

Optimal location of biorefineries considering sustainable integration with the environment



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ABSTRACT

A typical biorefining supply chain exerts substantial impact on the regional water resources. Indeed, a complex relationship exists between the production of biomass, the processing of biomass into fuels and chemicals, the usage of fresh water, and the discharge of wastewater. This paper introduces an optimization framework for the design of a biorefining system while accounting for the interactions with the surrounding watershed. Special attention is paid in the use of fresh water and the discharge of wastewater to the surrounded watershed. The optimization approach also accounts for the selection of feedstocks, location of cultivation sites and biomass processing facilities, and conversion technologies. Economic and environmental objectives are used. A case study for the central-west part of Mexico is presented. The results show that economic gains may be achieved while optimizing water usage and discharge and satisfying watershed constraints.

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1. Introduction

With the growing interest in sustainable development, it is necessary to consider the effective usage of renewable natural resources. In this context, biorefineries (see Fig. 1) offer attractive options for the conversion of biomass into fuels and chemicals and the reduction of greenhouse gas emissions through the sequestration of carbon dioxide during photosynthesis [1,2]. There are several challenges associated with viable operation of a biorefinery. Biomass availability is dependent on location and seasonal variability within these locations, there is needed to planning the optimal location of such facilities in a distributed framework [3,4]. The construction and operation of new and distributed biorefineries will inevitably increase the demand for biomass and expand the cultivation areas for the growth of the desired crops. In some regions, it is relatively straightforward to determine the lands to be used for cultivating the needed [5]. Nonetheless, in the more

general case, several factors must be considered and reconciled to determine the cultivation areas. Key factors include the type of bioresources to be cultivated, the available land, water resources, energy, infrastructure, and socio-economic aspects [6]. The location of the cultivations areas is intertwined with the location of end-use biorefineries. Several research contributions have been made in the area of site location for biorefining supply chains while accounting for the available biomass resources and the product (e.g., biofuel) demands. Bowling et al. [7], De Meyer et al. [8], Marvin et al. [9], Santibañez-Aguilar et al. [10] and Zhang et al. [11] developed methodologies for optimizing the facility location of biorefineries as part of designing the associated supply chain. Murillo-Alvadado et al. [12] and Yeh et al. [13] optimized supply chains for biorefineries using the available feedstocks and harvest management in a given location. Several works have considered environmental and economic aspects as objective function in optimizing supply chains of biorefineries (e.g., Osmani et al. [14], Santibañez-Aguilar et al. [15,16], You et al. [17]). These approaches have been expanded to include additional sustainability criteria (e.g., Ba et al. [18], Corsano et al. [19], Giarola et al. [20], Santibañez-Aguilar et al. [21]). Furthermore, Guillén-Gosálbez et al. [22], Kim et al. [23], Ruiz-Femenia et al. [24], and Tong et al. [25] incorporated approaches

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Densities and Viscosities for Binary Liquid Mixtures of *n*-Undecane + 1-Heptanol, 1-Octanol, 1-Nonanol, and 1-Decanol from 283.15 to 363.15 K at 0.1 MPa

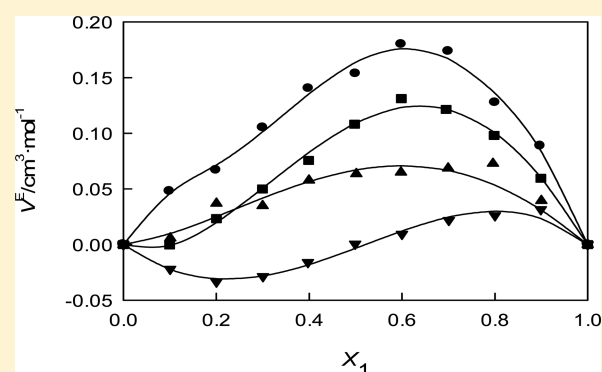
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ABSTRACT: This paper presents densities and viscosities of binary mixtures of *n*-undecane with 1-alcohols with carbon atoms from C₇ to C₁₀ from 283.15 to 363.15 K at 0.1 MPa. Densities are measured using a vibrating tube densimeter, while viscosities are from a pellet microviscometer. Excess molar volumes and viscosity deviations are calculated from the experimental data. The excess molar volumes present positive deviations for the binary mixtures with 1-heptanol, 1-octanol, and 1-nonanol. The excess molar volumes of *n*-undecane + 1-decanol present negative deviations at lower temperatures. The viscosity deviations show negative deviations from ideality over the entire temperature range. Also we present a correlation for the kinematic viscosity based upon the activation Gibbs energy.



1. INTRODUCTION

Densities and viscosities of mixtures are used in industrial applications of mass and heat transfer. Currently, the mixtures of *n*-alkanes + alcohol have been become relevant because of their applications as additives and solvents in the fuel and petrochemical industries.¹ This work is a continuation of our previous report of *n*-alkanes + 1-alcohols.^{2,3} Densities and viscosities of binary mixtures of *n*-undecane + 1-alcohols have been measured by Peleteiro et al.⁴ and Iglesias-Silva et al.³ Densities and viscosities with *n*-undecane + 1-heptanol, + 1-octanol, + 1-nonanol, and + 1-decanol do not exist in the literature.

This work reports the densities and viscosities for mixtures of *n*-undecane with 1-heptanol through 1-decanol at 0.1 MPa from 283.15 and 363.15 K over the entire composition range. A Redlich–Kister⁵ type equation has been used to correlate excess molar volume and viscosity deviations. The Nava-Rios et al.⁶ equation is used to correlate the experimental kinematic viscosities. This equation is a semitheoretical equation based upon the McAllister⁷ principles.

2. EXPERIMENTAL SECTION

Samples. The samples are from SAFC for *n*-undecane (99.4% in mass fraction), Fluka for 1-heptanol (99.98% in mass fraction), Aldrich for 1-octanol (99.54% in mass fraction), Fluka for 1-nonanol (99.3% in mass fraction), and Aldrich for 1-decanol (99% in mass fraction). Samples are prepared using an analytical balance (Ohaus model AS120S) with an accuracy of 0.1 mg. Substances are used as received and kept in airtight

Table 1. Sample Information

chemical name	source	CAS No.	initial purity mass fraction	purification method	analysis method ^a
<i>n</i> -undecane	SAFC	1120-21-4	0.994	none	GC
1-heptanol	Fluka	111-70-6	0.9998	none	GC
1-octanol	Aldrich	111-87-5	0.9954	none	GC
1-nonanol	Fluka	143-08-8	0.993	none	GC
1-decanol	Aldrich	112-30-1	0.99	none	GC

^aGas chromatography provided by the supplier.

containers. Table 1 shows the specifications for all of the substances. Mixtures are prepared using an analytical balance (Ohaus model AS120S) with an accuracy of 0.1 mg. We have a standard uncertainty in the mole fraction of less than 0.0002.

Apparatuses and Procedures. Densities are measured using a vibrating tube densimeter (Anton Paar, DMA 5000). Details of the densimeter have been reported previously.³ The densimeter has a stated reproducibility by the manufacturer of $1 \times 10^{-6} \text{ g}\cdot\text{cm}^{-3}$ for the density and 0.001 K for the temperature. The densimeter was calibrated by the manufacturer using two reference fluids: ultrapure water and dry air.⁸ The standard

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