# Explosive decompression pretreatment in lignocellulosic ethanol production


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## Introduction

In this work two gases – nitrogen and compressed air are utilized for pressure generation and different pressures (1-60 bar) and temperatures (25-175°C) were applied to barley straw to evaluate the efficiency of the pretreatment. The explosive decompression pretreatment is a new method where no catalysts or chemicals are used in the process thereby, making it economically and environmentally attractive.

The method is based on sudden change in the gas volume, which breaks the cell walls and opens the biomass structure thereby, resulting in increased surface area of the substrate for enzymatic hydrolysis. In this work two gases, $N_2$ and compressed air, were used to elevate pressure. The pressurized air contains 78% of $N_2$ and thus, was used to estimate the potential to use it as a more economical pressure agent than $N_2$.

The pretreatment was followed by enzymatic hydrolysis and fermentation. Resulting glucose and ethanol concentrations were measured to estimate the most suitable set of pretreatment conditions and evaluate the possibilities of using compressed air as a cheaper alternative to nitrogen gas.

## Explosive decompression - method

During the pretreatment the small $N_2$ molecules penetrate more efficiently into the biomass fibres and biomass cells will be filled with solution saturated with dissolved gases. The increased temperature and pressure will increase the dissolution of gases, increase the diffusion of gases into biomass and additionally, start the autohydrolysis of biomass. When the pressure is suddenly decreased, the dissolved gas expands and sudden change in volume opens the cellulosic structure of biomass and thereby, increases the accessible surface area of biomass for further enzymatic hydrolysis.

## Explosive decompression - instrumentation

The simplified schematic of the pretreatment equipment is shown in figure 1.

For pretreatment, 100 g of dry biomass was weighed, placed into a pressure vessel and mixed with distilled water. The vessel was closed with customized pressure cap and pressurized with $N_2$ gas or compressed air to pressures of 1 to 60 bars and then heated to temperatures of 25-175°C. After the heating, the reactor was cooled down to 80 °C and pressure was released through a valve in an explosive manner.

The samples were cooled to a temperature below 50°C for enzymatic hydrolysis, followed by fermentation with dry yeast. The glucose and ethanol concentrations of the samples were measured and analyzed in order to find the most suitable pretreatment conditions.

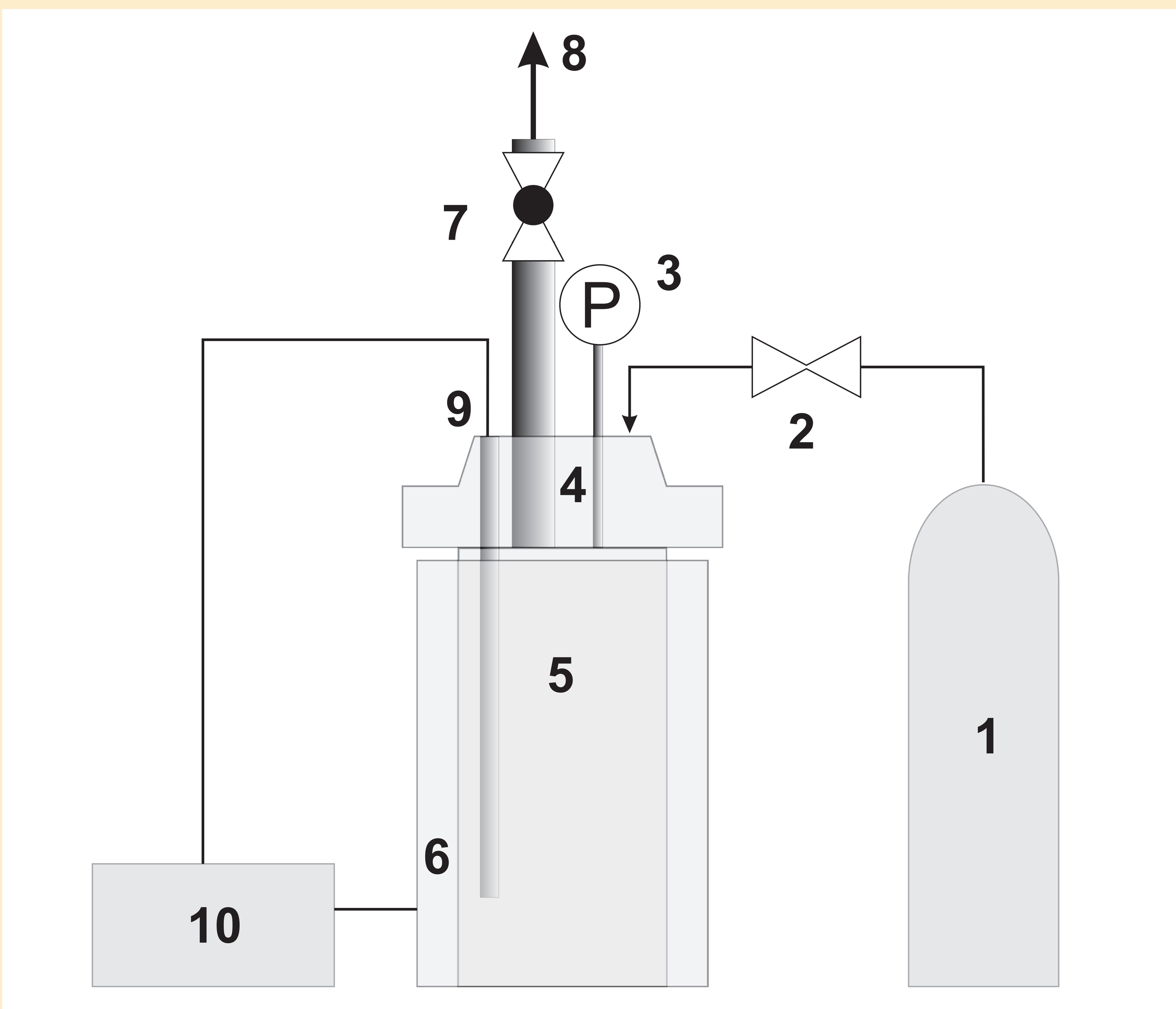


Figure 1 The schematic of explosive decompression device: 1- nitrogen or air tank, 2- pressure control valve, 3- manometer, 4- modified reactor vessel cap, 5- reactor vessel, 6- ceramic contact heater, 7- pressure release valve, 8- into ventilation system, 9- thermocouple, 10- controller unit

## Glucose yield

Using compressed air for pretreatment, a 68% increase in glucose yield can be seen as shown in figure 2A when the temperature was increased from 100°C to 150°C. The explosive pretreatment with compressed air had little to no effect on the glucose yield, which was approximately the same as with autohydrolysis.

However, in case of explosive decompression with $N_2$ gas, a sharp - 218% increase in glucose yield was noted when the pretreatment temperature was increased from 100°C to 150°C. At 150°C explosive decompression with $N_2$ gas enabled to gain 95% higher glucose yield than when using explosive decompression with compressed air or autohydrolysis.

Figure 2B illustrates the effect of pretreatment pressure to the glucose yield of biomass at 150°C. As can be seen, the pretreatment pressure has little effect on the glucose yield of biomass and the glucose yields change only to a small degree. However, the pretreatment with $N_2$ gas enabled to gain 90-150% higher glucose yield than when compressed air was used for pretreatment.

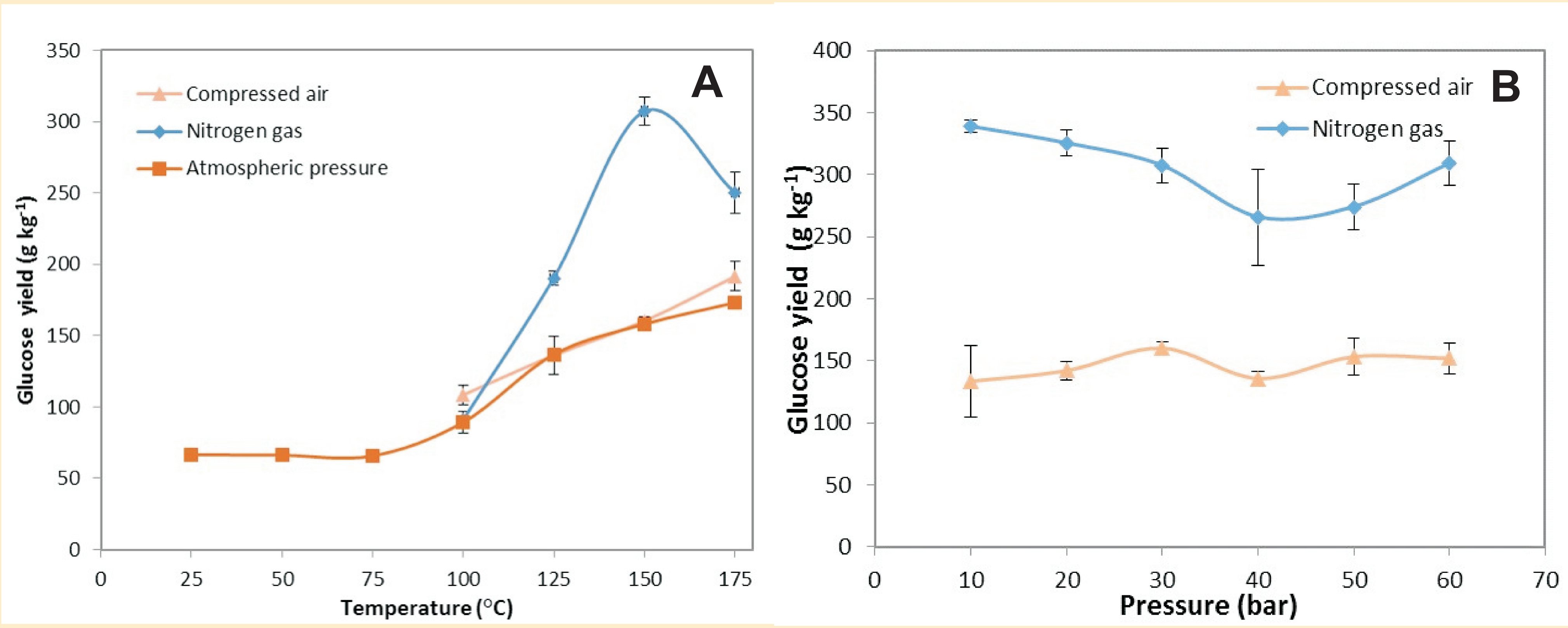


Figure 2 The glucose yields with different pretreatment gases when the pretreatment temperature (A) or pressure (B) was gradually increased

## Ethanol yields

The ethanol yields increased as the pretreatment temperature was increased. The highest ethanol yields were gained at 150°C while at temperatures higher or lower than 150°C lower ethanol yields were gained. At these conditions, 82 g ethanol per kg of biomass was gained when only autohydrolysis was applied. Highest ethanol yield – 113 g per kg of biomass was gained when explosive decompression pretreatment was used with nitrogen gas. The increased ethanol yields gained with nitrogen gas in pretreatment was expected since the glucose yields at these conditions were more than two times higher.

The ethanol yields decreased significantly when temperature above 150°C was used. The sharp decrease in ethanol yield can be attributed to formation of inhibiting compounds at higher pretreatment temperatures.

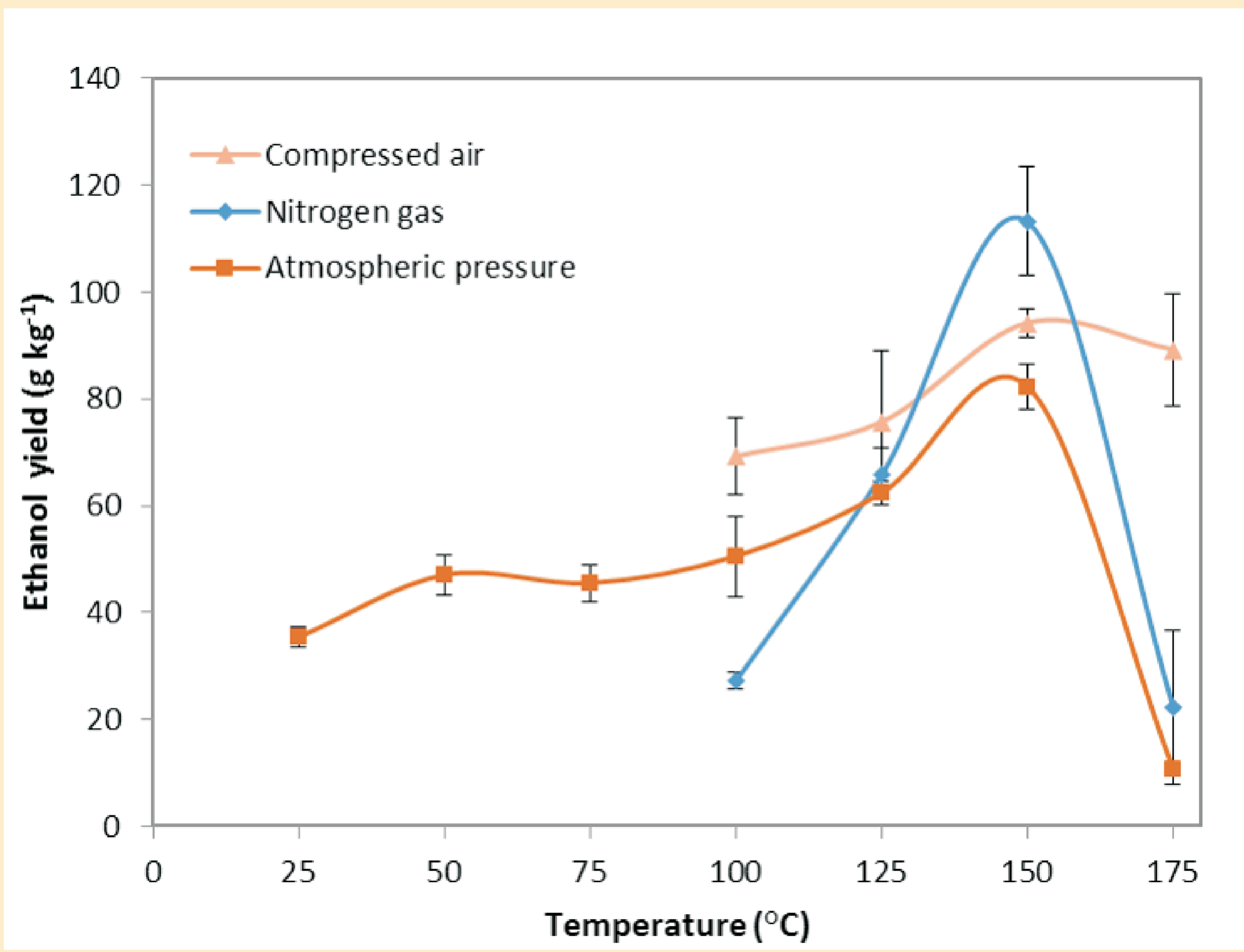


Figure 3 The ethanol yields with different pretreatment gases when the pretreatment temperature was gradually increased

## Conclusions

- Nitrogen is most suitable pressure agent for explosive decompression pretreatment
- Highest glucose and ethanol yields were gained at 150°C and 30 bars
- Even though the presence of pressure and its explosive release has effect on the biomass, the extent of pressure has negligible effect on the pretreatment process
- Explosive decompression with compressed air resulted similar glucose yield as autohydrolysis
- Although the pressurized air contains 78% of $N_2$, it does not effectively penetrate into the biomass cells and therefore, it is not as effective for use in explosive pretreatment of biomass as pure nitrogen gas.
- By choosing the suitable gas for pressure elevation and temperature combination considerably higher glucose yields can be gained.