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ORIGINAL RESEARCH PAPER

Optimal Planning for Sustainable Production of Avocado in Mexico

Joan Cristian González-Estudillo[1] · J. Betzabe González-Campos[2] · Fabricio Nápoles-Rivera[1] · José María Ponce-Ortega[1] · Mahmoud M. El-Halwagi[3,4]

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Abstract The global avocado market has increased significantly in recent years. The state of Michoacán in Mexico is one of the largest producers of avocado in the world. The ideal climatic conditions and favorable yields have spurred an interest in growing new orchards for enhancing avocado production. Such growth has a major impact on the environment due to the land use change and the substantial use of fresh water. Therefore, there is a need for an optimal strategic planning for the avocado production while accounting for the sustainable use of the available resources. This paper presents an optimization model for the optimal strategic planning of avocado production to satisfy the current and future demands while simultaneously accounting for the environmental impact (caused by land and water use) and economic factors. The proposed model is based on a new mathematical programming formulation. The results show that with proper planning, it is possible to satisfy the future demands for avocado while protecting the environment and achieving economic gains.

✉ José María Ponce-Ortega
jmponce@umich.mx

[1] Chemical Engineering Department, Universidad Michoacana de San Nicolás de Hidalgo, Edificio V1, Ciudad Universitaria, 58060 Morelia, Michoacán, Mexico

[2] Institute for Chemical and Biological Researches, Universidad Michoacana de San Nicolás de Hidalgo, Edificio B1, Ciudad Universitaria, 58030 Morelia, Michoacán, Mexico

[3] Chemical Engineering Department, Texas A&M University, College Station, TX 77843, USA

[4] Adjunct Faculty at the Chemical and Materials Engineering Department, King Abdulaziz University, Jeddah, Saudi Arabia

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Introduction

Recently, the global avocado market has dramatically increased to about 4 million tonnes annually (Schaffer et al. 2013). Mexico produces about 40% of the world's supply of avocado and the state of Michoacán, located in the west-central region of Mexico, supplies about 80% of Mexico's production making Michoacán the world's largest producer of avocado. The increasing demand for avocado and the attractive selling price have motivated the producers in Michoacán to increase avocado production (SIAP 2017). This cultivation increase poses a significant potential for environmental damage due to the land use change, the decrease in forest areas, the alteration of the flora and fauna in the region, the increased use of fresh water, the high use of agrochemicals, and the added infrastructure to access and transport the produced avocados (Chávez-León et al. 2008). Saenz-Reyes and Tapia-Vargas (2012) estimated that, in the period 1993–2000, 102,538.2 ha of forest and 322,613 ha of jungle changed their use to cultivate avocado and other crops.

With the continuous growth in demand, there is a critical need to develop strategic planning for the sustainable cultivation of avocado to satisfy the demands while addressing the environmental and resource challenges as well as the economic factors. Approaches from analogous fields of research may be adapted to aid in the sustainable planning of avocado production. Several optimization approaches have been developed for the optimal planning in different fields and for incorporating sustainability metrics in the optimization. For example, Murillo-Alvarado et al. (2013) reported an optimization approach that determines the optimal supply chain for

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In Focus: Biotechnology and chemical technology for biorefineries and biofuel production

This In Focus presents some of the research efforts that are being undertaken in the fields of biotechnology, biofuels, and biorefineries, by members of the National Research Council (CONACYT) Mexican Thematic Network on Bioenergy. The network addresses topics of science, technology, and innovation in bioenergy, biofuels, and biomaterials, to stimulate their sustainable large-scale use in Mexico.

Worldwide, fossil fuels currently continue to be the largest source of primary energy and feedstocks for the manufacture of chemicals. This dependence has caused adverse environmental, political, economic and social effects. Specifically, the problem of global climate change has reached such a magnitude that the governments of different countries have established strategies to implement an energy transition, building towards the elimination of fossils fuels at the end of the 21st century. In this energy transition, bioenergy can play a key role, since it is estimated that biomass (forest residues, municipal waste, livestock residues, industrial waste, agricultural residues, energy crops, and other biomass materials) has the potential to cover several fossil fuel applications in the fields of liquid, solid and gaseous fuels.

Also, biomaterials obtained from biomass can substitute the chemicals obtained from fossil fuels. This transition, including energy, feedstocks, and technologies, involves a paradigm shift: stop using fossil sources and instead use adequate biomasses, which, through different chemical techniques and biotechnologies, must be transformed into various bioproducts and types of bioenergy, such as pellets, briquettes, bioethanol, biodiesel, biogas, methane, biopetroleum, biohydrogen, and bioturbosine, among others.

This special In Focus issue contains eight manuscripts related to different topics of chemical technology and biotechnology in which the authors analyze the use of biomass for the production of biofuels and bioproducts. Three review articles address the concept of biorefinery, and five research manuscripts report the production of two of the most widely used biofuels in the world: bioethanol and biodiesel.

Romero-Cedillo et al.[1] reviewed the different pretreatments methods for lignocellulosic biomass, in particular, the organic fraction of municipal solid waste for the production of biomethane and biohydrogen within the context of a biorefinery. Choosing the best method is difficult because each pretreatment has its advantages and limitations. These authors also conclude that the environmental impacts of the different pretreatments should be evaluated by methodologies such as life cycle analysis, which must lead to objective conclusions and fair comparisons among processes and projects, and avoid partial comparisons based only on yields and productivities.

Escamilla-Alvarado et al.[2] reviewed the potential of using enzymes as biocatalysts for the transformation of biomass into biofuels and/or bioproducts with added value. They analyzed different configurations of biorefineries for the production of liquid and gaseous biofuels, as well as for the production of chemicals with added value.

Morales-Sanchez et al.[3] present a review on the production of bioproducts or metabolites from a source of biomass cultivated under heterotrophic (dark) conditions. They conclude that some microalgae can modify their metabolism and can grow heterotrophically; hence, it is possible to maximize both the oil content and their productivity for the production of biodiesel. Microalgae are becoming excellent raw materials for the production of bioproducts or metabolites in a biorefinery scheme, such as polyunsaturated fatty acids, pigments, antioxidants, polysaccharides, food, and aquaculture feed from carbon sources, such as glucose, acetate or glycerol.

The industrial production of any biofuel or bioproduct requires scale-up criteria to transfer the results obtained at the laboratory level to large volume bioreactors. In the Fernández-Sandoval et al. paper[5], the authors systematically studied and proposed the use of very low volumetric oxygen transfer coefficient ($k_L a$) values, as a scaling-up criterion for fermentative ethanol production with metabolically engineered ethanologenic *Escherichia coli* strains. Their results showed that the $k_L a$ is a suitable parameter for scaling-up, since the ethanol yields and productivities were similar for the different volumes of tested fermenters, from 0.75 up to 110 liters.

Huerta-Beristain et al.[6] genetically modified the metabolically engineered ethanologenic *E. coli* strain KO11 to channel the carbon flux trough the pentose phosphate and Entner-Doudoroff pathways. Key results demonstrate that it is feasible to obtain the same carbon flux from glucose to ethanol using these pathways as compared to the Embden–Meyerhof–Parnas pathway, which is mainly used by *E. coli* under fermentative conditions.

This In Focus issue includes two papers on biodiesel production. Firstly, Chavarria-Hernandez et al.[4] analyzed the potential biodiesel production in Mexico using residual animal fats, specifically beef cattle and fowl. They concluded that the reuse of these and other residual fats could contribute to the energy transition, committed to the elimination of fossils fuels, and also avoid the adverse effects of contamination and damage to health through inadequate disposal of residual fats and fowl. Navarro-Pineda et al.[7] developed an economic model for estimating the viability of biodiesel production from the plant *Jatropha curcas*. In this study, the net energy ratio was used as the criterion of analysis, considering the whole production chain: from the propagation of Jatropha up to the transformation process of the oil into biodiesel. However, the economic evaluation revealed a critical issue: that at the current conditions, biodiesel production from *J. curcas* is not economically viable.

OPTIMIZACIÓN DEL PROCESO DE ESTERIFICACIÓN DE ACEITES VEGETALES USADOS PARA LA PRODUCCIÓN DE BIODIESEL

OPTIMIZATION OF THE ESTERIFICATION PROCESS OF WASTE COOKING OILS FOR PRODUCING BIODIESEL

María F. Laborde[1,2], Medardo S. González[3], José M. Ponce[3], Ana M. Pagano[1], María C. Gely[1]
(1) Núcleo TECSE, Departamento de Ingeniería Química, Facultad de Ingeniería, Universidad Nacional del Centro de la Provincia de Buenos Aires (UNICEN), Av. Del Valle 5737, Olavarría, Buenos Aires - Argentina
(2) Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Av. Rivadavia 1917, Ciudad Autónoma de Buenos Aires - Argentina
(3) Universidad Michoacana de San Nicolás de Hidalgo (UMSNH), Gral. Francisco J. Múgica S/N, Ciudad Universitaria, Morelia, Michoacán - México
(e-mail: fernanda.laborde@fio.unicen.edu.ar)

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RESUMEN

Este trabajo describe la optimización del proceso de esterificación de aceites vegetales usados (AVUs) para la producción de biodiesel a partir de un análisis estructural mediante simulación. La optimización energética se determinó mediante una programación matemática, y posterior resolución mediante el software GAMS®. Se analizaron dos alternativas tecnológicas. La Alternativa 1 incluye el proceso de esterificación aplicando una torre de lavado a la salida del reactor, mientras que la Alternativa 2 aplica un decantador a la salida del reactor. Se determinó que la Alternativa 2 fue la mejor opción debido a que el costo de servicios totales anuales fue menor. Para la optimización energética del proceso seleccionado, se incorporó una bomba de calor entre las corrientes del condensador y del rehervidor de la torre de destilación y se diseñó una red de intercambio calórico entre las corrientes del proceso, esto permitiría un ahorro energético de servicios externos de 64,21%.

ABSTRACT

This paper describes the optimization of esterification of waste cooking oil (WCO) for the production of biodiesel from a structural analysis by means of simulation. The energetic optimization was determined through mathematical programming, and subsequent resolution using GAMS® software. Two technological alternatives were analyzed. Alternative 1 includes the esterification process applying a washing tower at the outlet of the reactor, while Alternative 2 applies a decanter at the outlet of the reactor. It was determined that Alternative 2 was the best option because the annual service cost was lower. For the energy optimization of the selected process, a heat pump was incorporated between the condenser and the reboiler of the distillation tower of product, and a heat exchange network between the process streams was designed, this would allow energy savings of external utilities of 64.21%.

Palabras clave: simulación, superestructura, GAMS, bomba de calor
Keywords: simulation, superstructure, GAMS, heat pump

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Optimal location of biorefineries considering sustainable integration with the environment

Dulce Celeste López-Díaz [a], Luis Fernando Lira-Barragán [a], Eusiel Rubio-Castro [b], José María Ponce-Ortega [a], Mahmoud M. El-Halwagi [c, d, *]

[a] Chemical Engineering Department, Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán, 58060, Mexico
[b] Chemical and Biological Sciences Department, Universidad Autonoma de Sinaloa, Culiacan, Sinaloa, 80000, Mexico
[c] Chemical Engineering Department, Texas A&M University, College Station, TX, 77843, USA
[d] Adjunct Faculty at the Chemical and Materials Engineering Department, King Abdulaziz University, Jeddah, 21589, Saudi Arabia

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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.

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

* Corresponding author. Chemical Engineering Department, Texas A&M University, College Station, TX, 77843, USA.
E-mail address: el-halwagi@tamu.edu (M.M. El-Halwagi).

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Research article

A multi-objective optimization approach for the selection of working fluids of geothermal facilities: Economic, environmental and social aspects

Juan Martínez-Gomez [a], Javier Peña-Lamas [b], Mariano Martín [b, *], José María Ponce-Ortega [a]

[a] Chemical Engineering Department, Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán, 58060, Mexico
[b] Department of Chemical Engineering, University of Salamanca, 37008, Salamanca, Spain

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A B S T R A C T

The selection of the working fluid for Organic Rankine Cycles has traditionally been addressed from systematic heuristic methods, which perform a characterization and prior selection considering mainly one objective, thus avoiding a selection considering simultaneously the objectives related to sustainability and safety. The objective of this work is to propose a methodology for the optimal selection of the working fluid for Organic Rankine Cycles. The model is presented as a multi-objective approach, which simultaneously considers the economic, environmental and safety aspects. The economic objective function considers the profit obtained by selling the energy produced. Safety was evaluated in terms of individual risk for each of the components of the Organic Rankine Cycles and it was formulated as a function of the operating conditions and hazardous properties of each working fluid. The environmental function is based on carbon dioxide emissions, considering carbon dioxide mitigation, emission due to the use of cooling water as well emissions due material release. The methodology was applied to the case of geothermal facilities to select the optimal working fluid although it can be extended to waste heat recovery. The results show that the hydrocarbons represent better solutions, thus among a list of 24 working fluids, toluene is selected as the best fluid.

1. Introduction

The use of renewable resources for energy production has been presented as a clean alternative to the use of fossil-based resources. Intensifying the use of natural resources has as main advantage the reduction of the environmental impact (Gunther and Hellmann, 2017), by reducing or mitigating the emission of pollutants (Wolf et al., 2016). Nowadays, the most used renewable resources are: Hydroelectric, wind, solar, bioenergy and geothermal. Of these, geothermal energy produces less than 1% of the world's energy consumed, despite its wide availability, which is of 43×10^6 EJ (World Energy Council, 2016). In the American continent, countries like USA and Mexico have potential reserves that have not yet been widely exploited (Gutierrez-Negrín and Lippmann, 2016). In Asia, Indonesia has a high reserve potential representing 40% of world reserves (Nasruddin et al., 2016), meanwhile China has been a pioneer in the use of its resources and today presents an installed capacity of 27.78 MWe (Zhu et al., 2015). The technologies used for the conversion of geothermal to electrical energy depend on the type of source. For sources of high enthalpy (>180 °C), steam is used directly to produce power (direct-steam, Phair, 2016). If the temperature is between 101 and 180 °C, the reservoir is referred to as medium enthalpy and in this case a binary cycle is used (Spadacini et al., 2016). The Organic Rankine Cycle (ORC) technology is often used as an interface in energy conversion from medium enthalpy sources to allow for an economic exploitation of these resources. Note that this technology is also used for the production of power from waste heat in general. However, the efficiency of the ORCs is currently still low and improving it depends mainly on the proper selection of the working fluid (Hung et al., 1997). The selection of the working fluid is a complicated task, because the list of candidates is large. Each fluid has different thermodynamic properties, which have a direct impact on the overall efficiency of the cycle, such is the case of molecular structure, which has a direct effect on

* Corresponding author.
E-mail address: mariano.m3@usal.es (M. Martín).

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Research Paper

Optimization of the production of syngas from shale gas with economic and safety considerations

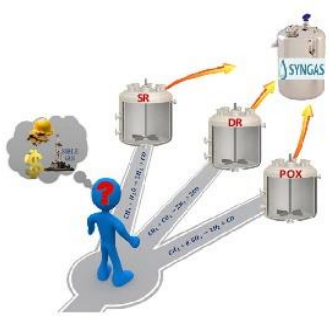
Juan Martinez-Gomez [a], Fabricio Nápoles-Rivera [a], José María Ponce-Ortega [a,*], Mahmoud M. El-Halwagi [b,c]

[a] Chemical Engineering Department, Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán 58060, Mexico
[b] Chemical Engineering Department, Texas A&M University, College Station, TX 77843, USA
[c] Adjunct Faculty at the Chemical and Materials Engineering Department, Faculty of Engineering, King Abdulaziz University, P.O. Box 80204, Jeddah 21589, Saudi Arabia

HIGHLIGHTS

- An optimization approach is presented for the production of syngas from shale gas.
- Economic and safety issues are considered.
- A solution approach that links ASPEN PLUS, MATLAB and SCRI has been implemented.
- A case study is presented to show the applicability of the proposed approach.

GRAPHICAL ABSTRACT



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ABSTRACT

Reforming is an essential technology for the monetization of shale gas through the production of syngas. Steam reforming, partial oxidation, dry reforming, or combined reforming may be used. Traditionally, H_2:CO ratio, yield or economic criteria have been used to select the type of reforming technology. The operating conditions, the nature of the reactions and compounds produced in the reforming technologies create the necessity to know the level of risk presented by these technologies. Thus, this paper introduces an approach for the optimal selection and design of reforming technologies incorporating economic aspects. A quantitative risk analysis is applied to the obtained solutions for evaluating the risk. The approach optimally selects the technology or set of technologies and operating conditions required to comply with a specific quality of syngas, maximizing the net profit. The optimization model was solved using genetic algorithms in the MATLAB® platform coupled with the ASPEN Plus® software for process and thermodynamic modeling. The results show that the steam reforming is the best technology to reach the highest quality of syngas with the lowest risk for the simulated conditions.

1. Introduction

Recently, shale gas production has drastically increased from an average growth of 2.7% per year from 1995 to 2000 to 47.9% per year from 2005 to 2011 [1]. With the continued growth, shale gas is estimated to provide up to 50% of the production of natural gas for 2040 [2]. This tendency is expected to continue because of the increasing demands for energy and feedstocks for chemical manufacturing [3]. Specifically, the interest in shale gas is attributed to technical, environmental, and economic benefits compared with other forms of fossil fuels [4]. Since shale gas can be converted into a multitude of value-added chemicals, it is anticipated to reshape the process industries in the US and around the world

* Corresponding author.
E-mail address: jmponce@umich.mx (J.M. Ponce-Ortega).

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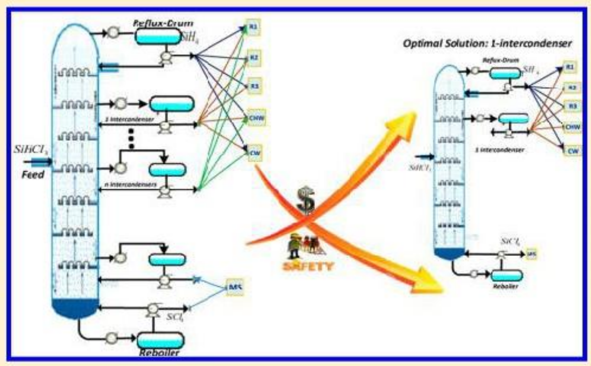
Intensification for the Silane Production Involving Economic and Safety Objectives

Juan Martinez-Gomez,[†] César Ramírez-Márquez,[‡] J. Rafael Alcántara-Ávila,[§] Juan Gabriel Segovia-Hernández,[‡] and José María Ponce-Ortega*,[†]

[†]Chemical Engineering Department, Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán 58060, México
[‡]Chemical Engineering Department, Universidad de Guanajuato, Noria Alta s/n, Guanajuato, Guanajuato 36050, México
[§]Department of Applied Chemistry, Graduate School of Science and Technology, Tokushima University, 2-1 minami Josanjima-cho, Tokushima 770-8506, Japan

ABSTRACT: The use of conventional reactive distillation columns for silane production has the disadvantage of large consumption of refrigerant because the silane is produced in the dome of the column and this must be condensed at about −78 °C. The incorporation of intercondensers may improve the cost and safety of the system; however, a proper study for the system is needed to determine the associated effects. Therefore, in this paper is presented an optimization approach for the silane production accounting simultaneously for economic and safety issues incorporating intercondensers. The presented approach is based on a software link between Microsoft Excel (for implementing the optimization algorithm based on differential evolution), Aspen Plus (for simulating the process), and SCRI (for quantifying the associated risk). The results show that the addition of intercondensers minimizes the total annual cost, because the amount of needed refrigerant is reduced. The safety analysis also shows that the use of intercondensers improves the risk of the system.



1. INTRODUCTION

Nowadays the energy demands have been satisfied through fossil and nuclear fuels; however, the intensive use of these resources has damaged significantly the environment. Furthermore, the enormous population growth has increased the energy demand, which cannot be satisfied with only fossil resources to yield a sustainable process. This way, several renewable energy resources have arisen to currently represent 22.1% of global energy.[1] In this context, solar energy has gained a lot of attention because of the availability of this resource[2] as well as the improvement for the solar technologies.[3] The use of photovoltaic cells has been one of the most used technologies for concentrating solar energy. These systems are made of cells that have a covering of silicon (i.e., silane).[4,5] The research has focused on finding the optimal technologies for the production of silane. The most widely used process for the production of silane is the Siemens process; this has as its main disadvantage excessive energy consumption.[6] Reactive distillation (RD) has become an important option for the production of silane;[7] this alternative represents energy savings and the associated cost is reduced, because in the conventional process the use of a reaction-separation system is required whereas the RD process only requires the use of a single vessel.[8] The reduction of number of process units decreases the needed substances that present a hazard to cause accidents related to fire, explosion and toxic release. Minimizing inventories depicts an inherent safety strategy; this is also called process intensification. RD represents a clear example of this strategy. To simplify, substitution and moderation are other strategies that use inherent safety to reduce or eliminate the hazard. The simplification improves the process design, avoiding unnecessary complexity and reducing the opportunity to present errors.[9,10] Substitution refers to replacing hazardous substances to provide a lower risk.[11] Finally, moderation refers to the use of substances under conditions that prevent a high hazard;[12] an example is the use of diluted substances, low temperatures, and low pressures. When a conventional process is modified, it is necessary to know the involved risk through the implementation of an inherent safety approach. In this case, the addition of intercondensers in a reactive distillation column for the production of silane is a modification to the conventional process that may help to decrease the cost;[13,14] however, we also need to know the effect of this modification in the associated risk. The existing methodologies do not consider the effect of this change in risk, these only assess the economic

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Involving economic, environmental and safety issues in the optimal purification of biobutanol

Juan Martinez-Gomez[a], *Eduardo Sánchez-Ramírez*[b], *Juan José Quiroz-Ramírez*[b], *Juan Gabriel Segovia-Hernandez*[b], *José María Ponce-Ortega*[a], *Mahmoud M. El-Halwagi*[c,d,*]

[a] *Chemical Engineering Department, Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Mich 58060, Mexico*
[b] *Chemical Engineering Department, Universidad de Guanajuato, Noria Alta s/n, Guanajuato, Gto. 36050, Mexico*
[c] *Chemical Engineering Department, Texas A&M University, College Station, TX 77843, USA*
[d] *Adjunct Faculty at the Chemical and Materials Engineering Department, Faculty of Engineering, King Abdulaziz University, Jeddah 21589, P.O. Box 80204, Saudi Arabia*

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A B S T R A C T

Traditionally, the design of a separation sequence for the biobutanol production has been based primarily on economic criteria with little or no consideration to the environmental and safety issues. Since biobutanol is produced from acetone–butanol–ethanol (ABE) fermentation, the process involves several substances that may cause fire and explosion and can lead to negative environmental and health impact. Hence, it is desirable to incorporate safety and environmental issues in the design objectives to determine the optimal separation route. This work presents an optimization approach for the biobutanol separation process from the *ABE* fermentation while accounting simultaneously for economic, environmental and safety objectives. The optimization is carried out through a differential evolution with a Tabu search algorithm, where several Pareto solutions are identified and some routes are highlighted to determine the best compensated solutions. In this case, the best economic solution involves elevated values of the *Eco-Indicator 99*, the best environmental solution incurs high costs, and the safest solution features less separation columns. The most compensated solutions include configurations that represent a balance among the economic, environmental and safety objectives.

1. Introduction

Biofuels are positioned to play an important role in the energy mix because of their ability to reduce CO_2 emissions. Although the search for renewable and sustainable biofuel additives that can be blended with gasoline has focused largely on bioethanol, there are merits for considering biobutanol. For instance, the energy density of bio-isobutanol is 26.5 MJ/l while for bioethanol it is 21.1 MJ/l). It should be noted that 8.27 billion of gallons/year of biobutanol can replace 7.55 billion of gallons/yr of gasoline (see Swanaa et al., 2011). In addition, biobutanol has desirable properties for use in internal combustion engines including lower corrosion, flammability and water miscibility compared with bioethanol. While much work has been reported for the design, environmental assessment, and safety enhancement for methanol (e.g., Ehlinger et al., 2014; Julián-Durán et al., 2014) and ethanol (Murillo-Alvarado et al., 2014; Conde-Mejía et al., 2013, 2012;

* Corresponding author at: Chemical Engineering Department, Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Mich, 58060, Mexico.
E-mail address: el-halwagi@tamu.edu (M.M. El-Halwagi).
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