Ethanol production from cotton-based unfit clothing via acid hydrolysis

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ABSTRACT

The present study objective is to explore the potential of producing ethanol from cellulose extracted from cotton fibers through an acid hydrolysis, followed by neutralization and then fermentation with *Saccharomyces cerevisiae*. Nowadays the growth in global textile consumption has led to a rise in textile waste, creating the need for more sustainable solutions for waste management. Considering the fact that cotton fibers contain a considerable amount of cellulose, a renewable resource, they offer an alternative source for ethanol production. The process of hydrolysis is to break down cellulose into simple sugars, which can then be accessible for fermentation by *Saccharomyces cerevisiae* generating as a by-product ethanol. Ethanol production varied significantly among the concentrations of sulfuric acid (1M, 5M, 5.6M, 6M, and 7M). The 1M sulfuric acid concentration resulted in the highest ethanol production, with an average of 0.580% alcohol, while 6M and 7M concentrations resulted in lower ethanol production, with averages of 0.080% and 0.380%, respectively. The results indicate that it is possible produce ethanol from cotton cellulose. However, further tests are needed, especially to evaluate the acid concentration and distillation time and to minimize the costs of production. That process does not only provide a renewable option for fossil fuels but also offers a chance to be valorizing textile waste and generating some income from it.

Keywords: Ethanol. Cellulose. Fermentation. Cotton.

1 INTRODUCTION

The rise in global consumption of textile fibers has been driven by different factors such as population growth, improvements in quality of life, and the exponential evolution of textile materials[1]. However, this rapid growth has resulted in a significant increase on the generation of waste on both post-industrial and post-consumer use[1]. Additionally, the rise of so-called "fast fashion", characterized by mass production, variety, and disposability of clothing, has enhanced the magnitude of the problem[1].

As the environmental and economic cost of textile production continues to escalate, the need for more sustainable waste management treatments becomes apparent. Understanding this industry's challenges and innovative solutions are crucial for advancing towards a more sustainable and eco-conscious future.

Faced with this challenge, finding a global solution for textile waste disposal is necessary. Cellulose can be hydrolyzed into glucose and be enable the yeast *Saccharomyces cerevisiae* to consume and produce ethanol as a byproduct.

2 MATERIAL & METHODS

The fermented fabric needs to be 100% cotton, so raw cotton was used since previous tests were conducted with printed cotton fabric and the results were not as clear due to the interference of the dye. The method of cotton hydrolysis followed by ethanol production was based on Jeihanipour and Taherzadeh (2009)[2] with some modifications.

Cotton-based clothing was cut into small pieces of 0.09 m^2, with an average weight of 20g, to increase the contact surface area between the sample and sulfuric acid. The samples were then weighed and separated into 5-liter glass beakers. The treatments performed were: control (with deionized water), sulfuric acid 1M; 5M; 5,6M; 6M and 7M. For each treatment, 5 samples were made, and in each beaker, 21.6 g of sample and 1 liter of acid solution were added.

These step was performed for acid to be able to broke the cellulose bonds of the cotton over a period of 24 h at room temperature. After this period, filtration was performed to remove undegraded cotton fibers, followed by neutralization was performed using sodium hydroxide with molarity respective to the molarity of the acid.

After neutralization, 5 samples of 250mL from each treatment were transferred to 500 mL Erlenmeyer flasks, sealed to create an anaerobic environment conducive to fermentation. For the fermentation of dissolved sugars, 3g of *Saccharomyces cerevisiae* dryed yeast was used, which develops in an anaerobic environment.

The Erlenmeyer flasks sealed with yeast and hydrolyzed cotton were placed in an incubator at a controlled temperature of 37°C for 4 days. Then, to evaluate the ethanol content, the samples were distilled and evaluated in the Anton Paar DMA 35N density meter.

As the final step of the experiment was performed the statistical analysis of the obtained data. This was made using an descriptive analysis and box a plot graphic, which were obtained with the Jamovi software.

3 RESULTS & DISCUSSION

Table 1 presents the descriptive analysis with mean, median, and standard deviation, and Figure 1 shows the alcohol content (%) of the treatments.

Table 1: Descriptive statistics

	Acid treatments (M)	Alcohol content (%)
N	1	5
	5	5
	5.6	5
	6	5
	7	5
	Control	5
Mean	1	0.580
	5	0.282
	5.6	0.260
	6	0.0800
	7	0.380
	Control	0.100
Median	1	0.350
	5	0.233
	5.6	0.300
	6	0.00
	7	0.400
	Control	0.100
Standard Deviation	1	0.619
	5	0.180
	5.6	0.114
	6	0.130
	7	0.0837
	Control	0.0707
Minimum	1	0.109
	5	0.0645
	5.6	0.100
	6	0.00
	7	0.300
	Control	0.00
Maximum	1	1.63
	5	0.533
	5.6	0.400
	6	0.300
	7	0.500
	Control	0.200

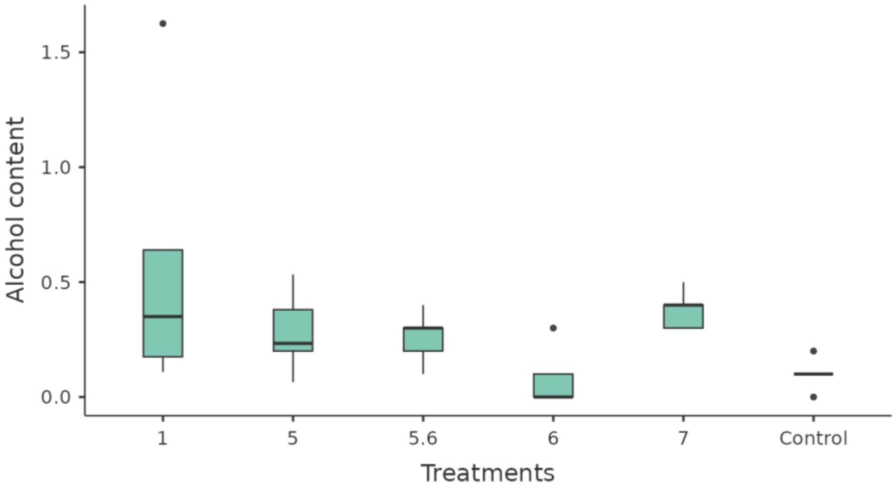

Figure 1: Graph 1. Results of ethanol content (%) produced by treatments with acid concentration of 1M, 5M, 5.6M, 6M and 7 M

Our results show that ethanol production varied significantly among the concentrations of sulfuric acid (1M, 5M, 5.6M, 6M, and 7M). The 1M sulfuric acid concentration resulted in the highest ethanol production, with an average of 0.580% alcohol. The 5M and 5.6M concentrations also produced considerable amounts of ethanol, with averages of 0.282% and 0.260%, respectively. On the other hand, the 6M and 7M concentrations resulted in lower ethanol production, with averages of 0.080% and 0.380%, respectively.

For comparison purposes, a study published in 2009 by Jeihanipour and Taherzadeh described the production of ethanol from cotton-based textile waste. The results of this study showed a final ethanol concentration exceeding 30%, which is approximately 50 times higher than our results. This disparity can be attributed to process variables such as the type of material used, hydrolysis methods, and fermentation conditions. In their study, an alkaline pretreatment was employed in addition to enzymatic hydrolysis, which may explain their superior results. Nevertheless, the findings of the study by Jeihanipour and Taherzadeh support the feasibility of our project and suggest that process improvements, such as the inclusion of alkaline pretreatments, could significantly increase the efficiency of ethanol production from textile waste.

Therefore, it is possible to produce ethanol from the cellulose present in cotton fabric, with the acid concentration significantly impacting production. The 1M sulfuric acid concentration was the most effective in producing ethanol. However, more tests are needed to optimize the acid concentration and distillation time, as well as to reduce production costs to compete with sugarcane ethanol. Ethanol production from textile waste can be a sustainable solution to the growing problem of fast fashion waste. Improvements in extraction methods, such as combining enzymatic and acid hydrolysis, can increase process efficiency. Transforming textile waste into a renewable energy source represents a significant step toward a more sustainable and environmentally conscious solution.

4 CONCLUSION

The results indicate that it is possible and feasible to produce ethanol from cotton cellulose due to the presence of cellulose in the fabric. However, further tests are still needed, especially to evaluate the acid concentration and distillation time and to minimize the costs of production since the competitive ethanol from sugar cane is relatively cost effective and well established on the current economy. In comparison if previous experiments regarding this topic the current results show some consistency demonstrating that the method is capable of producing ethanol.

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