GLOBAL WARMING POTENTIAL OF ENZYMATIC HYDROLYSIS FOR BIOETHANOL PRODUCTION FROM POTATO WASTE BLEND

Victória Dutra Fagundes[1], João Felipe Freitag[1], Viviane Simon[1], Mateus Torres Nazari[1], Rosana de Cássia de Souza Schneider[2] & Luciane Maria Colla[1*]

[1] Postgraduate Program in Civil and Environmental Engineering. Institute of Technology, University of Passo Fundo. Passo Fundo, Brazil.
** Corresponding author's email address: lucolla@upf.br*
[2] Postgraduate Program in Environmental Technology, University of Santa Cruz do Sul. Santa Cruz do Sul, Brazil.

ABSTRACT

The relationship between life cycle assessment (LCA) studies and biofuel strategies enables an integrated approach that allows efforts to be directed toward the economic and environmental viability of new processes. About food waste, it is highlighted that it is highly generated and that recovery and reuse techniques are little investigated, at the same time food waste generates numerous environmental impacts throughout its chain until its final destination. The potential impact of Global Warming (GWP) stands out for being the most representative category in terms of indicating direct impacts on the ecosystem, with the results expressed in Kg CO_2 eq. Therefore, the present study aims to analyze the GWP of the process of converting food waste from potato mixtures to generate bioethanol. As a result, it is observed that 95.3% of CO_2 emissions from the enzymatic hydrolysis stage refer to the energy consumption of the equipment, with enzymes representing 4.7% of emissions. The literature points out that energy consumption is the stage that generates the most impact, followed by the inputs and other products. Therefore, efforts to reduce the generation of CO_2 in processes involve investigating the recycling of enzymes and, above all, reducing energy consumption.

Keywords: Life cycle assessment. Biofuel. Food waste. Circular economy.

1 INTRODUCTION

With recent data indicating a global population of 8 billion inhabitants, searches for new technologies and processes based on more sustainable alternatives are emerging[1]. Conventional sources of fuel centered on the use of oil are in the process of exhaustion due to global warming and faster climate changes. To replace conventional fuels, biofuels such as biomethane, biodiesel, and bioethanol are emerging[2,3].

Food residues can be classified into various types such as fruit and vegetables (39%), cereals (24%), roots and tubers (19%), milk and eggs (9%), meat (5%), oilseeds and vegetables (3%), and fish and seafood (1%), contains significant quantities of carbohydrates[4]. This composition of food waste presents opportunities for various applications, including the development of biofuels, particularly bioethanol. Enzymatic hydrolysis plays a crucial role in making sugars available for fermentation into bioethanol, offering an efficient method for releasing sugars from solid matrices like food waste[2]. Urgent studies are needed to assess the value of food waste, as globally, approximately 1.3 billion tonnes of edible food are lost or wasted each year, leading to the emission of approximately 3.3 billion tonnes of greenhouse gases[5].

Regarding life cycle analysis (LCA) studies, data from the entire life cycle of a product or process are utilized within the boundary of the system under consideration. This provides valuable information for analyzing potential impacts and damages[6]. In the context of biofuels, LCA helps identify gaps and opportunities for process improvement, starting from the extraction of natural resources to the final disposal of products. Specifically concerning bioethanol production from food waste, LCA indicates broad opportunities as waste is valorized, reducing emissions that contribute to climate change[7,8]. Therefore, the present study aims to analyze the Global Warming Potential (GWP) of converting food waste from potato mixtures into bioethanol.

2 MATERIAL & METHODS

The methods of the present work followed ISO 14040[6] guidelines about the aim and scope, inventory design, impact assessment, and interpretation of the life cycle. In the first stage, the objective and scope were determined as the assessment of global warming potential through the estimation of CO_2 emissions from the enzymatic hydrolysis stage for the production of bioethanol from a blend of potato waste (pink, white, and sweet). The aim was to provide information and the possibility of improvements for a more sustainable application of hydrolysis. The functional unit adopted was 1 kg of waste.

In the stage of designing the life cycle inventory, the inputs and outputs calculated for the enzymatic hydrolysis stage were considered. Input and output calculations were carried out through the mass balance of waste, processes, and products in the system. Thus, for enzymatic hydrolysis, 217.5 g of pre-treated waste, 0.68 g of the amyloglucosidase enzyme, and 0.76 g of the alpha-amylase enzyme were added, and the hydrolysis process was carried out for 3 hours culminating in an energy consumption of 5.88 kWh, considering the use of a hydrolysis bioreactor. Afterward, 0.17 g of reducing sugars/g of residue was obtained. At the end of the process, bioethanol production was 0.05 g bioethanol/g residue.

In the last stage of the LCA, CO_2 emissions and the global warming potential of the enzymatic hydrolysis process were evaluated and interpreted using SimaPro vs. 8.5.0.0., a software known for life cycle analysis and impact assessment. The impact analysis was conducted using the IMPACT 2002+ methodology for the Global Warming category, represented by the unit of kg CO_2 eq. This unit represents the emissions of gases responsible for the greenhouse effect and consequently contributes to global warming. The estimated results and impacts were discussed and interpreted.

3 RESULTS & DISCUSSION

Figure 1 depicts the estimated CO_2 emissions for the enzymatic hydrolysis stage, taking into account the enzymes added and the energy consumption of the process. Energy consumption accounts for 95.3% of CO_2 emissions (1.31 kg CO_2 eq), while enzyme addition represents 4.7% of estimated CO_2 emissions (0.07 kg CO_2 eq). The enzymatic hydrolysis bioreactor used in the process consumed 5.88 kWh during the 3 hours of operation, with the energy input being considered in the software as "Electricity, low voltage {BR}| electricity voltage transformation from medium to low voltage", which more reliably represents the energy matrix in Brazil.

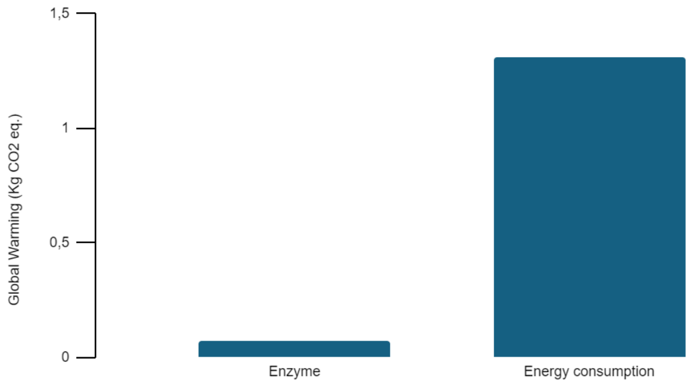

Figure 1. GW emissions in enzymatic hydrolysis process.

In LCA studies of biotechnological processes, it is known that the use of energy during the generation of the product directly contributes to atmospheric emissions, including CO_2 and greenhouse gases. This contributes to the greatest impacts related to global warming potential being associated with energy consumption during enzymatic hydrolysis[3,7]. To reduce the impacts generated by the supply of electricity in small-scale laboratories, the installation of an electrical network from renewable energy sources could reduce these adverse effects. However, this investigation must be specific to each country due to significant variations in the supply of energy between nations, as well as the location of experiments[3,9].

In the research carried out by Costa et al.[9], the LCA of bioethanol production from sweet potatoes was conducted in an experimental plant, in which the authors evaluated the impacts associated with the transportation of potatoes, the construction of the production plant, washing, and milling, enzymatic hydrolysis, fermentation, and distillation. As a result, enzymatic hydrolysis accounted for approximately 12% of impacts for the GWP category. The authors highlight that the hydrolysis process also has a significant impact on enzyme production. To fill the gaps regarding the use of enzymes in bioprocesses, researchers focus on recycling enzymes in enzymatic hydrolysis processes and also on the local production of enzymes, optimizing production, and even using dosages recommended by manufacturers[2]. From the perspective of developing materials and reusing inputs to replace conventional processes, such as recycling strategies and reusing chemicals/nutrients, it can be considered in future studies as a strategy to mitigate possible environmental consequences[9]. However, further studies regarding more sustainable alternatives for applying enzymes in enzymatic hydrolysis are still necessary.

Specifically, enzymes used in enzymatic hydrolysis for bioethanol production are not always considered in LCA studies due to the lack of reliable and transparent data, often associated with bureaucracy and confidentiality of manufacturers[7,8]. Available inventories do not disclose specific information on energy, nutrient, water, and infrastructure consumption, limiting sensitivity analysis and hiding the contributions of processes and inputs to the life cycle impact assessment (LCIA) phase[7,8].

4 CONCLUSION

When evaluating the global warming potential of the enzymatic hydrolysis step, it is evident that energy consumption plays a significant role in the estimated total CO_2 emissions, while the use of enzymes plays a smaller role in these emissions. There is a need for more in-depth and transparent studies to understand and mitigate the environmental impacts associated with enzymatic hydrolysis in bioethanol production. This includes consideration of the energy sources used and the definition of strategies for a more sustainable use of energy, as well as transparency in information about the enzymes used in the process. These measures are essential to move towards more sustainable and efficient practices in the biotechnology industry.

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ACKNOWLEDGEMENTS

This study was financed in part by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) (Finance Code 001 and CAPES PROCESSO 88881.846894/2023-01)