Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(2):475-479

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

An experimental study on the influencing factors of the biomass pretreated by steam explosion

Wang Xutao, Zhou Hengtao and Li Tiantian

Henan University of Urban Construction, Pingdingshan, China

ABSTRACT

This study experimentally investigated the influences of the varieties, granularity, moisture content, and loading density of biomasses on the steam explosion pretreatment effect. The steam explosion lasted for 120 s under pressure of 2.0 Mpa. The study results suggested that different biomass varieties show different sensitivities to the steam explosion treatment. The biomass with higher hemicelluloses content exhibited the optimum blasting effect. For corn straws, the reducing sugar yield and steam explosion treatment effect maximized at granularity of 20~30 meshes, with moisture content of 10%, and loading density of 80% respectively.

Keywords: Steam explosion pretreatment; influencing factors; lignocelluloses, reducing sugar

---

INTRODUCTION

In China, the waste biomass achieves a biomass resources quantity of 6.42×10^8 t standard coal every year, including 3.22×10^8 t standard coal of the straws of corn, rice, and wheat[1]. These biomasses are valuable renewable resources. In the times that energy determines the development, the reasonable and effective utilization of such biomasses have attracted increasing attentions. There are a lot of researches concerning the transformation from straws to solid, liquid, and gaseous clean fuel [2-5]. However, due to the special structures of the cell wall compositions of straw, including cellulose, hemicelluloses, and lignin, the cellulose in the straw are hard to be separated [6-8]. The transformation and utilization of straw are thereby affected.

Steam explosion is a pretreatment method by dissolving partial hemicelluloses at high temperature and blasting the biomass cell wall to realize the separation of cellulose and lignin [9]. This paper mainly studied the varieties, granularity, moisture content, and loading density of biomass on the steam explosion pretreatment effect. It was expected to find the main influencing factors and the optimum processing condition to improve the transformation efficiency and increase the technical economy and competitiveness of biomass straw [10, 11].

EXPERIMENTAL SECTION

Raw materials

The corn straws used in the test was got from the Shancheng District of Hebi City in China. The corn straws were prepared into grains in size of 1~3 cm, 1 ~ 6 mm, and 20 ~ 30 mesh respectively. The corn cobs were crushed to grains of 1~3mm. Green corn straws were prepared into grains of 1 ~ 6 cm.

Steam explosion treatment

Steam explosion on the raw materials lasted for 120 s at pressure of 2.0 Mpa using the Hebi Zhengdao QB-100 steam explosion machine.

The measurement on the lignocelluloses content in the materials
The lignocelluloses content was measured using Van Soest fiber measurement method.

The measurement of reducing sugar
The reducing sugar was measured by dinitrosalicyclic acid colorimetry (DNS).

RESULTS AND DISCUSSION

Biomass variety
Different kinds of biomass raw material are disparate in aspects of chemical composition, surface structure, and contents of cellulose, hemicelluloses, and lignin. Therefore, they show disparate sensitivities to the steam explosion pretreatment, which affects the treatment effect of steam explosion.

The composition variations of different biomass varieties
Table 1 shows the contents of hemicelluloses, cellulose, and lignin in three biomass varieties before and after steam explosion. As shown in Table 1, the compositions in the cell wall of the biomasses treated by steam explosion present certain variations, which are mainly represented as the great reduction of hemicelluloses content. The hemicelluloses content in the corn cobs shows the highest reduction (from 38.7% to 8.63%). After explosion, the cellulose content in the corn cob sees a slight increase. However, in the corn straw grains of 1~3 cm and green corn straws, the cellulose content slightly increases possibly attributing to the excessive reduction of hemicelluloses content in corn cob after explosion. The lignin content slightly decreases in the corn cob and green corn straw while slightly increases in corn straw.

Table 1 The main compositions of the three main biomass varieties

biomass	Cellulose wt/%		Lignin wt/%		Hemicelluloses wt/%	
	Before explosion	After explosion	Before explosion	After explosion	Before explosion	After explosion
Corn straw	36.8	35.31	10.4	11.67	27.4	7.57
Corn cob	35.6	37.32	16.3	11.68	38.7	8.63
Green corn straw	36.2	35.66	18.7	16.31	20.2	6.41

The reducing sugar yields of different biomass varieties
The reducing sugar yields of the corn cob; the corn straw grains in granularity of 1~3 cm and green corn straw are 12.23%, 8.75%, and 7.67% respectively. The corn cob and green corn straw shows the highest and lowest reducing sugar yields respectively, while the reducing sugar yield lies between the two. The three biomass varieties display different sensitivities to the steam explosion treatment.

The granularity of biomass
The process of stream explosion is indicated as follows: high pressure steam is infiltrated into the cell wall via the microspores on the surface of biomass. After keeping for a certain time, the pressure is instantaneously released to the atmospheric pressure to destroy the cell wall structure and degrade the biomass in turn. The crushing degree of biomass changes the permeability of the surface structure and thus exerts certain influences on the explosion treatment effect. In this study, three kinds of corn straws, which are in granularities of 1 ~ 3cm, 1 ~ 6 mm, and 20 ~ 30 mesh respectively, were used in the experiment.

The composition variations of the corn straws with different granularities
Figure 1 shows the contents of hemicelluloses, cellulose, and lignin in the corn straws of the three granularities before and after steam explosion. The largest variation is observed on the content of hemicelluloses. The smaller the granularity, the larger the reduction amplitude. At the granularity of 20~30 mesh, the hemicelluloses reduces to 7.41% (the largest reduction amplitude). The hemicelluloses contents of the corn straws in granularities of 1~3 cm, 1~6 mm, and 20~30 mesh are 48.61%, 31.5%, and 27.04% of the original contents respectively. The degradation rate difference between the corn straws in granularity of 1～6 mm and 20~30 mesh are easy to be recognized, while the differences between the hemicelluloses contents of the corn straws in granularity of 1~6 mm and 20~30 mesh are insignificant after steam explosion. This phenomenon suggests the convergence of the treatment effects of the steam explosion on the corn straws in granularity of 6 mm below. Moreover, the influences of granularity variation on hemicelluloses content are insignificant in. Therefore, to reduce energy consumption of biomass energy conversion and improve the competitiveness of technology, it is no need of crushing the corn straws into the granules of 6 mm below. The lignin content increases with the reduction of the granularity of corn straw. The cellulose content presents an irregular variation with the reduction of the granularity of corn straw.

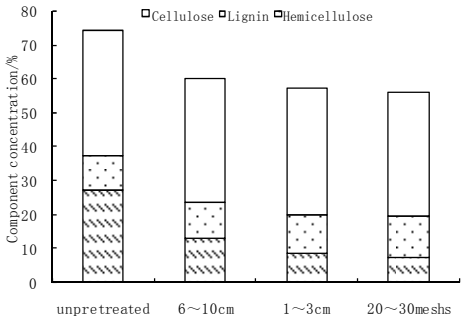

Fig 1 The composition of different granule corn stalk before and after explosion

The reducing sugar yields of the corn straws in different granularities

The reducing sugar yields of the corn straws in granularities of 1~3 mm, 1~6 mm, and 20~30 mesh are 7.71%, 8.75%, and 10.27% respectively after steam explosion. The smaller the granularity of the corn straw, the higher the reducing sugar yield. The reducing sugar yield of the corn straws in granularity of 20~30 mesh (the finest one) are 33.2% and17.4% higher than those of granularities of 1~3 cm and 1~6 mm. It can be seen that the granularity shows more influences on the reducing sugar yield than on other compositions.

Moisture content

Moisture content affects the difficulty (or ease) of high pressure steam entering into the biomass cell wall, time, and steam consumption amount in the steam explosion process. Subsequently, it determines the effective dissolving amount of hemicelluloses in steam explosion and the effect of steam explosion.

The composition variations of the corn straws with different moisture contents

As shown in Figure 2, the contents of cellulose and lignin of corn straw present insignificant variations with the initial moisture content in the corn straws, while the hemicelluloses content fluctuates significantly with the variation of initial moisture content. In the initial moisture content of 50% below, the hemicelluloses content presents an increasing trend with the growing of the moisture content in the corn straws. In the case of the initial moisture content exceeding 50%, the hemicelluloses content tends to be stable after steam explosion. The steam treatment effect is weakened. Thus steam explosion is inapplicable in this condition.

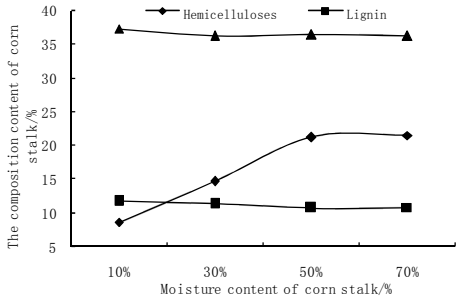

Fig 2 The lignocelluloses composition content of different moisture content corn stalks after explosion

The reducing sugar yields of the corn straws with different moisture contents

Figure 3 describes the reducing sugar yields of the corn straws with different moisture contents after steam explosion. The moisture content is intensively correlated with the reducing sugar yields. Increase of reducing sugar reduces the reducing sugar yields in steam explosion. This attributes to that the increase of moisture content changes the environmental condition for the hemicelluloses degradation by high-temperature steam. Under lower moisture content, insufficient moisture content in the steam explosion decreases the shear stress in the vaporization of water and thus weakens the explosion effect and the reducing sugar yields [9]. Test results implied that the reducing sugar yields are optimum at moisture content of 10% about in the steam explosion.

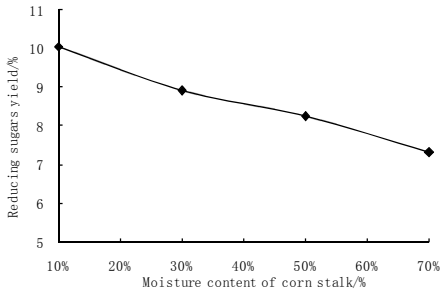

Fig3 Reducing sugar yields of different moisture content corn stalks after explosion

The loading density of the biomass materials

In the steam explosion, the loading density, namely, the dense degree of the biomasses (corn straw) filled in the explosion cylinder of steam explosion device affects the steam explosion effects. Given relatively higher loading density, steam has a hard access to the biomasses in the center of the explosion cylinder. Moreover, the half-explosion induced by the short duration of the steam explosion reduces the steam explosion effect. On contrast, low loading density is prone to lead to the increase of energy consumption in the treatment.

The composition variations of the corn straws in different loading densities

Table 2 shows the test results of the biomasses in loading density of 60%, 80% and 100% respectively. After explosion, the hemicelluloses content increases, while the cellulose content gradually reduces with the rise of loading density. In addition, the lignin content shows small and irregular variations. The test results suggest that, the lower the density, the more intensive the effect of steam to the biomasses, and the more the hemicelluloses dissolved and degraded in the steam explosion.

Table 2 The composition variations of the biomasses in different loading densities

Loading density	Hemicelluloses/%	Cellulose/%	Lignin/%
100%	8.05	34.05	9.84
80%	7.86	34.75	9.16
60%	5.59	37.61	10.37

The reducing sugar yields of the corn straws in different loading densities

The reducing sugar yields of the corn straws in loading density of 100%, 80%, and 60% are 7.61%, 8.38%, and 7.45% respectively. The corn straw with loading density of 80% therein show the highest reducing sugar yield, while that with loading density of 60% present the lowest one. The possible reason lies in that hemicelluloses are partially degraded into inhabiting substances such as aldehydes with the intensifying of the steaming and boiling effect of high temperature steam.

CONCLUSION

(1) Different biomass varieties show disparate sensitivities to the steam explosion. Under pressure of 2.0 Mpa and steam explosion duration of 120 s, the corn cob with higher hemicelluloses content is most sensitive to the steam explosion, while the green corn straw with higher moisture content and denser structure exhibits the poorest explosion effect.

(2) With the reducing of the biomass granularity in steam explosion, the reducing sugar yield increases in a smaller amplitude. However, it tends to be convergent under granularity of 6 mm below. In this condition, the continuous reduction of granularity contributes less to the steam explosion effect gradually. Therefore, the corn straws in granularity of 6 mm around are more suitable for the steam explosion pretreatment, while the corn straws in much smaller granularity is prone to increase the energy consumption in the treatment process.

(3) The moisture content of the corn straw is intensively correlated with the reducing sugar yield. The steam explosion effect reaches to the optimum state at moisture content of 10% around. The constant increase of moisture content weakens the steam explosion effect, while insufficient moisture content is prone to induce the carbonization of biomasses. Therefore, the excessive or insufficient moisture contents both reduce the reducing sugar yields.

(4) The loading density of the biomasses exerts certain influences on the steam explosion effect. Unfortunately, the influences are irregular. At loading density of 60%, the reducing sugar yield is minimized, while the reducing sugar

yields at loading density of 80% and 100% exhibit insignificant differences. Considering the treating ability of the device, it is suggested to set the loading density at 100%.

Acknowledgements
The authors express their sincere thanks to Henan Agricultural University, Government of China, Henan Province, for having the financial assistance under minor research project. They also thank B.L. Zhang, J.H. Liu and X.T. Zhao for technical assistance.

REFFERENCES

[1]Zhang Bailiang, Wang Jiqing, Xu Guizhuan, Yang Shiguan, Song Andong, Wang Xutao. *Transactions of the CSAE*, **2009**, 25(9)：226-231.
[2]T Jeoh, F A Agblevor. *Biomass and Bioenergy*, **2001**, (21): 109-120.
[3]F Alfani,A Gallifuoco,A Saporosi.*Journal of Industrial Microbiology & Biotechnology*, **2000**, 25: 184-192.
[4]MA Tijjani, FI Abdurahman, SW Buba, GI Mala, JC Akan, BKM Aji, AS Abdullahi. *J. Chem. Pharm. Res.*,**2012**, 4(5):2409-2414.
[5]SS Nair, CM Nithyakala, IG Noronha, N Sultana, BV Somashekharaiah. *J. Chem. Pharm. Res.*, **2012**, 4(7): 3529-3534.
[6]Wang Xutao, Zhang Bailiang, Song Andong, Luo Zhihua, Ren Tianbao. *Transactions of the CSAE*, **2008**, 24(8): 189-192.
[7]J Manjunathan, V Kaviyarasan. *J. Chem. Pharm. Res.*, **2010**, 2(3):575-578.
[8]Pankaj Saikia, Dibakar Chandra Deka. *J. Chem. Pharm. Res.*, **2013**, 5(3):117-121.
[9]Chen Hongzhang,Li Zuohu. *Journal of Cellulose Science and Technology*, **2002**, 10(3): 47-51.
[10]Zhang Bailiang. Bioenergy Technology and Engineering, 1st Edition, Science Press, Beijing, **2009**; 1-28.
[11]Liu Qingyu,Meng Fanlei,Zhang Min.*Renewable Energy Resources*, **2009**,2(3):40-42.