Valorization of Brewers Spent Grains towards bioethanol production

K. Passadis*, K. Vassileiou, D. Malamis, S. Mai, E.M. Barampouti

National Technical University of Athens, School of Chemical Engineering, Unit of Environmental Science Technology, 9 Iroon Polytechniou Str., Zographou Campus, GR-15780 Athens, Greece
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Presenting author email: konpassadis@gmail.com

Introduction

In 2023, reducing greenhouse gas emissions, addressing resource depletion and environmental pollution and optimizing waste management are in the top of European priorities. With the 2030 Climate Target Plan, the Commission proposes to raise the EU's ambition on reducing greenhouse gas emissions to at least 55% by 2030. To achieve this, the need for the development and implementation of policies in favor of the circular economy and sustainability has been recognized worldwide. In this context, the effective management of urban, as well as industrial waste, is a major issue. The production of biofuels using biowaste as feedstock seems as a promising way of managing it. By 2030, the EU aims to increase the share of renewable energy in transport to at least 14% including a minimum share of 3.5% of advanced biofuels. Bioethanol is one of the main renewable and sustainable liquid biofuels that can contribute to addressing the current energy crisis as well as the deterioration of the quality of the environment. Brewer's spent grains (BSG), which is the main by-product of brewing industry, are considered as a rich source of lignocellulose that can be converted into fermentable sugars towards bioethanol production. In this work, the bioethanol production potential from BSG using enzymatic cocktails developed by Novozymes was carried out.

Materials and Methods

The raw material used in this study was Brewers Spent Grains (BSG) produced from the Hellenic Brewery of Atalanti, Fthiotida, Greece. After their delivery to National Technical University of Athens, School of Chemical Engineering, Unit of Environmental Science and Technology, they were submitted to a simultaneous drying and milling process by a GAIA (GC-100) waste dryer. The initial moisture of the feedstock was around 83 %. The characteristics of the dried raw material were as follows (%w/w dry basis): residual moisture 9.35 ± 0.07, volatile solids 87.21 ± 0.12, starch 0.91 ± 0.01, cellulose 19.54 ± 0.04, hemicellulose 23.9 ± 0.01, fats and oils 6.59 ± 0.02, acid soluble lignin 1.8 ± 0.03, acid insoluble residue 28.3 ± 0.01, water soluble solids 15.38 ± 0.06.

For the scope of this research, simultaneous saccharification fermentation (SSF) was studied as fermentation mode and the effect of two parameters on ethanol yield was examined: the dosage of cellulolytic enzyme (Cellic CTec3) and the dosage of yeast (S.Cerevisiae). Specifically, two 22 factorial experiments were designed at lab scale aiming to evaluate the impact of the process variables (cellulase and yeast dosages) to ethanol yield, YEtOH. The difference between the 1st and the 2nd cycle, is that in the 1st one defatted BSG were used aiming to examine the impact of oil in the bioethanol production process. SSF at lab scale was conducted at 35 oC and 10% solid loading, based on preliminary experiments. In Table 1, the controlling parameters of the two factorial experiments along with their levels are given.

Table 1. Controlling parameters of the two experimental cycles

Parameter	Low level (-)	High level (+)	Center (0)
Cellic CTec 3 (μL/g_{cell})	600	2200	1400
S. Cerevisiae (%)	1	3	2

All chemicals used were of analytical grade. Cellic CTec3 which is a cellulolytic enzyme was provided by Novozymes (Denmark) and Saccharomyces cerevisiae was utilized as fermentation yeast. The NREL laboratory analytical procedure was followed for the determination of lignin, cellulose and hemicellulose in biowaste (raw and pretreated). Glucose and ethanol were determined in the liquid fraction photometrically. All analyses took place in duplicate.

Results

The main key performance indicator for the success of the trials performed was ethanol yield (Y_{EtOH}). So, the results regarding the ethanol yield for all of the trials are presented in Table 2.

Table 1. Ethanol yields for both of the experiment cycles

	Parameters		Y_{EtOH} (%)	
Trials	Cellic CTec 3 (μL/gcel)	S.Cerevisiae (%)	1st Cycle	2nd Cycle
1	600	1	30.47 ± 5.59	24.04 ± 1.71
2	600	3	27.07 ± 2.02	26.1 ± 0.31
3	2200	1	51.46 ±1.45	66.13 ± 1.35
4	2200	3	61.08 ± 7.23	71.12 ± 1.29
Center	1400	2	36.06 ± 0.69	50.56 ± 1.04

The mean ethanol yields of the trials performed were: 40.6 % ± 14.3 % and 47.6 % ± 18.8 % for the 1^{st} and the 2^{nd} cycle respectively. The highest ethanol yield was achieved for both cases in the higher level of the controlling parameters at 2200 μL/gcell Cellic CTec3 and 3 % of yeast. Under these operational conditions, the ethanol yield Y_{EtOH} was equal to 61.08 % ± 7.23 % and 71.12 % ± 1.29 % for the 1^{st} and 2^{nd} cycle respectively. It is also noteworthy that these trials were conducted without any pretreatment to examine the potential to avoid this step that obviously increases the total cost of the process. In the study of Kavalopoulos et al. (2021) the ethanol yield achieved was 45.56 % using three times lower enzyme dosage, but also making one more step, acid hydrolysis pretreatment.

Conclusions

It was proven that the extraction of oil from BSG seems to have a positive impact on ethanol yield as it was increased about 15% in respect to the ethanol yield of untreated BSG. The bioethanol production potential from BSG without pretreatment and through the SSF process proved to be encouraging. However, a technoeconomic analysis should be conducted to examine if the increase of the dosage of cellulolytic enzyme and the avoidance of the pretreatment step, could promote the sustainability of whole process.

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