Issues such as production costs, supply chain logistics, and regulatory approvals can impede widespread adoption [26]. Additionally, ensuring consistent quality and efficacy in bioalcohol production requires robust technological and infrastructural support [27]. Nonetheless, advancements in biotechnology and increasing consumer demand for sustainable products are driving innovation and investment in this area [28].

This study aims to explore the potential of bioalcohols as green alternatives in personal care products, focusing on their application in wipes, hand sanitizers, and sprays. By examining the properties, benefits, and challenges associated with bioalcohol integration, the research seeks to provide insights into sustainable product development and inform future practices in the personal care industry.

## 2 Fundamental Properties and Sources of Bioalcohols

Biofermented alcohols, commonly referred to as bioalcohols, are organic compounds produced through the fermentation of biomass by microorganisms. These alcohols, including bioethanol and biobutanol [29], serve as renewable alternatives to petrochemical-based alcohols and are utilized in various applications, notably in personal care products such as wipes, hand sanitizers, and sprays [30, 31]. Understanding their properties and sources is essential for assessing their potential as sustainable components in these products.

Bioalcohols possess several characteristics that make them suitable for use in personal care products. Bioethanol and biobutanol exhibit strong antimicrobial properties, effectively eliminating a broad spectrum of pathogens [32,

33]. This makes them valuable as active ingredients in disinfectants and sanitizers. These alcohols are highly volatile, allowing them to evaporate quickly upon application. This rapid evaporation ensures that products like hand sanitizers do not leave a sticky residue, enhancing user comfort. Bioalcohols are excellent solvents, capable of dissolving various substances. This property facilitates the incorporation of diverse active ingredients and fragrances into personal care formulations. Their affinity for water enables bioalcohols to mix readily with aqueous solutions, which is beneficial in formulating products that require a consistent and uniform composition [6].

The production of bioalcohols involves fermenting biomass derived from various feedstocks [34]. These feedstocks are categorized based on their generation and origin. **First-Generation Feedstocks:** These include edible crops rich in sugars and starches, such as sugarcane, corn, and wheat [35]. While they are efficient for bioalcohol production, their use raises concerns about food security and competition for arable land. **Second-Generation Feedstocks:** Comprising non-edible lignocellulosic biomass like agricultural residues (e.g., corn stover, wheat straw), forestry waste, and dedicated energy crops, these feedstocks offer a more sustainable alternative [36]. They do not compete with food crops and make use of waste materials, aligning with environmental sustainability goals. **Third-Generation Feedstocks:** This category includes algae and other microorganisms cultivated specifically for bioalcohol production [37]. Algae, for instance, have high growth rates and can be cultivated on non-arable land, reducing competition with food production and minimizing environmental impact [38].

The conversion of biomass into bioalcohols involves several key steps:

- 1) **Pretreatment:** Lignocellulosic biomass undergoes pretreatment to break down complex structures and enhance the accessibility of fermentable sugars [39]. Methods include physical (e.g., milling), chemical (e.g., acid or alkali treatment), physicochemical (e.g., steam explosion), and biological processes. Each method has its advantages and challenges, with ongoing research aimed at optimizing efficiency and cost-effectiveness.
- 2) **Hydrolysis:** Following pretreatment, enzymes hydrolyze the exposed polysaccharides into simple sugars [40]. Cellulases and hemicellulases play crucial roles in breaking down cellulose and hemicellulose into fermentable sugars like glucose and xy-

lose [41].

- 3) **Fermentation:** Microorganisms such as *Saccharomyces cerevisiae* for bioethanol and *Clostridium acetobutylicum* for biobutanol ferment the sugars into respective bioalcohols [40, 42–44]. The choice of microorganism and fermentation conditions significantly influences yield and productivity [11, 12, 17, 45].
- 4) **Separation and Purification:** The final step involves separating and purifying the bioalcohol from the fermentation broth [46–48]. Techniques like distillation are commonly employed [49, 50], though they can be energy-intensive [51]. Innovations in separation technologies aim to improve energy efficiency and reduce costs [52–57].

## 3 Role of Bioalcohols in Personal Care Products

Bioalcohols, such as bioethanol and biobutanol, are increasingly utilized in personal care products due to their effective antimicrobial properties and skin compatibility [16]. This discussion delves into their applications in wipes, hand sanitizers, and antimicrobial sprays, highlighting their benefits and suitability for various user groups.

### 3.1 Wipes: Enhancing Skin-Friendly Disinfection

Traditional disinfecting wipes often contain isopropyl alcohol, which can be harsh on the skin [58]. In contrast, some products have transitioned to using bioethanol, reducing skin irritation [59]. Bioethanol not only possesses strong antimicrobial properties but also offers moisturizing effects, making it suitable for infants and individuals with sensitive skin [60]. For instance, the "Techspray 1606-30pk Ethanol Wipes" spray utilizes ethanol as its active ingredient, providing effective disinfection with minimal skin irritation.

### 3.2 Hand Sanitizers: Promoting Hygiene with Reduced Skin Damage

Bioethanol's broad-spectrum bactericidal activity and renewable nature have led to its widespread adoption in

hospitals and public spaces. Products containing 65-80% ethanol are considered optimal for microbial eradication, balancing efficacy and skin safety. Notably, formulations incorporating moisturizers like glycerin help mitigate dryness associated with frequent use. The "Nipahol" spray exemplifies this approach, combining ethanol with moisturizing agents to enhance user compliance and skin comfort [61].

### 3.3 Antimicrobial Sprays: Effective Disinfection with User Comfort

Bioalcohols, particularly bioethanol, are utilized in antimicrobial sprays due to their favorable properties. Bioethanol's low odor and strong lipophilicity make it suitable for application on clothing, air, and skin surfaces, offering a promising solution for comprehensive disinfection without unpleasant scents [62]. These characteristics ensure user comfort while maintaining effective microbial control.

## 4 Advantages of Bioalcohols

Bioalcohols, such as bioethanol and biobutanol, are gaining prominence in various industries, including personal care, energy, and manufacturing, due to their numerous benefits [63]. These advantages encompass high safety profiles, environmental friendliness, renewable sourcing, and versatile functionalities.

Bioalcohols are known for their low skin irritation potential, making them suitable for prolonged use in personal care products. For instance, bioethanol has been favored over isopropyl alcohol in wipes, reducing skin sensitivity issues. Additionally, bioalcohols like biobutanol's low odor and strong lipophilicity make them suitable for antimicrobial sprays, enhancing user comfort.

One of the most compelling advantages of bioalcohols is their minimal environmental impact. They are considered carbon-neutral or even carbon-negative, as the carbon dioxide absorbed during their biomass growth offsets the emissions from their combustion [21]. Moreover, bioalcohols are biodegradable, reducing the risk of environmental pollution. This eco-friendly nature aligns with global sustainability goals, encouraging the adoption of bioalcohols over traditional petrochemical alternatives.

Bioalcohols are derived from renewable resources, such as agricultural residues, forestry waste, and dedicated energy crops [64]. This sourcing diminishes reliance on fi-

nite fossil fuels, promoting energy security [65]. Utilizing agricultural waste for bioalcohol production also supports waste valorization, contributing to a circular economy [66, 67]. For example, second-generation bioalcohols produced from non-edible lignocellulosic biomass do not compete with food crops, aligning with environmental sustainability goals [68].

The strong antimicrobial properties of bioalcohols make them valuable in disinfectants and sanitizers, ensuring effective pathogen control. Bioethanol serves as a renewable fuel, reducing greenhouse gas emissions when used as an alternative to gasoline [69]. Its incorporation into fuel blends contributes to cleaner energy solutions [70].

## 5 Challenges and Recommendations in Promoting the Application of Bioalcohols

Despite the numerous advantages of bioalcohols, such as bioethanol and biobutanol, their widespread adoption faces several challenges, including higher costs, stability issues, and the absence of standardized regulations [71]. To address these challenges and enhance the integration of bioalcohols into various applications, the following strategies are recommended:

- 1) **Policy Support: Encouraging the Development and Application of Green Nursing Products.** Government policies play a pivotal role in promoting the use of bioalcohols in personal care products. Implementing supportive measures, such as subsidies, tax incentives, and research grants, can stimulate innovation and investment in green nursing products. For instance, the "Key technologies and applications for the preparation of biostimulants of microbial origin" project, led by Professor Xu Hong from Nanjing Tech University, received recognition for achieving international advanced levels in developing microbial-derived bio-stimulants. Such initiatives highlight the importance of policy backing in advancing bioalcohol-based products.
- 2) **Standard Development: Establishing Quality Control Systems for Bioalcohol Nursing Products.** The lack of standardized quality control measures for bioalcohol-based nursing products can lead to inconsistencies and safety concerns. Developing

comprehensive standards is essential to ensure product efficacy and consumer safety. An example is the "General Technical Requirements for Safety in the Use of Alcohol-based Biofuels in the Catering Industry" standard, which provides guidelines for the safe use of alcohol-based biofuels in the catering industry. Establishing similar standards for bioalcohol nursing products would enhance consumer trust and facilitate market growth.

- 3) **Technological Innovation: Optimizing Extraction Processes and Enhancing Stability.** Addressing the stability issues of bioalcohols requires continuous technological advancements. Research into optimizing extraction processes and formulating stabilizing agents can improve product shelf life and performance. For example, the development of "Bio-based polyurethane and its key manufacturing technologies" has led to the creation of high-performance bio-based polyurethanes, demonstrating the potential of technological innovation in enhancing bioalcohol applications.
- 4) **Educational Guidance: Raising Awareness Among Caregivers and Consumers About Green Practices.** Educating both caregivers and consumers about the benefits of green nursing products is crucial for fostering acceptance and demand. Educational campaigns, workshops, and informational resources can increase awareness of the environmental and health advantages of bioalcohol-based products. This heightened awareness can drive consumer preference towards products that are both effective and environmentally friendly.

## 6 Conclusion

The application of bioalcohols in personal care products, including wipes, hand sanitizers, and sprays, offers a promising and practical approach to enhancing user safety and addressing environmental concerns. These bio-based alternatives not only improve the safety profile of personal care items but also align with the growing consumer demand for eco-friendly products. To further advance the integration of bioalcohols in personal care, it is essential to foster interdisciplinary collaboration, expedite the standardization and commercialization processes of green nursing products, and promote the sustainable development of the personal care industry. These efforts will contribute to a more sustainable and health-conscious future in personal care.

## Notes

The authors declare no competing financial interest.

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