BIOETHANOL PRODUCTION FROM MILLING INDUSTRY BY-PRODUCT IN A LABORATORY-SCALE BIOREACTOR

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Abstract

Bioethanol produced by biomass fermentation is a renewable and environmentally friendly energy source and has significant potential as a replacement for liquid fossil fuels. Due to the world moving toward more sustainable energy sources, the production of bioethanol has been steadily increasing. This research aims to investigate the efficiency of bioethanol fermentation from a milling industry by-product in a laboratory-scale bioreactor. Prior to fermentation in a bioreactor, for preparation of a milling industry by-product, two different thermo-enzymatic procedures were investigated and compared, and based on the obtained results the more efficient procedure was selected and used for the experiment in a bioreactor. The bioethanol fermentation was carried out in a 14-litre bioreactor in batch mode under anaerobic conditions at 30°C. The obtained results showed that this by-product can be used for the production of bioethanol but that further optimization is necessary to improve the overall efficiency of the bioprocess.

Introduction

As industrial development and the worldwide population increase, the need for energy consumption in the world is growing. The expected environmental threats such as global warming, acid rain and urban smog have caused humanity to move toward utilizing a variety of renewable energy resources, such as bioethanol, that are less toxic for the environment [1]. Bioethanol is mostly produced by fermentation of sugar or starch based raw materials as first generation bioethanol. Usage of these raw materials competes with their use as food sources and has led to the development of bioethanol production from various other sources such as agro-industrial wastes and by-products [2]. There are different by-products and waste materials rich in sugars that have been presented as great raw materials for fermentation processes and a by-product made in the milling industry with a high percentage of starch can be used as a raw material for bioethanol production [3,4]. The aim of this paper was to examine the efficiency of the bioethanol fermentation using a milling industry by-product, which consists of shrunken and damaged wheat grains as well as a small portion of other impurities, and cannot be used as a raw material in the milling industry for the production of wheat flour. The application of this by-product as a raw material in bioethanol production is of great importance considering its high value and wide application, as well as the fact that this bioprocess produces stillage that has the potential to be used as animal feed.

Experimental

Milling industry by-product, i.e. shrunken and damaged wheat grains were ground and mashed with water (at the hydromodule of 1:3, temperature 55°C and pH 6.5). Thermo-enzymatic preparation of the raw material was performed by the following procedure: the addition of Termamyl SC enzyme (keeping the mixture for 30 min at 50°C), heating and keeping the mixture for 30 min at a temperature of 65°C (for experiment 1) or 90°C (for experiment 2),

cooling the mixture to the temperature of 55°C, addition of SAN Super 360 L enzyme and after 30 min cooling to the temperature of 30°C.

The first set of experiments (experiment 1 and experiment 2), i.e. the experiment that was used to select the appropriate temperature of the thermo-enzymatic preparation of the raw material was conducted in the Erlenmeyer flasks of 1 L. The second experiment, i.e. the experiment used to investigate the efficiency of the bioethanol fermentation was performed in the 14-litre laboratory scale bioreactor (Chemap AG). After hydrolysis, 1 mL of 10% (m/v) $(NH_4)_2HPO_3$ solution was added, pH was set to 5.0, and fermentation medium was inoculated with *Saccharomyces cerevisiae* (Voronejskiye, Russia). The fermentation process was performed at 30°C with continuous mixing (200 rpm) under anaerobic conditions.

For determination of dry mass, starch in raw material, protein content in raw material and stillage and bioethanol content in the distillate obtained after destilation of fermentation broth, the standard AOAC methods were used [5].

Results and discussion

In order to properly formulate fermentation media based on the milling industry by-product, it is necessary to characterize the raw material or determine the parameters that are important for bioethanol production. This raw material is characterized by high dry matter content (89.75±0.19 g/100g) and it can be concluded that it has good stability and the possibility of safe storage over a long period of time, without a high risk of contamination. The amount of starch (54.26±0.83 g/100g) and proteins (8.34±0.20 g/100g) shows that this raw material is viable for bioethanol production because it will provide yeast cells with sufficient amounts of nutrients and energy necessary for growth and production of the desired product.

The results obtained after the first set of experiments (experiment 1 and experiment 2) showed that when using lower temperature of liquefaction, i.e. 65°C, the bioethanol yield (g/100g of raw material) is higher by about 5% compared to the experiment conducted under liquefaction temperature of 90°C. Therefore, it is more efficient to use the conditions from experiment 1, due to the higher concentration of the desired product, as well as energy savings due to the application of lower liquefaction temperature.

The results obtained after bioethanol fermentation in a 14-liter bioreactor, content of bioethanol as well as reducing sugars [6] obtained after hydrolysis of starch were measured during the course of fermentation and the obtained results are shown on the figure 1.

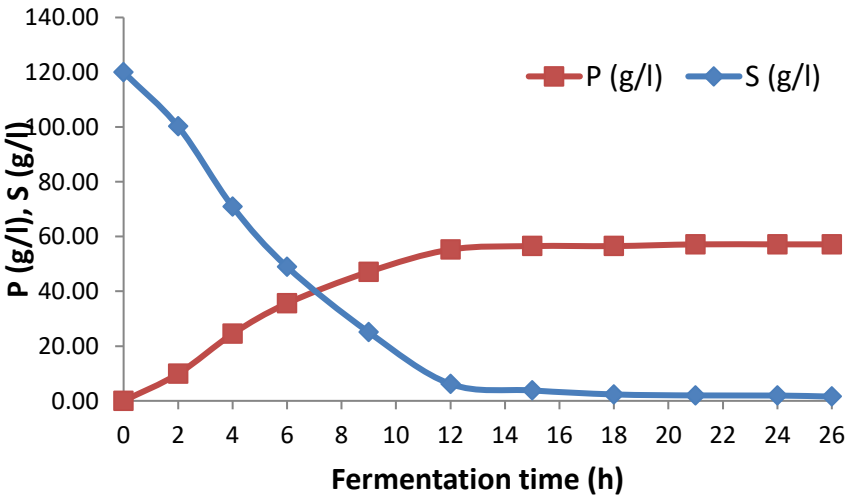

Figure 1. Bioethanol (P) and reducing sugar (S) content obtained during bioethanol fermentation with *Saccharomyces cerevisiae* in a laboratory-scale bioreactor

Under applied experimental conditions, the obtained concentration of bioethanol was 57.1 g/L. The conversion of reducing sugars is 98.7%, while the yield of sugar to ethanol is 89.5%. Changes in the concentration of substrates and products are intense during the first 14 hours of fermentation, after which the intensity decreases and based on the course of fermentation, it can be concluded that it is necessary to shorten the fermentation time. The content of nitrogen in stillage obtained after distillation of fermentation broth was determined and has a value of 4.3 (% m/m).

Conclusion

The obtained results showed that shrunken and damaged wheat grains as a milling industry by-product can be used as raw material for the production of bioethanol, during which bioprocess stillage is obtained that can potentially be used as animal feed. Further research should encompass further optimization of pretreatment and hydrolysis of raw material, optimization of milling industry by-product based media as well as fermentation parameters in order to increase yield and quality of the desired products.

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