Energy-saving simultaneous saccharification and fermentation of cereal native starch

Ewelina Strąk-Graczyk, MSc

Supervisor: Maria Balcerek, Prof.

Auxiliary supervisor: Katarzyna Pielech – Przybylska, Assoc. prof.

Abstract

The aim of the conducted research was to optimize the energy-saving method of simultaneous saccharification and fermentation of native cereal starch (rye, triticale and wheat). The influence of the conditions of native starch hydrolysis and cereal mash fermentation was analyzed (analysed) in order to ensure efficiency of the process and the quality of the obtained distillate.

Comparative analysis of the raw materials, i.e. rye, wheat and triticale used in the research, and the assessment of their technological usefulness as distillery raw materials in the process of simultaneous hydrolysis and fermentation of native cereal starch confirmed their high starch content and the presence of characteristic changes (grooves and pores) on the surface of the granules of the analyzed(analysed) cereal starches, which determined the effectiveness of the native starch hydrolysis process, confirmed by graphic SEM analysis.

The preparation of rye mashes using the native starch hydrolysis method in relation to the methods of preparing sweet mash commonly used in Polish distilleries, i.e., pressure-thermal and non-pressurized starch release was compared. The obtained results confirmed that gelatinization of starch is not a necessary stage of the process in order to carry out efficient alcohol fermentation of rye mashes with Saccharomyces cerevisiae yeast, however, the process requires further optimization in order to reduce the concentration of dextrins in attenuated mashes. The work also attempts to optimize the conditions for enzymatic hydrolysis of rye starch (so-called activation) by assessing the effect of dry matter content in the mash, temperature and time of starch activation, as well as by adding supporting enzymes such as xylanase, cellulase and pullulanase, on the course of the process and fermentation efficiency. It was shown that the higher content of dry matter in the mash resulted in an increase in the concentration of reducing sugars, however, it did not show a proportional improvement in the efficiency of the process. The activation stage (at 35 °C, 60 min), in the process of native starch hydrolysis, improved the release of reducing sugars and high fermentation efficiency. The use of treatment with enzyme preparations containing xylanase and cellulase had a positive effect on the increase in fermentation efficiency.

Due to the inhibitory effect of the increased content of dry matter in sweet mashes on the efficiency of ethanol, the possibility of using the periodic-addition method in the process of simultaneous hydrolysis and fermentation of native rye starch was also assessed, while controlling the course and efficiency of the process. The results of the research showed that two-stage dosing of the raw material with a 24-hour interval brings measurable benefits in the form of improved efficiency of the fermentation process. The impact of rye grain grinding on the efficiency of hydrolysis and fermentation was also assessed, using two different amounts of fractions (75 and 85 %) with a diameter < 25 mm and grain conditioning treatment before grinding (25 % humidity). The analysis of the results showed that from the evaluated variants, only the one with a greater degree of raw material fragmentation was characterized by a higher efficiency of the process, with comparable sugar utilization by yeast.

In order to optimize the process of simultaneous saccharification and fermentation of native starch, taking into account the need to maintain the microbiological purity of the mash, a key criterion determining the quality of the obtained grain distillates, the study examined the effect of the addition of Isostab® solution containing hop α-acids on the number of lactic acid bacteria in fermentation samples prepared by cold hydrolysis. The use of hop α-acids reduces the growth of lactic acid bacteria during fermentation has been shown. Compared to the control sample (without the addition of Isostab®), the logarithm of cfu ml-1 of bacteria decreased from 6,74±0,30 to 3,18±0,1 in the attenuated mash with the addition of Isostab® (the initial pH of the mash was 4), along with a significant increase of fermentation efficiency.

The cereals distillates obtained as part of the research in terms of the content of aldehydes and methanol in them were evaluated. Particular attention was paid to acetaldehyde, which is a qualitative indicator of spirits. Rye distillates were characterized by the lowest concentration of this compound in relation to triticale and wheat distillates was shown that. Comparing distillates obtained after fermentation of mashes prepared by the barothermic method and non-pressure methods (classical and native starch hydrolysis), the lowest concentration of acetaldehyde, in accordance with the normative recommendations (PN-A-79523) (< 0,1 g l-1 of 100 % vol. spirit), in distillates from mashes prepared with the use of native starch hydrolysis was determined. In addition, the fermentation of mashes with an increased dry matter content (> 25 %) was found, as well as the use of additional treatments in the form of raw material conditioning, starch activation and the introduction of supporting enzymes (xylanase with cellulase) increase the concentration of acetaldehyde in distillates. However, the introduction of antibacterial protection through the addition of hop α-acids should be considered beneficial in the context of reducing the concentration of aldehydes.

Cereal distillates with a low content of methanol were characterized. Nevertheless, that in spirits obtained after fermentation of mashes containing native starch, it was noticed, the concentration of this compound decreased (49,606±3,730 mg l-1 sp. 100 % vol.) about the methanol content in rye spirits obtained from mashes prepared by methods commonly used in distilleries, such as BUS (67,174±3,359 mg l-1 sp. 100% vol.) and the pressure-thermal method (74,047±3,702 mg l-1 sp. 100 % vol.).

The presented research results in the framework of the discussed work enable the use of native application hydrolysis methods for the production of grain distillates with a focus on food purposes. The introduction of this solution to industrial practice makes it possible to reduce production costs while maintaining the appropriate quality of the final product.