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Genetic algorithm applied to study of the economic viability of alcohol production from Cassava root from 2002 to 2013

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ABSTRACT

This work aimed to investigate the economical and environmental viability of alcohol production from cassava root from 2002 to 2013 using genetic algorithms technique, a meta-heuristic technique inspired on biological natural selection process. Amylases from *Aspergillus niger* have been used in starch hydrolysis processes and *Saccharomyces cerevisiae* yeast in fermentation process. The carbon credits obtained of alcohol production and biomass from cassava residues were used to reduce cost production. The hydrolysis occurred at temperatures ranging from 30 to 60 °C, with starch concentrations from 8.0 to 22 g/L. Results showed the best conditions for starch hydrolysis at 23.4 g/L, 61.9 °C and 111.0 min, where an yield of 84% was achieved. In this condition, though in the presence of yeast, the hydrolysis yield is close 100% and the ethanol yield was 88%, after fermentation process. An alcohol cost between 0.04 and 0.62 US$/L has been found for the studied period. In addition, the company acquires 7.8 billion of carbon credits, is environment friendly, and improves its image in the society. Results show that this meta-heuristic optimization technique could be useful for improvement of industrial alcohol production.

1. Introduction

1.1. Advantages and disadvantages of biofuels

Ethanol and biodiesel are considered as important energy options as a substitute for fossil fuels, once they are a renewable resource and endless, and they are produced from biomass in general, a culture of farming. The current belief is that replacing fossil fuels with ethanol and biodiesel can reduce emissions of greenhouse gases (Giraçol et al., 2011; Pereira and Ortega, 2010) and is a highly profitable investment (Giraçol et al., 2011; Solomon et al., 2007).

According to Pereira et al. (2012), renewable energies play an important role in sustainability; their use in energy production contributes to sustainability development in view of their environmental, energetic, and socio-economic benefits. Alcohol, biodiesel, and biomass are natural resource to obtain energy and due to they be renewable and more environment friendly; its use is incentive and carbon credits are associated to its used quantities (Giraçol et al., 2011).

Brazil is world's alcohol producer with more than 28 billion liters (crop 2013/2014) and the state of São Paulo with about 14 billion liters is the largest alcohol producer in Brazil (CONAB, 2013). However, the production of alcohol undergoes abrupt changes from year to year because the harvest of sugar-cane has a constant influence of seasonality, the alcohol competes with the sugar production from sugar-cane and in addition sugar-cane cannot be stored. Thus, the production of ethanol from other sources could solve such problems of variation of ethanol production in Brazil. In addition, as common practice in the Brazilian ethanol industry, the residues derived from cassava peels can also be used in energy conversion, as bagasse from sugar cane and to purchasing carbon credits due to the direct isolation of the plant and the production of a renewable fuel (alcohol) (Chohfi et al., 2004).

De Castro et al. (2014) showed that sugarcane alcohol should not be considered as an environmentally friendly fuel because its carbon footprint (in m2/W) obtained from the sugar cane life cycle was greater than the fossil fuels. In addition, they cite the increase of the

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area occupied for the sugar cane crop and lower production of sugar because of competition with the ethanol production, 1975 to 2010 in Brazil.

Moreover, sugar-cane production model adopted in Brazil is based, generally, on monoculture farming practices and the extensive use of herbicides/pesticides and burning, with consequent water, air, and soil degradation (Ometto and Roma, 2010).

There is considerable criticism worldwide regarding the use of sugar-cane crop for alcohol production due to the tendency toward driving up the prices of food product (sugar). Furthermore, this process will require an expansion of the farming industry, which may cause further devastation to remaining forest fragments (Giraçol et al., 2011).

Florin et al. (2014) emphasize the potential threats of biofuels including loss of land entitlements, social exclusion, environmental degradation, dependency upon the biofuel industry, and diminished food security. For minimizing the harmful effects to society and the environment, Florin et al. (2014) highlight that regulation and certification of biofuel production often needs to complete with improvements in governance structures and, that policy targeting smallholder involvement with biofuel production should account for a diversity of smallholder characteristics.

The environmental benefits resulting from the emissions inherent to the use of alcohol fuel in engines, as opposed to those from petroleum fuels are: alcohol is sulfur-free, non-toxic, and biodegradable, it reduces the emission of gas pollutants, reduces global warming, is economically competitive, and is a renewable fuel (Pereira and Ortega, 2010).

Furthermore, De Castro et al. (2014) showed that productivity in Brazilian model of ethanol production is four times higher than the European (roots) and American (corn) models. In the same article, they cite other authors showing that the ecological footprint (W/m2) of alcohol is lower than that of clean energy such as photovoltaic and wind powers. According to Florin et al. (2014), the biofuels show potential opportunities for smallholders including access to markets, access to employment, local infrastructure developments, and spillover effects such as new agronomic knowledge. However, it was proven that the use of alcohol blended fuels leads to the formation of aldehydes that are exhausted of the engines, which are carcinogenic in nature and harmful to human begins (Murali Krishna et al., 2006, 2011; Kumar and Nagarajan, 2009).

Various modeling techniques have been used to investigate the production of biofuels and their economic, environmental, and social viability. The results of such simulation showed that well-structured projects can be viable government policies and financial investment to make possible the production of biofuels in certain regions or countries.

1.2. Genetic algorithm

Currently, some models have been developed to optimize the inventory of environmental credits, such as carbon credit, as non-classical model shown in Bonney and Jaber (2011), or an Economic Order Quantity (EOQ) model proposed by Chen et al. (2013) adapted from Chang et al. (2003) model to make the carbon credit accounting, Dye and Yang (2015) have obtained an exponential model to determine the following joint decision: how long the credit period showed and inventory replenishment policy. The results showed that the model is better than the commonly used, such as non-classical and EOQ models.

Yu and Mallory (2014) developed a model from partial differential equations of carbon credit of variations and the price per year, and called for SVAR. Responses had at 95% confidence intervals a 5–6% standard deviation shock by bootstrapping 1500 iterations. The model error was between 0.007 and 0.420, indicating that the SVAR model has been fitted to the experimental data.

Although the use of some model to represent the environmental viability of projects by including carbon credits should be noted, there is no mention to applications of metaheuristic techniques for decision-making in the business field. Among these techniques, one can cite Genetics Algorithm (GA) and simulated annealing (SA).

The GA consists of a meta-heuristic technique of optimization inspired by biological natural selection process that has used for solving optimization problems in several areas over the last decades, mainly because its efficiency in irregular search spaces (Goldberg, 1989). Hence, this method has been used to solve many problems involving complex combinatorial optimization (Goldberg, 1989; Pham and Pham, 1999). Different from other search methods, the GA operates over the population in parallel, yielding various solutions at a time (Almeida et al., 2014; Pham and Pham, 1999).

Genetic algorithms and their applications are topics of active research in many areas, such as chemical, food and environmental engineering (Almeida et al., 2014; Cantelli et al., 2015; Librantz et al., 2011; Santana et al., 2010; Schneider et al., 2013).

1.3. Starch to produce second-generation alcohol

Today, all the gasoline sold in Brazil must be composed, at least, by 20% anhydrous alcohol blend (E20). Ethanol currently comprises about 30% of the total vehicle fuel used within the country.

An alternative to replacement of this raw material is the use of syrups obtained by the hydrolysis of starch. The use of starch for alcohol production agro-industrial development can lead to several Brazilian regions with a tradition in the cultivation of starch, especially corn (*Zea mays*), rice (*Oriza sativa*), cassava (*Manihot* spp), and others (Biazus et al., 2009; Curvelo-Santana et al., 2010; Leonel and Cereda, 2000). According to Alves (2005), 1 ton of sugar-cane produces 85 L of alcohol; however, 1 ton of cassava produces 104 L of alcohol. The hydrolysis of starch to product with low molecular weight, catalyzed by amylases, is the most important commercial enzyme process. The hydrolyzed products are widely applied in food, paper, and textile industries (Konsula and Liakopoulou-Kyriakides, 2004).

Starch, the main reserve carbohydrate of several crops, is highly abundant in nature and has been extracted with high purity and at low cost (Leonel and Cereda, 2000). The food industry is using starch for a long time as ingredient because of its functional properties. Depending on the source, the starches have different applications, improving consistency, stability, and other properties. All starches have structural and compositional differences and a great number of studies have been done to show each particularity. These differences directly affect the yield of starch hydrolysis (Leonel and Cereda, 2000). Starchy crops like cassava are candidates for commercial alcohol. Starch hydrolysis at 30–80 °C could reduce energy costs and improve fermentation yields (Krishnan et al., 2000; Yingling et al., 2011).

Africa is the largest producer of cassava, especially Nigeria with 16.3% of the world production. Brazil and Indonesia compete for the second place with just over 10% of world production of cassava. The state of São Paulo is the fifth largest producer of cassava in Brazil with 6% of the Country's production (DERAL, 2014). Thus, to demonstrate that it is possible to produce alcohol from starch cassava with economic feasibility is very important to help in keeping a constant alcohol production in Brazil.

Thus, this work shows how to produce alcohol from cassava starch so that the process becomes economical feasible using the meta-heuristic technique of GA. Amylases from *Aspergillus niger*

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