Optimization condition for steam explosion pretreatment of lignocellulosic cassava root fiber

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Abstract

Lignocellulosic cassava root fiber obtained after acid saccharification of residual starch from cassava waste pulp was pretreated by steam explosion method. Optimal condition for the pretreatment was 6% (w/v, dry weight) substrate loading, 180 °C for 5 min. Hydrolysis of the pretreated lignocellulosic fiber by cellulase for 6 h yielded reducing sugar 3.73 g/100 g.

Keywords: steam explosion, cassava waste pulp, lignocellulose, pretreatment

Introduction

Cassava waste pulp, a solid waste of cassava starch production, produces annually 25 million ton in Thailand (United Nation Conference on Trade and Development. 2010). It contains, in general, residual starch 60-70% (w/w). After the starch was extracted from the cassava waste pulp, residual solid was lignocellulosic cassava root fiber which was 11.2% (w/w) (Akaracharanya et al. 2011).

The lignocellulosic cassava root fiber composed of cellulose 59.9%, hemicellulose 20% and lignin 10.7%; (w/w) (Akaracharanya et al. 2011). Due to the high content of cellulose and small particle in size (20-40 meshes), the lignocellulosic fiber is interesting source of fermentable sugar for second generation bioethanol production. However, to maximize cellulolytic hydrolysis of the cellulose component, efficient pretreatment to separate hemicellulose and lignin from the cellulose component is required.

Steam explosion is a physico-chemical pretreatment method which lignocellulosic substrate is subjected to high temperature (160 ^{o}C-260 ^{o}C) and high pressure (0.69-4.83 MPa) for a short time. Under this condition, hemicellulose and lignin are degraded and separated from the cellulose component (Sun et al. 2002).

In this study, optimal condition for steam explosion pretreatment of HCl-impregnanted lignocellulosic cassava root fiber obtained after acid saccharification of residual starch in cassava waste pulp by HCl was optimized.

Methodology

Preparation of lignocellulosic cassava root fiber

Cassava waste pulp was collected from Sanguan Wongse Industries, Nakhonratchasima province, Thailand and kept at -20 °C until use. The cassava waste pulp was thawed at room temperature, weighted, analysed for moisture content by drying at 70°C until weight was constant, and analysed for chemical composition at Department of Science Service, Ministry of Science and Technology, Bangkok. Lignocellulosic cassava root fiber was prepared by suspending one gram (dry weight) of the cassava waste pulp in 10 ml of 1N HCl and autoclaved at 121 °C for 15 min (Thongchul et al. 2010). After autoclaving, lignocellulosic cassava root fiber (solid residue) was harvested by filtration using stainless mesh.

Chemical composition analysis

Chemical composition of the lignocellulosic cassava root fiber was determined according to TAPPI (Technical Association of the Pulp and Paper Industry) analytical procedures ; acid insoluble lignin (T222 om-02), holocellulose (TAPPI Section), alpha-cellulose, beta-cellulose and gamma-cellulose (TAPPI T203 cm-99) at Department of Science Service, Ministry of Science and Technology, Bangkok.

Steam explosion pretreatment

The lignocellulosic cassava root fiber was steam explosion pretreated by pressure reactor (1L reactor, 4523 Parr Instrument Company, USA) using 6% (w/v, dry weight) substrate loading at 180 °C for 5 min. The pretreated lignocellulosic fiber was washed with distilled water until pH was neutral. Then, it was suspended at 10% (w/v, dry weight) in 100 mM Sodium-citrate buffer pH 5.0 and hydrolyzed by cellulase (Accellerase^{TM} 1500, Genencor, Finland), at 14,685 CMC units/g (and 3,594.89 pPNG units /g) at 50 °C for 6 h. Supernatant obtained after centrifugation at 4 °C, 8000 rpm for 5 min was analysed for reducing sugar by Somogyi-Nelson method (1952) and for glucose by glucose analyzer (YSI, model 7100, USA). The pretreatment condition was optimized by univariation of substrate loading (2%, 6% and 10%, w/v), pretreatment temperature (160, 180 and 200 °C) and pretreatment time (2, 5 and 10 min). The condition which gave the highest reducing sugar in previous experiment was used in following experiments.

Results

Chemical composition

Chemical composition of lignocellulosic cassava root fiber is shown in Table 1. Cellulose and hemicellulose contents were 59.9 and 20% (w/v) respectively. The moisture content of the lignocellulosic cassava root fiber was 40% (w/w), wet weight.

Table 1 Chemical composition of lignocellulosic cassava root fiber

Components	% Content (dry weight)
Lignin	10.7
Holocellulose	79.9
Alpha-cellulose	59.9
Beta-cellulose	4.6
Gamma-cellulose	15.4

Optimum condition for steam explosion pretreatment

Lignocellulosic cassava root fiber was subjected to steam explosion pretreatment at 180 °C for 5 min by varying substrate loading at 2%, 6% and 10% (w/v, dry weight). Then, the pretreated lignocellulosic fiber was further hydrolyzed by cellulase for 6 h. Supernatant obtained after centrifugation was analysed for reducing sugar. As shown in Fig. 1, maximum reducing sugar (3.70 g/100 g) was obtained when the lignocellulosic fiber was pretreated at 6% (w/v, dry weight) substrate loading.

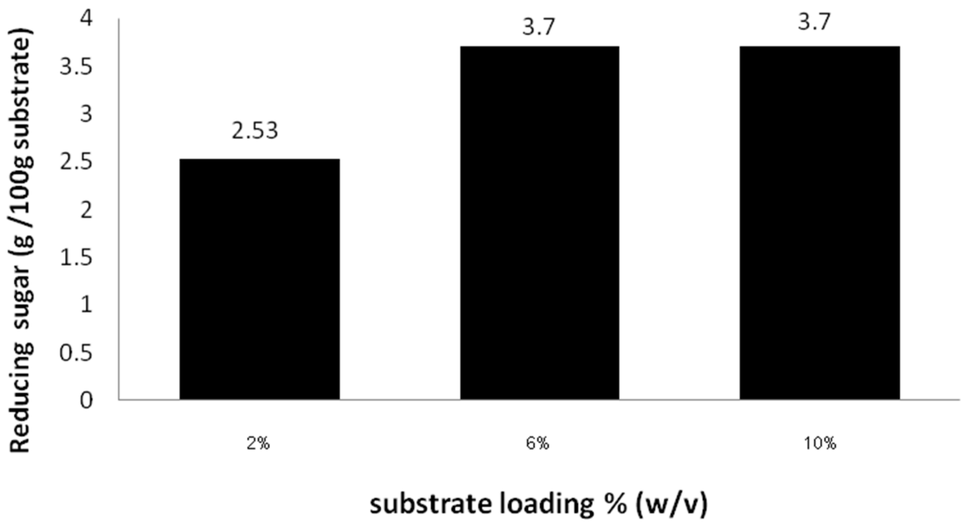

Figure 1: Effect of substrate loading on reducing sugar liberation

After the steam explosion pretreatment was performed at various temperature (160, 180 and 200 °C) for 5 min using 6% (w/v, dry weight) substrate loading, hydrolysis of the pretreated lignocellulosic fiber by cellulase, maximum reducing sugar (3.73 g/ 100 g) was released when the pretreatment was performed at 180 °C (Fig. 2).

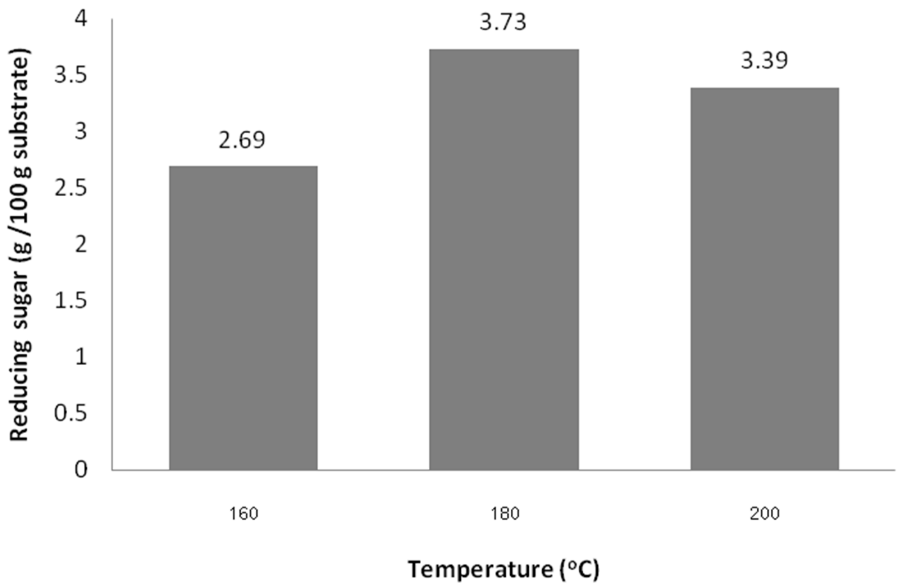

Figure 2: Effect of pretreatment temperature on reducing sugar liberation.

Steam explosion pretreatment of lignocellulosic cassava root fiber was performed by using 6% (w/v, dry weight) substrate loading and 180 °C at various pretreatment time (2, 5 and 10 min). Maximum reducing sugar was obtained when the lignocellulosic fiber was pretreated for 5 min (Fig. 3).

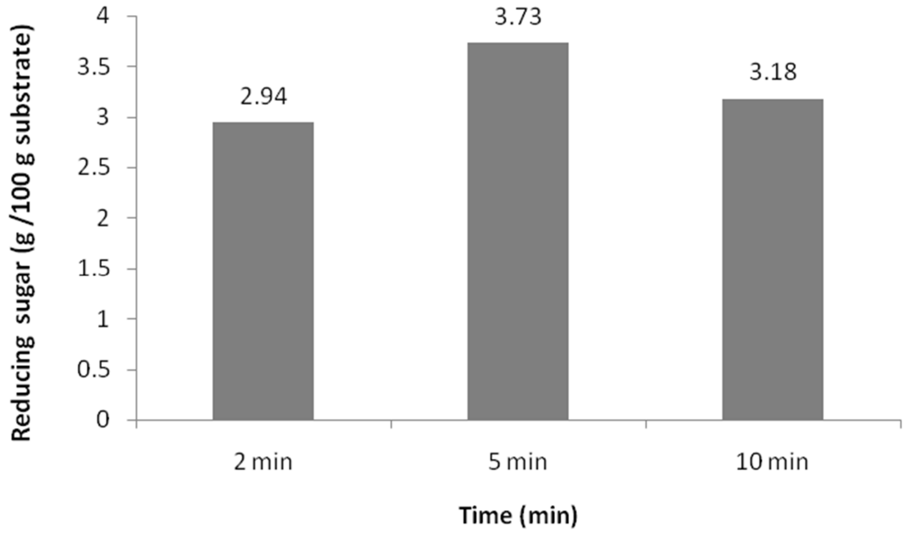

Figure 3: Effect of pretreatment time on reducing sugar liberation.

Discussion

Lignocellulosic cassava root fiber used in this study was obtained after acid saccharification of residual starch in cassava waste pulp by HCl. It was HCl-impregnanted lignocellulosic fiber. The lignocellulosic fiber pretreated at optimized condition (6% (w/v) substrate loading, 180°C, 5 min) released maximum reducing sugar (3.73 g/ 100 g) after hydrolysis by cellulase for 6 h. The pretreatment of wheat straw by steam explosion at 210°C and 10 min was increasing yield of reducing sugar (177.3 g/kg DS) (Zabihi et al. 2010).

Conclusion

Optimal condition for steam explosion pretreatment of lignocellulosic cassava root fiber were 6% (w/v, dry weight) substrate loading, 180 °C for 5 min.

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