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Thermal integration of natural gas combined cycle power plants with CO_2 capture systems and organic Rankine cycles

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Keywords:
NGCC power plant
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Thermal integration
Organic Rankine cycle
Global warming potential

ABSTRACT

In this paper, the thermal integration of a natural gas combined cycle (NGCC) power plant integrated with post-combustion carbon capture (PCC) and CO_2 compression is proposed. With the objective of finding a heat exchanger network (HEN) that decrease the energy impact of the PCC process, which reduce the power output of the turbines as it requires a large amount of steam for its operation and it uses part of the power generated by the NGCC power plant. Also, the possibility of implementing an Organic Rankine Cycle (ORC) to generate electricity with the wasted energy of the process is analyzed. This study consists of a 453 MW_e NGCC power plant with an MEA-based PCC process, and the option to consider a fixed 260 kW_e ORC or an ORC with variable power output, which are simulated in ASPEN PLUS® to obtain all the process inventories. Then the thermal integration is performed using the SYNHEAT model. Result show that the proposed HENs can reduce the use of steam in the striper reboiler to 65.43 Kg/s and it can also reduce the use of hot water to heat the input of natural gas producing a 126.571 MWe power output of the steam turbines increasing the thermal efficiency to 50.94% whereas the implementation of the ORC can increase the power output up to 1.651 MW_e using the wasted energy of the plant and also the global warming potential (GWP) decrease 78% due to the reduction in CO_2 emission and the generation of more power in comparison with the stand alone NGCC.

1. Introduction

Currently world population growth and the widespread use of technology, demand an increase in the use of energy which is produced mostly by processes that use fossil fuels for its operation (power plants, combined cycles, coal-fired power plants and dual plants, etc.). These different processes of power generation produce a large amount of greenhouse gas emissions, which make power generation from fossil fuel fired power plants the largest single source of CO_2 emissions in the world [1]. NGCC power plants produce around half the emissions than coal-fired power plants, however even if coal consumption is replaced with natural gas, the reduction would not be enough to achieve the global emission targets set in international agreements [2]. Thus, it becomes necessary to search sustainable alternatives to cope with the world energy demands and at the same time to help reduce the impact in the ecosystem (by reducing the greenhouse gas emissions). Among the alternatives that can be found to reduce the greenhouse gas emissions, coupling power cycles with CO_2 capture and compression systems has been proposed, where the capture with amines is one of the most studied process, in which it has been analyzed the advantages and disadvantages of using different types of amines [3], in aqueous mixtures [4] coupled with NGCC power plants [5] and also with coal fired power plants [6], actually a number of pilot-plants around the world are in operation proving the applicability and operability of various capture technologies [7], however the main limitation for the implementation of these technologies is the detrimental impact of the PCC processes in the net efficiency of the NGCC power plants with a reduction which some authors have estimated around 8% [8] with up to 11% reduction in the power output due to the extraction of LP steam of the NGCC for the regeneration of the absorbent and also due to the energy requirements of the CO_2 compression train[9].

Other studies have been done in this matter such as the analysis of O_2/CO_2 cycles for CO_2 capture [10], thermodynamic analysis [11], and the use of different capture technologies with power cogeneration [12], with the objective to find a sustainable way to improve thermal efficiency with a high CO_2 recovery in the PCC process. However, there are other alternatives that must be studied to make these processes profitable and reduce the greenhouse gas emissions that might help to achieve the target of limiting average global temperature increase to 2 °C in 2050 [13]. These alternatives are the mass integration, thermal integration and use of thermodynamic cycles for power generation using low grade heat. For example in the mass integration field it has

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ORIGINAL PAPER

Mathematical optimization of a supply chain for the production of fuel pellets from residual biomass

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Abstract One of the main concerns of humankind in the last years is the availability of energy sources. Research has been focused on finding clean and renewable ways to satisfy the energy demand worldwide. In the particular case of the state of Guanajuato, Mexico, clay industry burns each year about 15,000 m^3 of fuel oil and residual oils, and 96,000 t of wood derivatives. As a way to reduce the environmental impact of clay industry, the use of solid fuel pellets, obtained from vegetable residual material, is proposed. The raw material for the pellets is obtained from agribusiness and from the cities of the state. The solid biofuel has high density, low content of humidity, a homogeneous shape and high energy density. Nevertheless, special care must be taken about the location of the production facility and hubs, in order to make the production of the biofuel economically feasible. Furthermore, to have an environmentally friendly fuel, the supply chain and the production process must minimize the global environmental impact. In this work, a mathematical programming model is proposed to determinate the optimal location of the production facilities, the hubs, and the best distribution logistics. The problem is modelled using a general disjunctive programming approach, and then relaxed into a mixed-integer non-linear programming (MINLP) problem. It has been determined that the main plant should be located in the city of Irapuato, while secondary plants must be established in the cities of León, Irapuato, Abasolo and Salamanca. Moreover, it has been estimated that, when the residual biomass is converted into pellets, about 72,548 t/year of equivalent CO_2 are avoided in the main plant, together with 24,182 of equivalent CO_2 avoided per secondary facility.

Keywords Solid biofuel · Pellet · Supply chain optimization · Mathematical programming

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List of symbols

Variables

$Absorbed_w$ [t $year^{-1}$]	Carbon dioxide absorbed by trees
$Cost_{RM}$ [USD]	Cost of raw material
$Cost_{TRANS}$ [USD]	Cost of transport of raw material
$Cost_{PROC}$ [USD]	Cost of processing raw material
C_C [USD $year^{-1}$]	Capital cost
C_{OP} [USD $year^{-1}$]	Operational cost
G_P [kg h^{-1}]	Production rate
C_{eq} [USD]	Cost of equipment
$CO_{2,\ Base}$ [t $year^{-1}$]	Emissions of carbon dioxide for the base case
$CO_{2,\ scenario}$ [t $year^{-1}$]	Emissions of carbon dioxide when using pellets

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Autohydrolysis pretreatment assessment in ethanol production from agave bagasse

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HIGHLIGHTS

- Autohydrolysis pretreatment was applied to *Agave tequilana* bagasse.
- Total xylan removal was achieved at severity factors higher than 4.12.
- Enzymatic hydrolysis was carried out using a high solid load (25% w/w).
- 81% of total glucan content was hydrolyzed.
- 12 kg of ethanol per 100 kg of raw material in dry weight base were obtained.

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ABSTRACT

The aim of the present work was to assess the autohydrolysis pretreatment of *Agave tequilana* bagasse for ethanol production. The pretreatment was conducted using a one-liter high pressure Parr reactor under different severity factors (SF) at a 1:6 w/v ratio (solid:liquid) and 200 rpm. The solids obtained under the selected autohydrolysis conditions were subjected to enzymatic hydrolysis with a commercial cellulase cocktail, and the enzymatic hydrolysate was fermented using *Saccharomyces cerevisiae*. The results obtained from the pretreatment process showed that the glucan content in the pretreated solid was mostly preserved, and an increase in the digestibility was observed for the case with a SF of 4.13 (190 °C, 30 min). Enzymatic hydrolysis of the pretreated solids showed a yield of 74.3%, with a glucose concentration of 126 g/L, resulting in 65.26 g/L of ethanol after 10 h of fermentation, which represent a 98.4% conversion according to the theoretical ethanol yield value.

1. Introduction

The future depletion of fossil fuels and the environmental problems associated with their use have boosted the search for renewable energy sources. Recent studies have focused on the biorefinery concept, looking for sustainable production of a variety of fuels, chemicals and materials from biomass. Worldwide, many governments consider biofuels as a strategic alternative to reduce both the dependence on non-renewable resources and greenhouse gas (GHG) emissions. Commercial biofuels are already a reality in several countries. For example, in Brazil and the USA first generation bioethanol is produced on a large scale from sugarcane and corn-starch, respectively. However, the production of biofuels from feedstocks suitable as food or feed entails a number of undesirable consequences in several countries, particularly a shortage of supply and the concomitant increase in price of basic foods (Buruiana et al., 2014).

To avoid food security issues, lignocellulosic materials (LCM) are more suitable feedstocks in bioethanol production than starchy materials or sucrose that can be used as food or feed. Due to the complex plant cell wall structures in LCM, various physical and chemical pretreatment methods, including steam explosion, ammonium fiber expansion, dilute acid, lime, and organic solvent pretreatments, have been shown to be capable of decreasing the recalcitrance of biomass to subsequent enzymatic saccharification in order to obtain biofuels or high value added products (Vargas-Tah et al., 2015). The delignification alone sometimes may not be

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An optimization approach for the sustainable water management at macroscopic level accounting for the surrounding watershed

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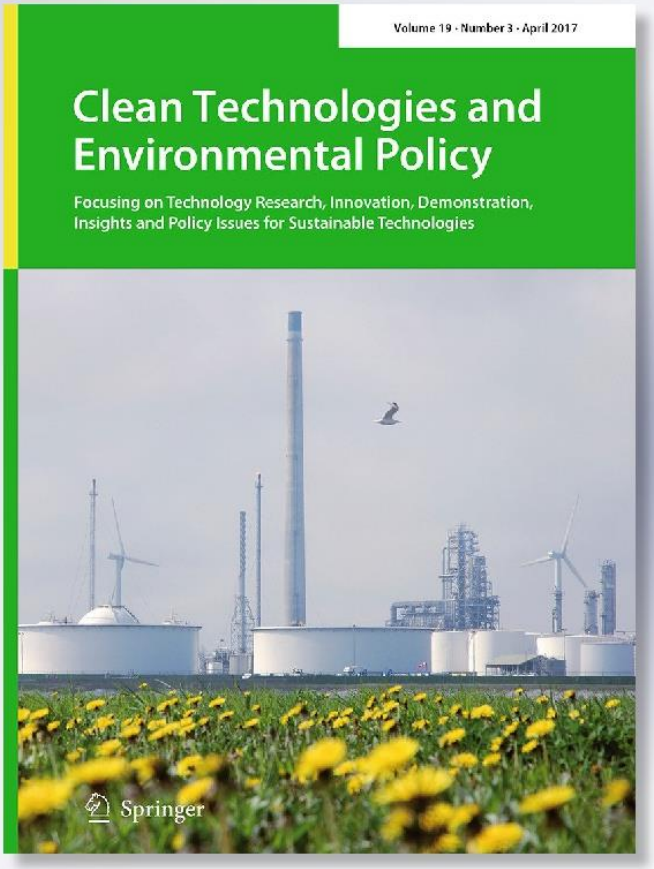

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ORIGINAL ARTICLE

Characterization of ligninolytic enzyme production in white-rot wild fungal strains suitable for kraft pulp bleaching

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Abstract Fungal strains identified by phylogenetic analysis of the ITS rDNA region as *Trametes versicolor* (CMU-TA01), *Irpex lacteus* (CMU-84/13), and *Phlebiopsis* sp. (CMU-47/13) are able to grow on and bleach kraft pulp (KP) in a simple solid-state fermentation (SSF) assay conducted in Petri dishes. Kappa number reductions obtained with *Phlebiopsis* sp. (48.3%), *T. versicolor* (43%), and *I. lacteus* (39.3%), evidence their capability for lignin breakdown. Scanning electron microscopy images of KP fibers from SSF assays demonstrated increased roughness and striation, evidencing significant cell wall modification. *T. versicolor* produces laccase (Lac), manganese peroxidase (MnP), and lignin peroxidase (LiP) in potato dextrose broth (PDB), PDB + $CuSO_4$, and PDB + KP, whereas *Phlebiopsis* sp. and *I. lacteus* showed no Lac and low LiP activities in all media. Compared to PDB, the highest increase in Lac (7.25-fold) and MnP (2.37-fold) activities in PDB + $CuSO_4$ occur in *T. versicolor*; for LiP, the greatest changes (6.95-fold) were observed in *I. lacteus*. Incubation in PDB + KP shows significant increases in Lac and MnP for *T. versicolor*, MnP and LiP for *Phlebiopsis* sp., and none for *I. lacteus*. SSF assays in Petri plates are a valuable tool to select fungi that are able to delignify KP. Here, delignification by *Phlebiopsis* sp. of this substrate is reported for the first time, and MnP activity was strongly associated with the delignification ability of the studied strains. The obtained results suggest that the studied fungal strains have biotechnological potential for use in the paper industry.

Keywords White-rot fungi · Ligninolytic enzymes · Kraft pulp bleaching · *Trametes* · *Phlebiopsis* · *Irpex*

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Introduction

Biotechnology applied to pulping and bleaching in the paper industry has been developed to reduce the environmental impact of these processes, while maintaining high pulp quality (Martín-Sampedro et al. 2015; Kumar et al. 2016). In particular, stages involving oxidative fungal enzymes laccase (Lac), Mn peroxidase (MnP), and lignin peroxidase (LiP) have shown promising results for pulp bleaching (Bajpai 2012; Upadhyay et al. 2016). This biotechnological approach is currently being used with excellent results in pulp and paper at mill-scale production (Bajpai 2012). The use of microbial lignocellulolytic enzymes may enhance the bleaching effect of chemical reagents, resulting in reduced consumption and lower amounts of required energy (Bajpai 2012; Martín-Sampedro et al. 2015). Extracellular oxidative enzymes that degrade lignin are produced by bacteria and fungi (Hatakka and Hammel 2011; Cragg et al. 2015), and have been studied for their use in pulping and bleaching (Bajpai

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Control properties of hybrid distillation processes for the separation of biobutanol

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Abstract

BACKGROUND: Butanol produced from fermentation has attracted the interest of research groups because its physicochemical properties show several enhancements over bioethanol. Recent studies have proposed alternative methods to separate and purify biobutanol from a fermentation broth. These alternatives offer energy and economic savings; in addition, a reduction in environmental impact is observed. However few studies have analyzed the control properties of the process which involves separation of an acetone–butanol–ethanol (ABE) mixture.

RESULTS: A controllability analysis using the singular value decomposition technique and a closed-loop dynamic analysis was performed on several hybrid distillation processes including conventional, thermally coupled, thermodynamically equivalent and intensified designs. The results indicated that under the closed-loop control policy, an intensified design which is integrated for only two distillation columns instead of three distillation columns, showed good dynamic properties. In addition, thermally coupled sequence A showed better control properties under open-loop analysis.

CONCLUSIONS: Using both SVD analysis and closed-loop tests the dynamics properties were obtained for several hybrid processes to separate an effluent produced by fermentation. It was possible to control all schemes under both methodologies and it was clear that when the base case became more complex with thermal coupling, section movement or elimination of a column section improved the control properties.

Keywords: control properties; thermal couplings; ABE fermentation; biobutanol

INTRODUCTION

At the end of the Second World War in 1945, nearly 66% of butanol consumed was produced by fermentation through ABE (acetone–butanol–ethanol) fermentation. After this, butanol production was completely supplied by the petrochemical industry through the oxo process. However, the necessity for renewable energy sources, the volatility in crude oil prices, environmental pollution and greenhouse gas emissions have become major issues.

Over the last two decades, society and research groups have focused their efforts on exploring options that could either replace or be blended with petroleum fuels. Among several biofuels, biobutanol has shown properties such as energy density (27.8 MJ L^{-1}), a low vapor pressure at ambient temperature (5.6 hPa) and a higher flash point (35 °C).[1] Furthermore, engine modifications are unnecessary to completely replace fossil fuels with biobutanol.[1] Currently, biobutanol produced from fermentation broth is attracting the attention of research groups due to its potential for reducing the dependence on crude oil as a main energy source. Nevertheless, the main hurdle with biobutanol fermentation is the use of dilute sugar solutions, because of the toxicity/inhibition to the culture and the highly demanding energy process for separating and purifying the biobutanol produced from fermentation broth.[2] Under this scenario, a solution to these issues could lead to the use of engineering techniques in fermentation cultures. Furthermore, the recovery technique should show high selectivity and high energy savings.[3] To separate the ABE mixture, several operations have been proposed; some do not show promising results because the presence of two azeotropes renders the ABE mixture difficult to handle, i.e. some adsorbent materials have been tested with poor results in industrial applications.[4] Gas stripping is the usual technique applied to processes where low yields are present.[3] When the distillation process is considered, several hurdles must be overcome. Errico *et al.*[5] presented several

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Research Article

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Sustainable Optimization of Food Networks in Disenfranchised Communities

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ABSTRACT: With the growing concerns about food security around the world, there is a need to develop sustainable strategies and proactive measures especially in developing countries with disenfranchised communities. These strategies must account for the specific nature and resources of each community and should be integrated with the need for economic growth. This work presents a conceptual framework and a mathematical programming model for the strategic planning of a sustainable food assistance program to satisfy the nutritional needs of disenfranchised communities while taking into account the objective of economic growth and the constraints of local resources. A case study from Mexico is presented as an example of applying the proposed approach. Fourteen municipalities with the lowest human development index are considered. The results show that it is possible to satisfy the nutritional needs while simultaneously improving the local economy of these disenfranchised communities.

KEYWORDS: *Suitable nutrition, Social development, Food networks, Strategic planning*

INTRODUCTION

The deficiency in providing sufficient needs of nutrients for impoverished communities is a problem that is closely related to food supply security and economic disenfranchisement. Around the world, 159 million children under the age of five suffer from nutritional stunting, whereas 50 million children of the same age group have low weight compared to their normal-weight counterparts.[1] In 2016, the Food and Agriculture Organization reported that 795 million people worldwide are undernourished and 98% of them are in developing regions (see Figure 1 for regional distribution). Therefore, governments around the world have applied actions to mitigate this problem by mainly focusing on food aid, subsidy and assistance programs. Several concerns have been raised with respect to the sustainability of these programs and their effectiveness in addressing the more underlying problem of the lack of economic growth and reliable food supply.

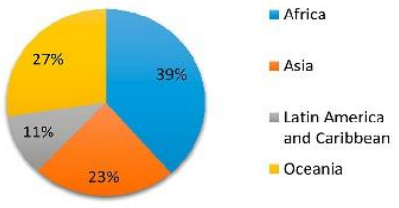

Figure 1. Undernourishment distribution in developing regions.

The food supply problem must be analyzed taking into account all the steps involved in the supply chain while focusing on economic, social, political and environmental benefits. Consideration should also be given to community development, local resources, supply and demand, food production and distribution centers.[2] Additionally, the quality, safety, health and nutritional aspects in diets should be addressed[3] while creating a symbiosis network between the demand and sustainable production and distribution of food.[4] The analogy between food supply chains and industrial supply chains offers valuable lessons and efficient tools. The supply chains of different industrial processes have been analyzed through various optimization models addressing a broad range of case studies. For example, Guillén-Gosálbez and Grossmann[5] proposed a global optimization approach for the environmentally conscious design of chemical supply chains. These

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RESEARCH PAPER

Environmental, Technical, and Economic Evaluation of a New Treatment for Wastewater from Slaughterhouses

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Abstract The wastewater treatment has a fundamental role for all the industrial processes, being a crucial part in the water cycle. The meat industry around the world has severe problems associated with the huge freshwater requirements that increase with the population growth. However, nowadays, the most used slaughterhouse wastewater treatment (SWWT) system has negative environment impacts. Hence, the inclusion of the life cycle assessment method, as decision technique in the design and configuration of the treatment train for these industries, results in an attractive innovation. Particularly for the SWWT, the aerobic process is the most used approach; however, its high-energy requirements increase significantly the associated total cost. On the other hand, the upflow anaerobic sludge blanket process has been reported as an attractive treatment, but this needs a secondary treatment for achieving the environmental regulations for some pollutants. Therefore, this paper presents a techno-economic–environmental–social evaluation as a sustainable alternative in wastewater treatment train configuration based on the obtained results of the Trail and Refrigerator of the city of Morelia in Mexico. The results show that with the new configuration, the energetic requirement is reduced by 76%; thus, the operational cost is minimized in the same way, while the environmental impact is reduced by 30% with the integration of anaerobic and aerobic processes.

Keywords Slaughterhouses wastewater · Treatment train · Environmental impact · Life cycle assessment · Aerobic process · Anaerobic process

Abbreviations

SWWT	Slaughterhouse wastewater treatment
LCA	Life cycle assessment
UASB	Upflow anaerobic sludge blanket
WWS	Slaughterhouse wastewater
MPN	Most probable number
BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
TN	Total nitrogen
TP	Total phosphorous
FOG	Fats, oils, and greases
TSS	Total suspended solids
TDS	Total dissolved solids
EIA	Environmental impact analysis
EIAP	Aerobic process environmental impact analysis
EIANP	Anaerobic process environmental impact analysis
EIA-WW	Untreatment wastewater discharge environmental impact analysis

Introduction

The water-energy nexus is a very important issue when analyzed the wastewater treatment train performance in developing economies due to the supply, consumption,

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