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Opinion

Reduction Food Loss and Waste: The Role of Deep Eutectic Solvents (DESs)

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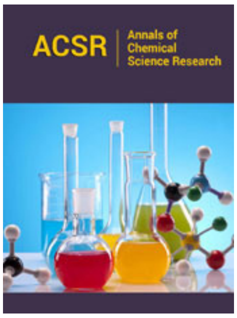

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Opinion

Food loss and waste has significant environmental, economic and social impacts, as 1.3 billion tonnes of food are wasted annually according to the Food and Agriculture Organization (FAO). Awareness of environmental issues is on the rise, and the 2030 Agenda's Sustainable Development Goals emphasize the need for the efficient utilization of natural resources and the environmentally responsible handling of chemicals and waste at every stage of their life cycle. As part of the Sustainable Development Goals (SDGs), the United Nations strives to achieve a 50% reduction in global food waste at retail and consumer levels, along with a decrease in post-harvest food loss by the year 2030. The monetary value of this amount of Food Loss and Waste (FLW) is estimated to be around USD $936 billion, without accounting for the social and environmental costs borne by society as a whole. This quantity of FLW could potentially alleviate hunger for one-eighth of the world's population. Moreover, addressing the global challenge of meeting the increased demand for food, projected to reach about 150-170% of the current demand by 2050, could be facilitated by efficiently managing and reducing FLW [1-3].

The food processing industry, known for generating substantial byproducts, frequently discharges them, posing significant environmental challenges. A substantial body of research indicates that agro-food waste can serve as a valuable and cost-effective source for obtaining high-value compounds with applications in the pharmaceutical, medical, or food industry. Food by-products represent an opportunity to extract bioactive compounds. Furthermore, utilizing food by-products as a source of bioactive compounds presents a promising opportunity to promote a circular economy and mitigate the ongoing rise in the production of organic waste.

In recent decades, innovation in the food industry has been focused on both reducing waste and creating new products with high added value derived from the processing of this waste. Strengthening agricultural, scientific, and technological innovation is an essential solution for achieving zero waste, 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 [4-6].

Strengthening innovation in science, agriculture and technology is a crucial solution for achieving zero waste. Promoting the integration and development of various disciplines is a key pathway towards this goal. In this context, this perspective focuses on a novel group of innovative designer solvents known as Deep Eutectic Solvents (DESs). Additionally, it highlights initiatives and general approaches regarding the use of DESs to enhance food preservation and the valorization of biomass with nutritional and alimentary significance, providing sustainable solutions.

This study focuses on deep eutectic solvents and whether they can reduce food loss and waste. DESs are considered eco-friendly solvents, formed by mixing two or more components that, under specific conditions, exhibit a significant reduction in melting point, turning into liquids at room temperature. When these components are primary metabolites like amino acids, organic acids, sugars, or choline derivatives, they are termed Natural Deep Eutectic Solvents (NADES). NADESs generally demonstrate a substantial depression in freezing point, often exceeding 150 °C [7-11].

Deep Eutectic Solvents (DESs) or Natural Deep Eutectic Solvents (NADESs) arise from the interaction between a hydrogen-bond donor (HBD) and a hydrogen-bond acceptor (HBA). Compared to Ionic Liquids (ILs), NADESs offer advantages such as biodegradability, lower cost-effectiveness, low toxicity and lower flammability since they can be synthesized from natural primary metabolites. NADESs are increasingly recognized as green solvents due to their properties, including polarity, non-volatility, and thermal stability [12].

Common DESs are based on choline chloride (ChCl), carboxylic acids, and other hydrogen-bond donors, with Choline Chloride being a popular choice due to its natural compatibility. Choline chloride, being a readily available quaternary ammonium salt, was consistently selected in this study to investigate the impact of the hydrogen-bond donor.

The preparation of DESs is scalable, suggesting that both DESs and those exclusively composed of naturally occurring components (NaDESs) have the potential to address, on an industrial scale, the recovery of various products from diverse sources. Examples include agricultural biomass, food, and lignocellulosic wastes, leading to the production of dietary fibers, edible products, food packaging, (bio) polymers, coatings, biopesticides, food supplements, functional extracts, food additives and synthetic building blocks (Figure 1). This contributes to implementing a circular economy in both rural areas and the industries of leading food-producing countries worldwide.

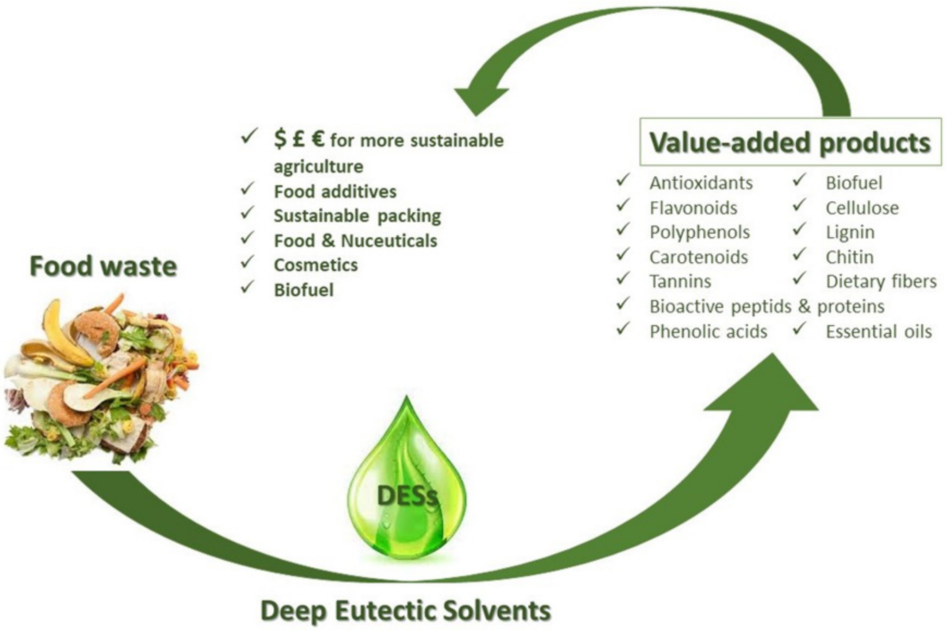

Figure 1: The use of DESs towards a sustainable approach reducing food waste.

DESs and NaDESs have proven to be exceptional solvents for extracting significant amounts of phytochemicals from biomass and agricultural byproducts, surpassing the selectivity and extraction efficiency of traditional volatile and toxic organic solvents. These extracts exhibit activity against phytopathogenic microorganisms, allowing for their reintegration into the production chain. This promotes sustainable agriculture by reducing the reliance on synthetic pesticides and valorizing agricultural biomasses. DESs exhibit notable compositional flexibility, enabling designer solvation mechanisms to solubilize both hydrophilic and hydrophobic molecules.

Many Deep Eutectic Solvents (DESs) are acknowledged for their safety and eco-friendly nature, attributed to their food and pharmaceutical-grade purity. These solvents possess the capacity to extract a diverse range of substances, including pigments, antioxidants, preservatives, vitamins and other compounds. These extracted substances can function as additives in complex food systems, encompassing emulsions and various food formulations. Furthermore, DESs contribute to solubilizing additives, serving as a medium that not only stabilizes them but also shields them from degradation. Consequently, the utilization of DESs can play a role in extending the shelf life of processed foods.

On the other side, harnessing the rich protein, sugar and fat content found in current food waste streams through enzymatic and biotechnological methods offers a practical solution. This is due to the high specificity and less energy-intensive processes compared to artificial catalytic procedures. Deep Eutectic Solvents (DESs) have been explored as innovative mediums to support viable whole cells and enzymatic reactions. Implementing DESs can enhance biocatalytic systems by broadening the temperature range in which enzymes remain active. This, in turn, propels food waste processing into unexplored realms, leading to the creation of specific value-added products through biocatalysis.

The use of DESs for extracting and processing agricultural biomass can lead to the production of various products, such as dietary fibers, edible products, biopolymers and others. This contributes to waste reduction and enhances sustainability. DESs can be employed in the production of biodegradable packaging materials, aiding in the reduction of plastic waste and promoting sustainable practices in food packaging. A noteworthy aspect in the battle against food waste involves considering food packaging materials. These materials, in high demand in the market, play a pivotal role in extending the shelf life and facilitating the efficient transportation of food products. Compliance with environmental and health regulations is essential for these materials, all while preserving the freshness of the food. DESs possess the capability to remove lignin and extract robust biomass (such as chitin, lignin, and cellulose), which can be used for sustainable food packaging. Furthermore, DESs and (bio)polymers can be utilized to produce bioplastics and innovative biomaterials, including freshness food sensors, pH sensors, and microbial growth sensors enriched with phytochemicals [3-6,13-19].

Considering the plethora of potential combinations for designing Deep Eutectic Solvents (DESs), a fundamental understanding of their thermodynamics and molecular arrangements that lead to exceptional properties is required. This is crucial to unveil the full potential of DESs, considering the possible long-term impacts on ecosystems and the eutrophication of wastewaters. However, the approaches presented in this perspective aim to inform the community in agricultural, food chemistry and related technological fields about a family of designer solvents, namely DESs. These have the potential to contribute to reducing the waste of food and agricultural biomass, thus aiding in the creation of a more sustainable future.

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