Study on the Pretreating Approaches for the Potato Straws

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Abstract. This paper proposes an approach to pretreat the potato straws. Specifically, potato straws are handled using various kinds of chemical solutions, including *HCI*, H_2SO_4, *NaOH* and $NaOH+H_2O_2$, under different concentrations. For each kind of solution, particular indicators, such as the cellulose content as well as scarification ratio of the treated straws, are studied in the paper. Based on orthogonal experiments, the best pretreatment effect is obtained by using the solution of 4% *NaOH* under temperature of 60º Celsius, solid-to-liquid ratio of 1:10, and processing time of 6d.

1 Introduction

In recent years, the resource comprehensive utilization becomes a hot topic both for the academia and the industry due to the excessive resource consumptions in the world. As a by-product of the crop production, straws are important and useful renewable resources. It is reported that the energy in 2-ton straws is equal to that in 1-ton coal. Utilization of straws is playing an increasingly more important role in agricultural production, natural resource development and environment protection. LOGEN in Canada [1] built a factory which made use of wheat straws to produce fuel ethanol in 2000. China has also made huge progress on utilizing cellulose to produce fuel ethanol in recent years. In the “863” Program of China [2], East China University of Science and Technology has built a factory on Fengxian, Shanghai, which made use of cellulose and could produce 600-ton fuel ethanol per year. Both of the two factories in Canada and China focused on using maize straws to produce fuel ethanol. However, there is no report of re-using potato straws as we know so far. In fact, potato production dominates the agriculture in Ningxia, China. There are over 1 million ton of potato straws produced per year in Ningxia, and traditionally, those straws are considered useless and thus stacked or even burned in the open air, resulting in amount of dust and fume, which takes greatly harm to the environment. Therefore, if we use those “useless” potato straws to produce fuel ethanol which is possible as verified by our experiments, natural resources would be re-used and environment could be protected. Thus, utilization of potato straws would take great advantages, especially be beneficial in Ningxia, China.

There is a technical bottleneck in the pretreatment of the potato straws, which is to enzymolyze the cellulose to get C_2H_6O efficiently. In the potato straws or other plants’ straws, the lignin and the hemicellulose are combined by a covalent bond and the cellulose molecule is hidden inside, resulting in a natural barrier which prevents the cellulose molecule from touching the enzyme. Furthermore, considering that lignin is not water-soluble and has a complex chemical formation, straws are quite difficult to be degraded. All of these make it difficult to enzymolyze the cellulose in straws, which could only reach a ratio of 10%~20% [3].

Therefore, in order to enzymolyze the cellulose efficiently, straws must be pretreated with the problem of lignin degradation solved. The pretreatment process has a direct effect on the hydrolyzing and saccharifying result of the cellulose enzyme.

Lots of research have been done on the pretreatment problem for the maize straws. There are mainly three pretreatment approaches: physical approach [4], [5], chemical approach, and the combined approach of both [6]. So far, many papers focused on the dilute acid hydrolysis method, which has reached great achievements. In this paper, based on the efforts mentioned in the reference papers, we conduct a series of experiments using *HCI*, H_2SO_4, *NaOH*, $NaOH+H_2O_2$ to treat the potato straws and measure the resulting scarification ratios. Finally, we find the best pretreatment solution for the potato straws based on our experiments.

2 Proposed Approach

2.1 Experimental Materials

2.1.1 Potato Straws

The potato straws in the experiment were collected from Xiji and Guyuan region. They were crushed after insolation, and then sifted using 70 mesh sieves.

2.1.2 Experiment Instruments

Our experiment instruments include the electronic scales SE-202F, which is from the instrument factory in Dongguan, Guangdong; the air dry oven J2X-9076 from Shanghai BoXun Industrial Co., Ltd; the vacuum pump SHB-IV from Zhengzhou ChangCheng Industry and Trade Co., Ltd; the beater 79-2 from Changzhou GuoHua Electrical Appliance Co., Ltd; the spectrophotometer UV-1750 from Shimadzu Company; and the oscillator ZD-85 from Changzhou GuoHua Electrical Appliance Co., Ltd.

2.2 Proposed Approach

2.2.1 Pretreatment Using Different Solutions

HCI: We conducted three different experiments using *HCI*. Each of them would use 10 g straws which are released in 250 ml iodine flasks. The difference of those three experiments is the concentration (1%, 2% and 3%) of corresponding *HCI* solutions used. Note that these three experiments share the same solid-liquid ratio (1:10) of the *HCI*. The iodine flask, with *HCI* solution and straws in it, is covered by the plastic wrap and sealed by the elastic rubber band, then pretreated for 5 d under the temperature of 20º Celsius. After that, the solution will be neutralized using alkali for 1 d and then fully rinsed with water. Finally, the solution would be dried under the temperature of 80º Celsius, and we take the record of corresponding loss rate of cellulose, hemicellulose and lignin as well as scarification ratio.

We also conducted different experiments with solutions of H_2SO_4, *NaOH* and $NaOH+H_2O_2$. The experimental process and configuration are same as applied in the *HCI* experiments.

2.2.2 Standard Glucose Curve Plotting

With this experiment, we record the absorption photometry of the standard glucose solution with DNS method [7] and then draw corresponding standard curve. In this experiment, we need 0.100 g solid glucose which has been dried for 2 hours under the temperature of 80º Celsius. The glucose then is dissolved with water in a flask and the solution is kept of 100 ml. Next, with 6 10-ml colorimetric flasks which have been washed and dried, we respectively put standard glucose solutions (1.0 mg/ml) of 0, 0.2 ml, 0.4 ml, 0.6 ml, 0.8 ml, 1 ml to corresponding flasks and then add distilled water to make sure finally the solution in each flask is 2 ml. Then we put 1.5 ml DNS to each flask, shake up, and heat the solution for 5 minutes. After cooling, we keep the solution at constant volume of 10 ml and record the absorption photometry with spectrophotometer in a 540 nm wave-length.

2.2.3 Experiment Process

Recording loss rate for the cellulose, hemicellulose and lignin: After the straws' pretreatment, straws are weighed and the amount of cellulose, hemicellulose as well as lignin are recorded. Based on those data, we can get corresponding loss rate. Note that the loss rate = (weight before pretreatment * amount of corresponding components – weight after pretreatment * amount of corresponding components) / weight before pretreatment * amount of corresponding components * 100.

Straws' enzymolysis and saccharization: we add 1 g straw, which has already been pretreated, 50 ml 0.1 mol/L HAc-NaAc (pH=4.8), 1 ml 2% cellulose solution, and 2 drops of toluene to a 100 ml trigonal tank with stopper. Then the tank is put to an oscillator (60 r/min) with constant temperature of 50º Celsius for 36 hours. Next we put 0.5 ml glucose solution to a 10 ml colorimetric tube, add 1.5 ml DNS, and shake up. The colorimetric tube is heated using boiling water for 5 minutes. When the solution is cooled, we keep it at a constant volume of 10 ml. Then we record the absorption photometry with spectrophotometer in a 540 nm wave-length. Besides, we also record corresponding absorption photometry for the straws' solution without cellulose under the same experimental configuration. Then the scarification ratio could be calculated using this equation: (absorption photometry with cellulose – absorption photometry without cellulose) * 0.9 * 10 * 51 * 10-3 / amount of the cellulose in straws after pretreatment * sample mass * 0.5 * 14.638.

Table 1. The element rate and loss rate in the sample after pretreatment.

Solution	The weight, element rate and loss rate in the sample after treatment (loss rate -> LR)						
	Weigh-t (g)	Cel-Lul-ose	LR	Hemi-cellul-ose	LR	Lig-nin	LR
1%HCI	8.99	36.2	15.1	16.39	32.2	5.36	42.1
2%HCI	8.44	36.6	14.2	15.38	36.4	5.20	43.8
3%HCI	8.28	37.0	13.3	15.10	37.5	5.13	44.5
1% H_2SO_4	8.65	39.5	7.36	17.96	25.7	7.12	23.0
2% H_2SO_4	9.28	38.6	9.50	16.80	30.5	7.23	21.8
3% H_2SO_4	8.51	38.4	9.96	15.90	34.2	7.40	20.0
1% NaOH	8.00	39.1	8.30	17.34	28.3	4.70	49.2
2% NaOH	8.21	39.0	8.65	16.92	30.0	4.20	54.6
3% NaOH	7.68	38.8	9.03	16.5	31.7	3.9	57.8
1% NaOH + H_2O_2	8.31	35.1	17.6	17.3	28.4	7.30	21.1
2% NaOH + H_2O_2	8.10	34.3	19.6	16.5	31.7	7.20	22.2
3% NaOH + H_2O_2	7.55	33.9	20.5	16.2	33.0	6.9	25.4

3 Experiment Results

3.1. The Amount and Loss Rate of the Cellulose, Hemicellulose as well as Lignin in the Sample

The amount and loss rate of the cellulose, hemicellulose as well as lignin in the sample ,which has been pretreated, is shown in Table 1, the weights of the samples before treatment are all 10 g.

According to Table 1, the sample pretreated by *NaOH+*H_2O_2 suffers from the greatest loss of cellulose, *HCI* for the loss of hemicellulose and *NaOH* for the loss of lignin.

3.2 The Standard Glucose Curve

The absorption photometry of the standard glucose solution is shown in Table 2. The weights of samples before treatment are all 10 g.

Table 2. Absorption photometry of the standard glucose solution.

concentration (mg/ml)	0	0.02	0.04	0.06	0.08	0.10
absorption photometry	0	0.302	0.595	0.888	1.209	1.438

Based on the data in table 2, we can get the standard glucose curve which is shown in Figure 1.

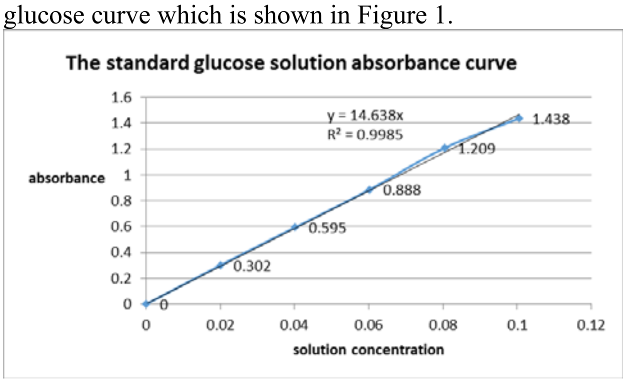

Figure 1. Absorption photometry curve of the standard glucose solution

3.3 The Scarification Ratio of Samples

The absorption photometry and scarification ratio of samples which have been pretreated with cellulose or without cellulose are shown in table 3, where the weight of sample before treatment is always 1 g. Based on data shown in table 3, we get the Figure 2.

Table 3. Scarification ratio of the samples after pretreatment.

solution	absorption photometry with cellulose	absorption photometry without cellulose	Scarific-ation ratio
1% HCI	0.428	0.057	6.43
2% HCI	0.580	0.014	9.70
3% HCI	0.693	0.004	11.68
1% H_2SO_4	0.645	0.034	9.70
2% H_2SO_4	0.487	0.049	7.12
3% H_2SO_4	0.404	0.002	6.60
1% NaOH	1.129	0.061	17.12
2% NaOH	1.192	0.023	18.82
3% NaOH	1.402	0.083	21.32
1%NaOH+ H_2O_2	0.617	0.066	9.83
2% NaOH+H_2O_2	0.570	0.023	10.0
3% NaOH+H_2O_2	0.797	0.154	11.9

According to Table 3 and Figure 2, the sample which is handled using *NaOH* has the largest scarification ratio.

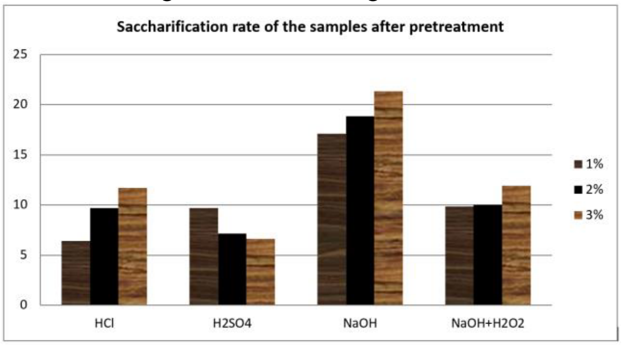

Figure 2. Sample scarification rate

Based on previous experiments, we conduct another orthogonal experiment with potato straw pretreated by *NaOH*. The control parameters in the experiment are the concentration of the *NaOH* solution, pretreating temperature, pretreating duration, solid-to-liquid ratio, and mixing speed. Results are shown in Table 4 and Table 5.

Table 4. Control parameters in the orthogonal experiment.

level	A: NaOH (%)	B: tempe-rature	C: Duration (d)	D: Solid-to-liquid ratio	E: Mixing speed (r/min)
1	1	40	3	8	60
2	2	50	4	10	70
3	3	60	5	12	80
4	4	70	6	14	90

According to Table 4 and Table 5, the concentration is the most important parameter. Then comes temperature. Followed by solid-to-liquid ratio, duration and mixing speed.

4 Conclusion

From the view of the economic cost and influence on the environment, this paper suggests an efficient pretreating approach for potato straws after comparing the experimental results from different pretreating parameters. The suggestive method is applying 4% *NaOH* solution with a 1:10 solid-to-liquid ratio and 70 r/min mixing speed under 60º for 6d. Using the proposed approach, the scarification ratio of the straws could be more than 19%.

Table 5. Orthogonal experimental results(Absorption phtometry --> AP, Amount of glucose --> AOG, Scarification rate --> SR).

No	A	B	C	D	E	AP	AOG	SR

.							(%)	
1	1	40	3	8	60	0.317	5.38	4.104
2	1	50	4	10	70	0.756	13.16	11.12
3	1	60	5	12	80	0.650	11.13	9.424
4	1	70	6	14	90	0.571	9.90	8.16
5	2	40	4	12	90	0.387	6.73	5.86
6	2	50	3	14	80	0.584	9.89	9.03
7	2	60	6	8	70	0.924	16.09	14.51
8	2	70	5	10	60	0.693	11.75	10.79
9	3	40	5	14	70	0.540	9.22	7.40
10	3	50	6	12	60	0.567	9.84	7.84
11	3	60	3	10	90	0.829	14.36	12.09
12	3	70	4	8	80	0.588	10.25	8.181
13	4	40	6	10	80	0.771	13.44	15.53
14	4	50	5	8	90	0.762	12.45	14.39
15	4	60	4	14	60	0.930	16.22	18.47
16	4	70	3	12	70	0.730	12.23	14.13

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