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Solvent-assisted switchable water (SASW): an alternative method for separating ethanol from water

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PURPOSE OF THE ABSTRACT

Bioethanol in the past 30 years became one of the most promising replacements for petroleum as a fuel; however, the greenness of this fuel alternative is still a point of concern. One of the challenges faced by bioethanol production is directly associated with its production, which takes place in water. Large amounts of water are used, but the ethanol solution concentration is limited, aggravating the separation issue. In addition, the energy consumed due to the poor thermal properties of water and the formation of an azeotrope aggravate the challenges faced by bioethanol [1, 2].

Looking to address this issue, we developed a new method for separating hydrophilic organics from water: high pressure switchable water (HPSW). HPSW takes advantage of two strategies previously described in the literature: CO2 expansion of liquids (CXL) and CO2-switchable water (SW). CO2 dissolves better in organics than in water, which promotes the expansion of the organic phase, among other changes. This expansion triggers the separation of organics from water [3]. SW uses amines to increase the ionic strength of aqueous solutions when CO2 is present. They then disrupt the interaction between the species in the system, causing the expulsion of organics from water [4].

Individually, these techniques are not able to promote the effective removal of hydrophilic organics from water [5]. By combining them, we were able to demonstrate a synergistic effect and the efficiency of several amines to promote phase separation of acetone from water at lower pressures than CXL alone [5]. In addition, we were able to use amines that were previously ineffective for normal SW [5]. Although this approach was efficient for the separation of acetone, the same was not observed for aqueous ethanol solutions. Due to ethanol's elevated hydrophilicity, phase separation was not observed even when high concentrations of amine were used in combination with 100 bar of CO2.

Due to the importance of ethanol for the migration to a more sustainable fuel grid, we modified our original HPSW method to create a new method, solvent-assisted switchable water (SASW), capable of recovering ethanol from water. This presentation will describe the results of these modifications to accomplish the separation of ethanol from water. In this process, instead of relying only on the changes in the interactions between ethanol and water, a less hydrophilic secondary extracting solvent was added to the system to improve phase separation. We screened both miscible and immiscible organic solvents with water (e.g. 1-butanol, isopropanol and cyclohexane) as the extracting component. Our results demonstrated that 1-butanol and isopropanol resulted in the highest recovery of ethanol from the aqueous phase. In these separations, 2,6,10-trimethyl-2,6,10-triazaundecane (TMTAD) was used as the amine, and the pressure was fixed at 50 bar of CO2. However, due to the ability of these solvents to form hydrogen bonding with water, the organic-rich phase still presented an undesirable amount of water mixed with the solvents. The presence of water is an issue, considering that additional purification steps might be required, and the environmental impact needs to be accounted for. We still envision SASW being effective if optimizations are performed on the method. HPSW and SASW might still decrease the energy requirements, even if further purification is necessary. There is also the potential to mitigate the negative impact of azeotropes. Our goal is to optimize the HPSW and SASW separations, reducing their energy consumption

compared to conventional processes. By doing so, we can hopefully make biomass-derived products more competitive with petroleum-based chemicals in terms of economic cost and environmental impact.

FIGURES

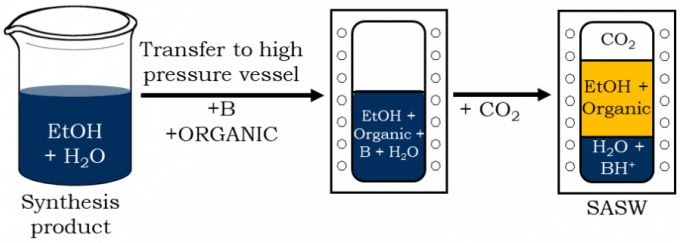

FIGURE 1

Solvent-assisted switchable water

A process in which ethanol is separated from water using a combination of high pressure of CO2, an switchable water base (B) and an extracting organic solvent (organic).

FIGURE 2

KEYWORDS

ethanol | carbon dioxide liquid expansion | phase separation | switchable water

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