STUDY OF THE FACTORS INVOLVED IN THE ACID PRETREATMENT OF DRAGON FRUIT PRUNING WASTE

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ABSTRACT

The application of bioeconomy is already a reality within industrial production, primary production, and the healthcare sector. Bioeconomy plays a fundamental role in dry and semi-arid regions, where natural resources can be scarce, and communities face challenges related to water availability. Finding energy solutions and high value-added products from biomass in these regions is essential for community development. One of such biomass is the pruning waste of pitaya (dragon fruit). Experiments were conducted using dried and ground pitaya pruning biomass. The biomass was hydrolyzed using sulfuric acid at concentrations of 0.5, 1, and 1.5% (v/v) and with solid loadings of 10 and 20% (m/v) under fixed temperature and time conditions of 121°C and 60 minutes respectively. To investigate the factors associated with the highest efficacy of sulfuric acid pretreatment, a factorial experiment was proposed, which revealed that the variation in the acid solution was a determining factor in achieving the highest concentration of total reducing sugars (34.8 g/L) in the hydrolysate. Although, pitaya pruning biomass is little explored scientifically, it shows considerable energy potential.

Keywords: Biomass. Bioeconomy. Acid Hydrolysis. Dragon Fruit Pruning.

1 INTRODUCTION

According to Dias & de Carvalho (2017), the Organisation for Economic Co-operation and Development (OECD) defined bioeconomy as a scenario in which biotechnology plays a crucial role in economic production. Implementing bioeconomy in addressing climate change offers a sustainable way to produce energy and materials. By utilizing biological resources, it is possible to develop biofuels that not only reduce dependence on fossil fuels but also promote the efficient use of biomass in arid and semi-arid regions.

A promising candidate for biofuel generation in dry and semi-arid regions is Pitaya (Hylocereus spp.). The fruit belongs to the cactus family, known as a group of species adapted to dry climates (Leong et al., 2018; Bartholomew et al., 2018). Regarding the physiochemical composition of the species, relevant components for saccharification, an important step in biofuel production, can be observed, such as cellulose (13.74%) and hemicellulose (12.28%). In addition to these components, the biomass also presented acid-soluble lignin (4.29%), acid-insoluble lignin (13.74%), and ash (12.31%) (Tien et al., 2023).

Currently, it is estimated that the global market size for Pitaya commercialization is $14.73 billion, potentially reaching $18.27 billion by 2029 (Mordor Intelligence, 2023). Although, the main producers are located in Asia, cultivation in Brazil has been gaining significant market space (Nguyen, 2017). According to the Brazil Fruits Project, the country produced between 5 and 8 thousand tons of Pitaya and completed two decades of cultivating Pitaya in 2023 (Frutas do Brasil, 2023).

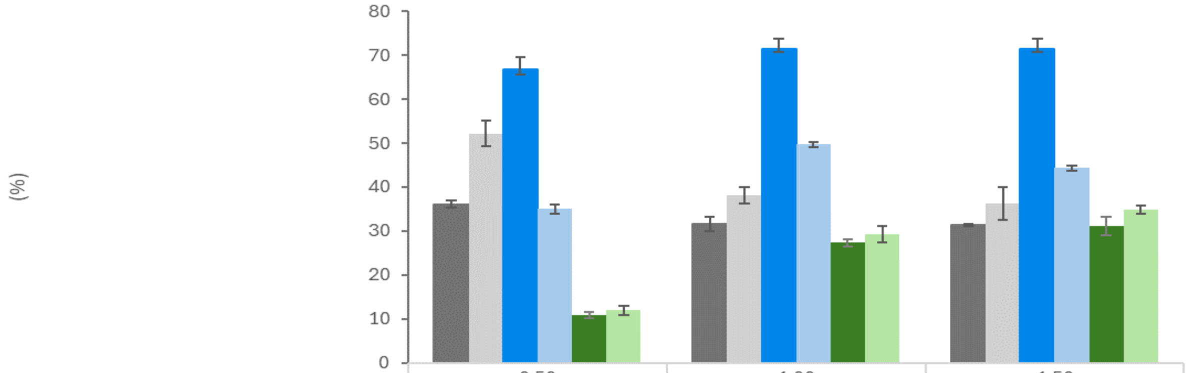
However, as with all fruits production, there are agricultural residues that must be considered when thinking about Pitaya cultivation. These residues consist of bagasse, peels, pruning waste, and straw that are discarded but have great potential for use in the energy industry (Oliveira et al., 2020). The use of acid hydrolysis in this process can yield a good output in sugar formation (Lv; Zhang; Xu, 2024). In this context, given the scarcity of data on the subject, this work aims to investigate how biomass derived from Pitaya waste reacts to pretreatment with diluted sulfuric acid, studying how the factors of acid concentration and solid load are associated with pretreatment efficacy.

2 MATERIAL & METHODS

The acid hydrolysis experiments were conducted using pitaya pruning biomass, which was dried in an oven at 105°C for 48 hours and ground using a knife mill with a 20 mesh size. The acid hydrolyses were performed in a bench-top autoclave according to a completely randomized design (CRD) with a 3x2 factorial arrangement under fixed time and temperature conditions, specifically 60 minutes and 121°C respectively. Only the solid loadings (10% and 20% (w/v)) and sulfuric acid concentrations (0.5%, 1%, and 1.5% (v/v)) varied. The hydrolyses were conducted in triplicate, and the reducing sugars were quantified by spectrophotometry using 3,5-dinitrosalicyclic acid (DNS). Statistical analysis of the data (ANOVA F-test and Tukey's test) was performed using Statistical software.

3 RESULTS & DISCUSSION

The experimental data from the acid pretreatment (Figure 1) show that less biomass was recovered in the treatments with 1.0% and 1.5% sulfuric acid in the pretreatment solutions, while the percentages of recovered volumes increased in these same treatments, indicating better solubilization of monosaccharides. The inevitable volume loss observed in the acid hydrolysis processes is a consequence of the strong influence of the solid loading, due to the property of organic materials to absorb liquids (Alencar et al., 2020).



	0,50	1,00	1,50
Recovered biomass, solids load 10%	36,05	31,58	31,4
Recovered biomass, solids load 20%	52,12	38,1	36,32
Recovered volume, solids load 10%	66,67	71,33	71,33
Recovered volume, solids load 20%	35	49,67	44,33
solubilized total reducing sugars (g/L), solids load 10%	10,78	27,28	31,16
solubilized total reducing sugars (g/L), solids load 20%	11,97	29,34	34,80

Concentration of the acid solution (%)

Figure 1: Experimental data and concentration of total reducing sugars in the acid hydrolysate.

Regarding the sugar concentration (Figure 1), the highest values (31.16 and 34.80 g/L) were obtained under the condition of 1.5% sulfuric acid, with solid loadings of 10% and 20%, respectively. However, the ANOVA F-tests and Tukey's test (Figure 2) showed that there were no significant differences between these solid loadings at any of the tested concentrations. No other studies were found on pitaya pruning biomass, but in the acid hydrolysate of palm, only 4.7 g/L of glucose was obtained (140°C, 10% solid loading, 1.5% sulfuric acid) (Torres Neto, 2015).

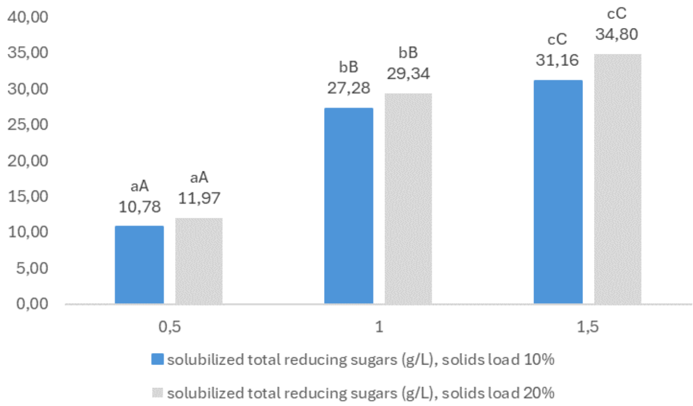


Figure 2: Data of means and significance analysis. Means followed by the same uppercase letter do not differ from each other according to Tukey's test at a 5% probability. Means followed by the same lowercase letter do not differ from each other according to ANOVA F-test at a 5% probability.

It is also possible to notice that in the treatment with 0.5% sulfuric acid, the data on biomass recovery and volume showed a significant difference when compared to the values obtained at concentrations of 1% and 1.5% sulfuric acid, under conditions of 10% and 20% solid loadings, suggesting the low performance of this concentration in destabilizing the hemicellulose structure and solubilizing the reducing sugars. This data is supported by the total reducing sugar values obtained at the 0.5% acid concentration, which were three times lower than those in treatments using a 1.5% sulfuric acid concentration. The data from this study highlighted that the acid concentration played a central role in the acid hydrolysis process under the given conditions, as expected since the proton of the catalyst acid initiates the molecular mechanism of the process, occurring in three steps, interacting with the glycosidic oxygen that binds the two sugar units (Fengel and Wegener, 1984).

4 CONCLUSION

Considering the results obtained, it is possible to conclude that the release of total reducing sugars increases with the severity of the hydrolysis treatment, represented here, by the increase in sulfuric acid concentration (0.5%, 1%, 1.5%). The 3x2 factorial CRD allowed us to analyze that under constant temperature and time (121°C; 60 min), only the variation in acid concentration is considerably significant in obtaining the sugars, as opposed to the solid loading, which only negatively influenced the final volume of the hydrolysate, resulting in less hydrolysate with concentrations almost equivalent to the hydrolysate with 10% solid loading.

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ACKNOWLEDGEMENTS

The authors acknowledge the financial support from PRH-ANP/FINEP, via PRH 48.1/UFPE, funded with resources from investments by qualified oil companies in the R&D Clause of ANP Resolution No. 50/2015, and the BiotecSemiárido project (APQ1379-9.25/21), CNPq Project VALORA-FORSU (440444/2022-5).