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Viewpoint

Deep Eutectic Solvents Can Contribute To Fight against Zero Hunger from a Sustainable Perspective

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The economic recession caused by the global epidemic has led to the most significant increase in hungry people in the world in decades, affecting almost all low- and middle-income countries. It is a huge challenge that undoubtedly concerns all health and science organizations and institutions. Facing the problem of reaching zero hunger from a sustainable perspective requires the joint action of the chemical sciences at large. Thus, there is a pressing need to act from different fronts framed by green chemistry and sustainability, especially in the post-epidemic era.

Strengthening agricultural, scientific, and technological innovation is an essential solution for achieving zero hunger, and promoting the integration and development of disciplines is one of the critical ways out. In this sense, this viewpoint focuses on a new family of innovative designer solvents called deep eutectic solvents (DESs). Furthermore, efforts leading the way and general approaches to the employment of DESs in improving food preservation and valorization of biomass of nutritional and alimentary interest, offering sustainability, are highlighted.

The DESs are mixtures of hydrogen bond acceptors (HBAs) and hydrogen bond donors (HBDs) characterized by a significant depression in the melting point of the pure components when mixed to make liquids with outstanding properties and green credentials.[1] The DESs exhibit a wide gamut of solvation properties, viscosities, and acidity, which, together with their negligible volatility and easy preparation in the pure state, makes them a game changer for the extraction of a large variety of secondary metabolites of agricultural, nutritional, functional, and biomedical interest. This is a new family of solvents whose properties can be fine-tuned thanks to the vast array of HBDs and HBAs available to form them, including alcohols, carboxylic acids, amides, amines, saccharides, and other secondary metabolites as HBDs and choline chloride (among other quaternary ammonium salts), betaine, and amino acids as HBAs. In addition, DESs typically exhibit high viscosities ($10-10^4$ cP), which complicates their handling and implementation in the extraction process; however, reasonable integration of water into DES formulations can dramatically modify their viscosity and other properties, like conductivity and acidity.

DES preparation is scalable; therefore, it is thought that the DESs and those containing only naturally occurring counterparts [natural deep eutectic solvents (NaDESs)] may be able to solve on an industrial scale the recovery of diverse products from many sources, for instance, agricultural biomass, food, and lignocellulosic wastes, to produce dietary fibers, edible products, coatings, (bio)polymers, food packaging, biopesticides, food supplements, functional extracts, synthetic building blocks, and food additives, which contribute to the integration of a circular economy in the countryside and industry of the first food-producing countries in the world[2] (Figure 1).

DESs and NaDESs have proven to be excellent solvents to extract large amounts of phytochemicals from biomass and agricultural byproducts, surpassing the selectivity and extractability of traditional volatile and toxic organic solvents. These extracts have shown activity against phytopathogenic microorganisms; therefore, they can be reintegrated into the production chain, promoting sustainable agriculture by mitigating the use of synthetic pesticides and valorizing agricultural biomasses. DESs exhibit a remarkable compositional plasticity that translates to designer solvation mechanisms to solubilize hydrophilic and hydrophobic molecules. Hence, there are plenty of opportunities for isolating

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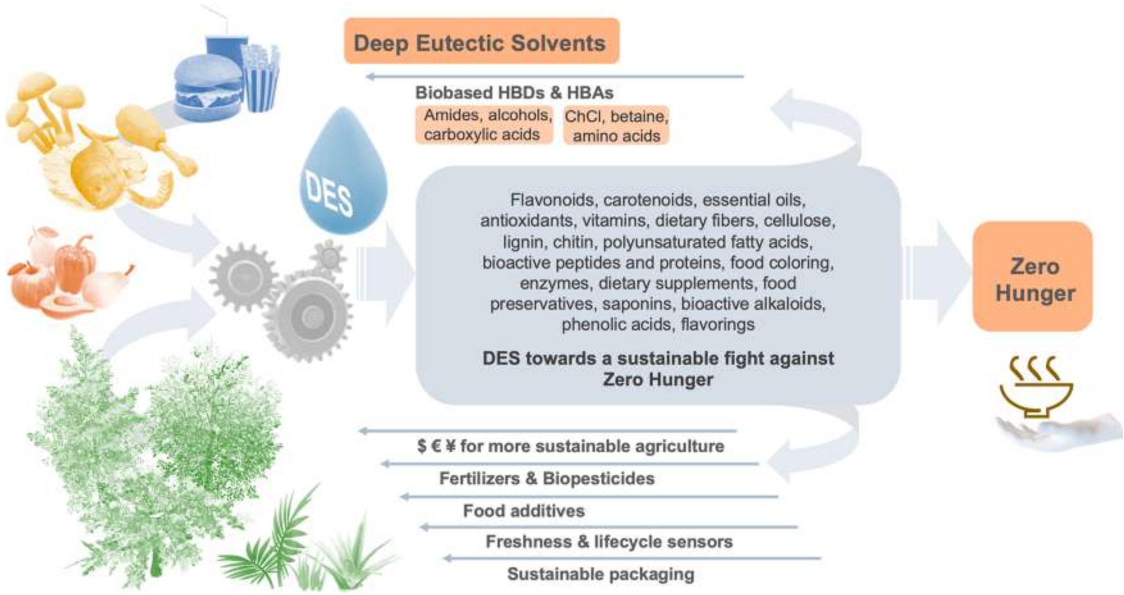

Figure 1. Uses of the DESs toward a sustainable approach against zero hunger.

compounds with potential as biopesticides and carriers for biological control agents loaded with phytochemicals or active ingredients that are immiscible in conventional solvents. As the vehicle of the active ingredients, DESs can provide greater stability for specific applications in the field (foliar or drench) to help to combat long-term insect resistance.

Many DESs are safe and biodegradable, resulting from the food and pharmaceutical grade of the pure constituents. DESs can be used to extract pigments, antioxidants, preservatives, vitamins, and other compounds that can be used as food additives in complex food systems, like emulsions and different food formulations.[3] Likewise, they can be used to solubilize additives and function as a vehicle that stabilizes and protects them from degradation. Therefore, the shelf life of processed foods would be increased.

On the other hand, the valorization of the high protein, sugar, and fat contents of current food waste streams through enzymatic and biotechnological approaches is a viable alternative as a result of the high specificity and less energy-intensive transformations compared to synthetic catalytic processes. Because the DESs have been explored as innovative media to host viable whole cells and enzymatic reactions, the implementation of DESs can further the biocatalytical systems by expanding the conditions of the temperature at which the enzymes are active, thus catapulting the food waste processing to new horizons in terms of specific value-added products obtained via biocatalysis.[4]

Of particular interest in preventing food waste is the topic of food packaging materials, which are highly demanded in the market and are a critical step toward extending the shelf life and the efficient transportation of alimentary goods. These must comply with a series of environmental and health regulations while preserving the food, ideally maintaining and monitoring the freshness of the food. The DESs have the ability to delignify and extract resilient biomass (chitin, lignin, and cellulose), which can serve as sustainable food packaging. Likewise, DESs and (bio)polymers can be applied to manufacture bioplastics and intelligent biomaterials, such as freshness food sensors, pH sensors, and microbial growth sensors enriched with phytochemicals. On the other hand, with the addition of gel-forming materials to DESs, eutectogels can be designed, which can be helpful in developing edible and intelligent biofilms that can extend the shelf life of fruits and vegetables.[5]

Given the myriad of possible combinations to design DESs, a basic understanding of their thermodynamics and molecular arrangements that give rise to outstanding properties are needed to reveal the full potential of DESs, besides the possible long-term impact on ecosystems and the eutrophication of wastewaters. However, the approaches presented in this viewpoint aim to aware the community of agricultural, food chemistry, and related technological areas about a family of designer solvents that are the DESs, which can contribute to fighting against hunger by avoiding food and agricultural biomasses going to waste, to help build a more sustainable future.

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Notes

The authors declare no competing financial interest.

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