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Environmental and economic feasibility study of flocculation process as a treatment of wastewater in ethanol production

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Abstract

Bio-based fuels are the most promising and ecological alternatives to fossil fuels. Sustainable technologies are being developed and applied to biofuel production in order to minimize the costs and the environmental impacts of the system. Wastes produced from ethanol plant have been concerned ethanol producers and environmental protectors due to the negative environmental impacts caused. Challenges are presented on the treatment of wastewater from an ethanol biorefinery. Therefore, the aim of this study was to investigate the feasibility of flocculation process as a treatment for wastewater in substitution of the evaporation process in an ethanol plant by analyzing the Life Cycle Assessment (LCA) and Techno-Economic Assessment (TEA).

Keywords

Bioethanol, Wastewater, Life Cycle Assessment, Techno-Economic Assessment

Disciplines

Agriculture | Bioresource and Agricultural Engineering

Comments

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ABSTRACT. *Bio-based fuels are the most promising and ecological alternatives to fossil fuels. Sustainable technologies are being developed and applied to biofuel production in order to minimize the costs and the environmental impacts of the system. Wastes produced from ethanol plant have been concerned ethanol producers and environmental protectors due to the negative environmental impacts caused. Challenges are presented on the treatment of wastewater from an ethanol biorefinery. Therefore, the aim of this study was to investigate the feasibility of flocculation process as a treatment for wastewater in substitution of the evaporation process in an ethanol plant by analyzing the Life Cycle Assessment (LCA) and Techno-Economic Assessment (TEA).*

Keywords. *Bioethanol, Wastewater, Life Cycle Assessment, Techno-Economic Assessment*

INTRODUCTION

Wastewater treatment is an existent concern in the ethanol production. Many kinds of treatments are being used and tested in order to achieve the minimum cost for wastewater treatment, and consequently, mitigate the environmental impacts. Thus, in this process, more effective and successful management strategies, which involve applications of innovative treatment technologies as being more environmentally benign, need to be applied (Aydiner et al., 2014).

Large amounts of wastewater are produced from corn ethanol plant. For each liter of ethanol produced using corn, about 13 L of wastewater are produced, having a biological oxygen demand (BOD) of 18,000–37,000 mg/L depending on the type of plant (Pimentel and Patzek, 2005). Wastewater is normally compounded by solids not recovered as primary product or coproducts. Treated wastewater from most food processes contain protein, vitamins and minerals which can be a potential food sources to animals. The no treatment of wastewater can reflect in lost product or coproduct (Singh et al., 2001). Mechanical removal of suspended particles, anaerobic treatment, aerobic treatment and recycling are some ways that can be used in order to reduce the amount of organic pollutants in wastewater (Goldemberg et al., 2008). In cellulosic biorefinery waste stream, Baral et al. (2016) affirmed that lignin is the main constituent of the remains in the waste stream, in addition of 15 L of process water per liter of ethanol produced. In a research done by Trinh et al. (2013), it was found that 79 wt % of lignin, 8.3 wt % cellulose, and 3.6 wt % hemicellulose constitute the remains. The wastewater also contains unutilized fermentable sugars and process chemicals, in addition to solid fractions, forming the stillage (Baral et al., 2016).

Due to the high energy consumption in the evaporation process in ethanol production, the flocculation process can be an alternative of wastewater treatment for minimizing the energy consumption and consequently the environmental impacts. In most cases, chemical flocculants are used in wastewater treatment plant. Nevertheless, it can produce a negative impact on the environmental and health. However, bioflocculants can replace chemical flocculants by being biodegradable and less harmful to the environment (Nguyen et al., 2016). The bioflocculants can be produced by microorganisms such as bacteria and fungus, or they can be extracted from natural resources, for instance, trees (Hameed et al., 2016).

Therefore, this work aims to investigate the life cycle assessment (LCA) and techno-economic analysis of flocculation process as a treatment of wastewater in ethanol production.

METHODOLOGY

For developing the life cycle assessment (LCA) and techno-economic analysis (TEA) from a corn-based ethanol plant, the evaporation process was substituted by flocculation in order to minimize the energy consumption and consequently the environmental impacts (Figure 01).

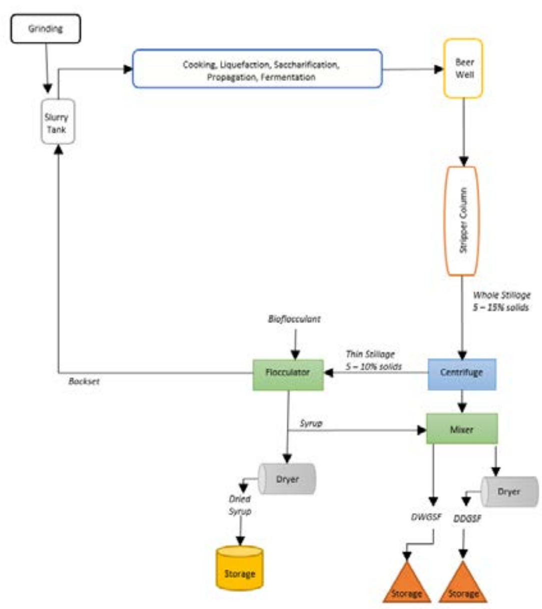

Figure 01. Flow chart of a corn-based ethanol plant utilized for investigate LCA and TEA considering the flocculation process for wastewater.

By using computer software, some assumptions related to coproducts composition need to be supposed. So, the inputs and outputs of a process can be estimated through process simulation. The life cycle assessment (LCA) was determined by using Sustainable Minds software, and the techno-economic analysis was obtained by using Excel software.

Goal and scope definition: The goal for this LCA was to investigate the environmental impacts by applying the flocculation process instead of evaporation. Thus, for analyzing the environmental impacts, greenhouse gases were investigated. This study analyzed gate-to-gate environmental impacts of producing corn-based ethanol coproducts. The studied system includes the whole stillage from distillation to coproducts from ethanol production using dry milling technology associated with flocculation technology.

Functional unit: The functional units utilized were GWP/yr/ton of DDGSF (Dried distillers grains with solubles from flocculation), GWP/yr/ton of DWGSF (wet distillers grains with solubles from flocculation), and GWP/yr/ton of Dried Syrup Solubles production for the greenhouse gas emissions.

Life cycle inventory: The inventory data in this study includes energy consumptions of equipment used on coproducts processing, handling and storage by doing some assumptions related to compositions of coproducts.

Assumptions: Assuming that the input on the system is equal to 2000 ton per day, the plant works 10 hours per day during 200 days per year. It was assumed that the whole stillage contained 15% solids and the thin stillage contained 10% solids. The bioflocculator used was chicken blood (C.B.) which is composed by 80% moisture and 20% dry matter. Assuming that is required 250 mg of C.B. for 1 g of dry matter, for 1000 ton of thin stillage (T.S.) into the flocculation is necessary 25 ton of C.B.

Impact assessment: In this study, the life cycle assessment was conducted by using the Sustainable Minds software. However, in several studies, the life cycle assessment is conducted using the SimaPro software, which is developed by Pre Consultants according to ISO 14044 standard procedures (Lu et al., 2016).

RESULTS AND DISCUSSIONS

The total amount of coproducts (dried syrup solubles, wet distillers grains with solubles from flocculation (DWGSF), and distillers grains with solubles from flocculation (DDGSF), can be observed on Table 1.

Table 1. Total coproducts produced from ethanol plant with flocculation

Coproduct	Mass (ton/day)
Dried Syrup Solubles Storage	78.31
DWGSF Storage	416.00
DDGSF Storage	229.20

By utilizing flocculation instead evaporation process, the coproduct that had the highest production was wet distillers grains with solubles from flocculation (DWGSF), and the lowest production was the total mass of dried syrup solubles. In the modeling, the total amount of outflow going into the slurry tank was equal to 878.10 ton/day.

Using Sustainable Minds, the total greenhouse gas (GHG) produced was equal to 204,027,363.45 GWP/yr/ton, considering the overall process. Analyzing the amount of greenhouse gas for each coproduct, for Dried Syrup Solubles Storage the GHG was equal to 13,026.90 GWP/yr/ton, for Wet Distillers Grains with Solubles from Flocculation the GHG was equal to 2,452.25 GWP/yr/ton, and for Distillers Grains with Solubles from Flocculation the GHG was equal to 4,450.86 GWP/yr/ton. The less amount of product generated higher value of greenhouse gas per year.

In Table 2, the values of TEA by analyzing the mass of coproducts and each operational unit, can be seen.

Table 2. TEA values considering coproducts and operational unit

Coproduct	Mass (ton/yr)	$/year/ton coproduct	Operational Unit	$/yr/ton coproduct
Dried Syrup Storage	15662.00	-$5,057.29	Centrifuge	-$7,737.20
DWGSF Storage	83200.00	-$952.01	Mixer	-$2,679.92
DDGSF Storage	45840.00	-$1,727.91	Dryer 1	-$1,727.91
Total mass of coproducts	144702.00	-$547.38	Dryer 2	-$5,057.29
			Flocculator	-$5,057.29
			Overall process	-$22,259.60

For the TEA was obtained a value equal to 22,259.60 $/yr/ton coproduct considering the all operational unit in overall process. The value for Flocculator was equal to 5,057.29 $/yr/ton coproduct it can be related to the amount of coproduct that is produced from flocculation process. It was obtained value equal to 547.38 $/yr/ton coproduct considering the total amount of coproducts produced from the ethanol plant.

CONCLUSION

The process of flocculation used in ethanol plant as a substitute of evaporation process seems a good option for minimizing the amount of energy used during ethanol production and consequently the greenhouse gas emission. However, research related to it needs to be more deeply studied, in order to quantify the real amount of coproducts as well as the environmental impacts.

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