Valorization of Brewers Spent Grains towards bioethanol production

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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% below 1990 levels by 2030. In this context, 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. The production of biofuels using biowaste as feedstock seems as a promising way of managing it. 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 are the main by-product of brewing industry, are considered as a rich source of lignocellulose that can be converted into fermentable sugars for bioethanol production. The aim of this study was to examine the ethanol yield of BSG through simultaneous saccharification and fermentation (SSF) process without applying any pretreatment step. In order to examine the impact of oil content on the SSF process two factorial designs were carried out using untreated and defatted BSG.

Materials & Methods

Brewers Spent Grains (BSG)

The raw material used in this study was BSG produced from the Hellenic Brewery of Atalanti, Fthiotida, Greece. After their delivery, they were dried, by a GAIA (GC-100) waste dryer. The substrate was characterized to determine its composition. The cellulose content was 19.54 ± 0.04 % of dry matter.

Factorial Design - SSF

SSF at lab scale was conducted at 35 °C and 10% solid loading for 24 hours, based on preliminary experiments. Specifically, two 2^2 factorial experiments were designed at lab scale aiming to evaluate the impact of the process variables (cellulase and yeast dosages) on ethanol yield, Y_{EtOH}.

The difference between the 1st and the 2nd cycle, is that in the 2nd one, defatted BSG were used aiming to examine the impact of oil content in the bioethanol production process. Experiments were carried out under a variety of operational conditions defined by two independent variables (enzyme quantity, yeast dosage), while hydrolysis time, fermentation time and temperature and solid loading were kept constant. Thus, an analysis of the potential, challenges and technical advances in bioethanol production from BSG was provided. In Table 1, the controlling parameters of the two factorial experiments along with their levels are given.

Table 1: Factorial design of SSF trials for both experimental cycles.

Parameter	Low level (-)	High Level (+)	Center
Cellic CTec3 (μL/ $g_{cellulose}$)	600	2200	1400
S.Cerevisiae (%)	1	3	2

Results & Discussion

Cycle 1 (SSF) – Raw BSG

Table 2 presents the ethanol yields of SSF experimental cycle 1. The optimum results were obtained at 2200 μL/g of initial cellulose and 3 % S.Cerevisiae, resulting in 61.08 ± 7.23% of ethanol yield. During the fermentation step, an ethanol yield of 0.0675 g/g initial dry solid was achieved, providing a final ethanol concentration of 7.5 g/L. The highest cellulose degradation of 48.4% was accomplished for the maximum values of both parameters. Its evident that as cellulase dosage is increased, ethanol yields are also rising with equivalent rate while the dosage of yeast seems to have a smaller impact on the efficiency of the whole process.

Cycle 2 (SSF) – Defatted BSG

In the second experimental cycle, defatted BSG were used in order to see the impact of fat on ethanol yield. The extraction process was carried out in a soxhlet apparatus using hexane as organic solvent. The rest of the conditions were the same to experimental cycle 1. SSF trials of this cycle as can be shown on Table 2, indicate the significant impact of fats on ethanol yield.

Table 2: Ethanol Yields of SSF for experimental cycle 1 and cycle 2

A/A	Cellic CTec3 (μL/ $g_{cellulose}$)	S.Cerevisiae (%)	Ethanol yield – Cycle 1 (%)	Ethanol yield - Cycle 2 (%)
1	600	1	30.47 ± 5.59	24.04 ± 1.71
2	600	3	27.08 ± 2.02	26.1 ± 0.31
3	2200	1	51.46 ± 1.45	66.13 ± 1.29
4	2200	3	61.08 ± 7.23	71.12 ± 1.29
Center	1400	2	36.06 ± 0.69	50.56 ± 1.04

The residues from the experiments presented above were fully characterized to determine the degradation of cellulose. As expected, cellulose was converted to glucose, which, in turn, was consumed achieving **64.50 % cellulose degradation**. This is a satisfactory yield given that the energy and cost demanding pretreatment step was avoided.

The results obtained in the present study are encouraging for choosing SSF pathway instead of SHF to produce bioethanol. This process is advantageous considering that SSF is less energy demanding, less time consuming and more cost efficient than SHF.

For both experimental cycles, the optimum yields were achieved for the highest doses of enzyme and yeast, and specifically for 2200 Cellic CTec3 (μL/ $g_{cellulose}$) and 3% S.Cerevisiae. Moreover, from the obtained results, it is obvious that the extraction of oils as a pretreatment step has a positive effect on SSF process as shown in Figure 1. It is also important that extracted oils are considered as a byproduct and could contribute to the sustainability of whole process.

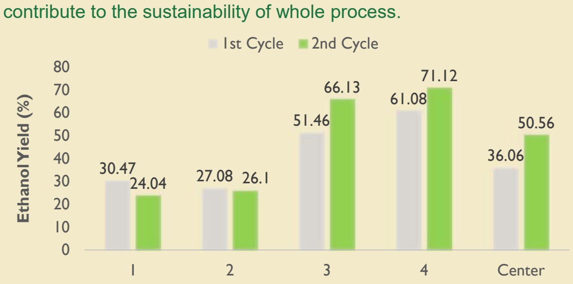

Figure 1: Ethanol yields of the two experimental cycles with BSG 10% solid loading, at 35 °C for 24h.

Conclusions

It was proven that the extraction of fats from BSG seems to have a positive impact on ethanol yield as the latter 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 of acid hydrolysis, could promote the sustainability of whole process.

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