Integration of deep eutectic solvents to develop advanced contact lens disinfectants

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Short-title: Deep eutectic solvents as contact lens disinfectants

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Text

Deep eutectic solvents have attracted significant interest in various fields due to their unique physicochemical properties.[1,2] Deep eutectic solvents are made by combining two types of molecules: one that donates hydrogen bonds (hydrogen bond donor) and one that accepts them (hydrogen bond acceptor). These two components interact through hydrogen bonds, creating a mixture with a much lower melting point than the individual components. The hydrogen bonds form a connected network, called a "self-associated network." This unique structure gives deep eutectic solvents special properties, such as low vapor pressure (making them less likely to evaporate) and the ability to dissolve many different types of substances, both organic and inorganic. This network structure results in properties to deep eutectic solvents that differentiate them from traditional solvents, exhibiting low vapor pressure, which makes them less volatile minimizing solvent loss, as well as solvation capabilities, allowing them to dissolve a wide range of organic and inorganic compounds.[1] Unlike traditional solvents, such as water, ethanol, or acetone, which are single compounds, deep eutectic solvents form a connected network of molecules through hydrogen bonding. This network gives them unique properties, such as low vapor pressure (making them less likely to evaporate) and the ability to dissolve a wide range of organic and inorganic compounds. The solvation properties of deep eutectic solvents are due to the formation of specific supramolecular complexes between the solvent components and the solute molecules. Supramolecular complexes are assemblies of two or more molecules held together by non-covalent interactions, such as hydrogen bonding or electrostatic forces, rather than strong chemical bonds. These interactions allow the molecules to organize into specific structures, which can disassemble under certain conditions.[2] The physicochemical properties of deep eutectic solvents can be modified by choosing different combinations of hydrogen bond donors and hydrogen bond acceptors, customizing properties such as viscosity, polarity, and thermal stability and performance.[1] In particular, deep eutectic solvents exhibit low toxicity, an important consideration for safety, sustainable and environmentally friendly disinfectant processes.[1]

Recently, deep eutectic solvents have demonstrated potent antimicrobial properties, making them effective in eliminating pathogenic microbes such as *Acanthamoeba* spp.[3 4] The integration of deep eutectic solvents into contact lens solutions offers significant potential for enhancing the performance and functionality of disinfection applications. The solvation capabilities of deep eutectic solvents allow efficient interaction with microorganisms, disrupting their cellular structures and inhibiting their growth.[5] The observed antimicrobial activity of deep eutectic solvents can be attributed to their ability to denature proteins, and interfere with essential cellular processes, ultimately leading to microbial inactivation. In addition to their direct antimicrobial effects, deep eutectic solvents inclusion can also inhibit microbial adhesion, colonization, and biofilm formation.[2] Various deep eutectic solvents formulations may exhibit variations in their effectiveness against specific microorganisms, necessitating optimization for targeted microbial removal.[5]

There are several methods for integrating deep eutectic solvents including direct mixing during the disinfection process. This will allow for the homogeneous distribution of deep eutectic solvents, resulting in improved interaction between the solvent and the lenses. Alternatively, impregnation of pre-formed contact lens cases with deep eutectic solvents can enhance the efficacy of disinfectants towards specific contaminants. The unique properties of deep eutectic solvents enable efficient interaction and degradation of target pathogens. The solvation capabilities of deep eutectic solvents can also be utilized to selectively remove additional specific contaminants, such as heavy metals, improving the overall treatment efficiency, albeit the long-term stability of deep eutectic solvents require further investigation. Deep eutectic solvents can modify the surface charge/properties, creating a physical barrier that can inhibit the adhesion of particles, organic matter, etc., thus minimizing biofilm-related issues.[6]

Despite the potential advantages of deep eutectic solvents in microbial removal, there is a need to evaluate long-term stability, toxicity, and compatibility with contact lens disinfectants. The integration of deep eutectic solvents in disinfection systems offers a promising avenue for improving the efficiency of microbial control strategies in disinfection processes, especially given the current inefficacy of contact lens disinfectants against *Acanthamoeba* species.[7] Exploring the use of natural compounds, such as amino acids, sugars, or organic acids, as deep eutectic solvents components can offer potential advantages in terms of biodegradability, lower toxicity, and reduced environmental impact.[8] Furthermore, numerous studies have highlighted the promising and potent antimicrobial properties of deep eutectic solvents against a wide range of pathogens, including multidrug-resistant bacteria, fungi, protists, and certain viruses. [9] A recent study evaluated the *in vitro* antifungal activity of *Premna odorata* Blanco extract, a medicinal plant, against the pathogenic fungi *Candida albicans* and *Monilinia* spp. The DES-based extracts of *P. odorata* Blanco showed notable antifungal effects against both *C. albicans* and *Monilinia* spp.[10] Moreover, research suggests that DES could serve as innovative, eco-friendly, and cost-effective antimicrobial agents. Evidence also indicates that deep eutectic solvents can disrupt cell membranes, alter cellular structures, and interfere with critical metabolic processes in cancer cells.[9] Nonetheless, optimization of deep eutectic solvent formulations will be crucial for enhancing their effectiveness in microbial removal. Key factors to optimize may include concentration, which should balance antimicrobial potency with minimal toxicity; exposure time, determine the necessary duration for effective microbial inhibition; temperature, which may affect the strength of hydrogen bonding and solvent stability; and the type of hydrogen bond donors and acceptors, which may influence the ability to disrupt microbial cells. Focusing on these factors in future studies will help tailor formulations for maximum efficacy. Such innovative approaches can open new avenues for advanced contact lens disinfection systems with improved performance and the development of environmentally friendly technologies.

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