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Chemical and Elemental composition study of Musa Acuminata x Balbisiana Colla (AB Group) banana plant for the Production of bioethanol

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ABSTRACT

Lignocellulosic wastes may be used as a potential renewable feedstock for biochemical production of ethanol as an alternative biofuel. However, cellulose which is the major source of fermentable sugars in these materials. Lignocellulosic wastes contains significant amounts of lignin, is also generally resistant to the hydrolysis of cellulose to monomeric sugars and requires chemo - mechanical pretreatment. This study deals with the isolation of lignin from the different morphological parts of Musa Acuminata x Balbisiana Colla (AB Group) banana plant by two different methods. The different morphological parts of banana plant were treated by two different cooking methods namely Kraft and soda pulping process in a batch digester. The percentage recovery of cellulose by kraft process is high compared to the soda process.

KEY WORDS: Musa Acuminata x Balbisiana Colla (AB Group), Delignification, Kraft and soda pulping process.

1. INTRODUCTION

Lignocellulosic materials will be relied upon as feedstock for the production of biofuels and biocompatible materials. Lignocellulosic biomass represents a rather unused source for biogas and ethanol production. Many factors, like lignin content, crystallinity of cellulose, moisture and particle size, limit the digestibility of the hemicellulose and cellulose present in the lignocellulosic biomass. Annual plants are also being a new source of lignocellulosic biomass; these materials could in many cases represent an abundant, cheap, and readily available. Pretreatments have as a goal to improve the digestibility of the lignocellulosic biomass.

Banana plant is among those raw materials. India ranks No.1 in position for the production of Banana plant. World production of banana is estimated at 48.9 million tonnes out of which 13.3 million tonnes, is contributed by India from an area of nearly 400 000 ha (FAO 2006). After harvesting, the residues of banana left in soil to be used as organic fertilizer. Among these residues Musa Acuminata X Balbisiana Colla (AB Group) variety produces 15% of the total production in India. The development of new applications for these agricultural residues could be an interesting income for banana producers and for a regional economy. A lot of literature is written about different pretreatment method to enhance the digestibility of lignocellulosic material such as mechanical pretreatment. But only a limited literature is available for pretreatment of banana plant residue for bioethanol production.

Agro waste from banana plant offer several advantages for producing biofuel, since these raw materials can be produced annually and have generally low lignin content. They are more easily delignified and require milder and faster delignification rate comparing with other lignocellulosic material for the production of bioethanol. This paper deals with the chemical analysis of banana plant (Musa Acuminata X Balbisiana Colla (AB Group) as well as soda and kraft pulping optimization. The banana plant was fractioned in to four morphological region midrib, floral stalk, leaf blades and sheaths.

2. MATERIALS AND METHODS

2.1. Sample Preparation: Matured banana plants ‘Musa Acuminata X Balbisiana Colla (AB Group)’were harvested from a banana plantation in Tiruchirappalli (Tamilnadu, India). The banana plant was separated in to four morphological regions: midrib vein, floral stalk, leaf blades (Lamina) and leaf sheaths. The humidity of midrib, leaf blades (Lamina), floral stalk and leaf sheaths materials was 90.0%, 80.8%, 89.9% and 95.7%, respectively. Afterwards, the different morphological parts were air dried, during 2 weeks. All parts of banana plant were milled and sieved to 60–80 mesh. These fractions were selected in order to find out its chemical composition.

2.2. Chemical Analysis: Ash content was determined by complete incineration of sample in a muffle furnace at 600°C for 6 h. The Composition of banana plant fractions was performed.

3. RESULTS AND DISCUSSION

Optimization of Banana sheath alkali pretreatment:

Table.1.Experimental range and levels of independent variables

Parameters	-2	-1	0	1	2
Time(A) (h)	1	1.5	2	2.5	3
Concentration (B) (%)	2	4	6	8	10
Weight (C) (g)	6	8	10	12	14
Size (D) (BSS MESH)	12	25	36	44	60

Table.1 shows the four independent variables (Residence time, concentration, weight, size) and their concentrations at different coded and actual levels of the variables employed in the design matrix. The data obtained from the five level central composite design matrix were used to develop models in which each dependent variable (cellulose yield & lignin removal) was obtained as the sum of the contributions of the independent variable through second order polynomial equation and interaction terms. The actual yields of cellulose and lignin obtained are given in Table 2. The contour plots described by the regression model were drawn to illustrate the effects of the independent variables, and effects of interactions of each independent variable, on the response variables. The shape of the corresponding surface plots indicates whether the mutual interactions between the independent variables are significant or not. Interactions of variables can be better determined by the orientation of the principal axis of the surface plots. From the surface plots, the optimal values of the independent variables could be observed, and the interaction between each independent variable pair can described. The surface plots based on independent variable was obtained using the same software package (Fig.1 & Fig.2) indicated that a local optimum exists in the area experimentally investigated. The orientation of the principal axes of the surface plots between the variables B&A, C&A, D&A, C&B, D&B and D&C (mentioned in Table 1) indicated that the mutual interactions between these set of variables had a significant effect on the cellulose and lignin yield.

The optimization of alkali pretreatment for cellulose yield was satisfactory. This was evidenced by the higher value of coefficient of determination ($r^2 = 0.9195$). Similarly the optimization of alkali pretreatment for lignin removal was successful and it was evidenced by higher value of coefficient of determination ($r^2=0.9407$).The Regression equation for cellulose is Cellulose % = 36.5000 + 0.6065A + 0.632167B + 0.8345C + 0.617750D - 0.150979A² + 0.0177708B² – 0.0607292C² – 0.252604D² + 0.116AB + 0.216AC - 0.009AD + 0.05350BC + 0.3035BD + 0.3785CD (1)

$$\text{Cellulose \%} = 36.5000 + 0.6065A + 0.632167B + 0.8345C + 0.617750D - 0.150979A^2 + 0.0177708B^2 - 0.0607292C^2 - 0.252604D^2 + 0.116AB + 0.216AC - 0.009AD + 0.05350BC + 0.3035BD + 0.3785CD \quad (1)$$

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Table.2.Experimental design in term of coded factors and results of Central Composite Design (CCD)

A	B	C	D	% cellulose	% lignin	A	B	C	D	% cellulose	% lignin
-1	-1	-1	-1	34.10	14.20	0	0	0	2	37.33	12.80
1	1	1	-1	37.20	13.80	1	-1	1	-1	35.70	13.30
0	-2	0	0	35.84	13.54	-1	1	-1	1	35.40	12.99
2	0	0	0	37.72	13.96	0	0	0	-2	34.74	13.62
0	0	-2	0	35.01	12.60	0	0	0	0	36.50	12.00
0	0	0	0	36.50	12.00	0	2	0	0	38.40	12.90
-1	1	-1	-1	34.70	13.70	0	0	0	0	36.50	12.00
0	0	0	0	36.50	12.00	1	1	1	1	39.15	13.20
1	-1	-1	-1	35.00	14.20	0	0	0	0	36.50	12.00
-1	-1	1	-1	34.60	14.10	-1	-1	1	1	35.80	14.80
-1	1	1	-1	34.90	13.70	1	1	-1	-1	35.20	14.60
-1	-1	-1	1	34.20	14.00	-2	0	0	0	35.17	14.33
1	-1	-1	1	34.30	13.50	-1	1	1	1	37.80	13.60
1	1	-1	1	36.90	13.10	1	-1	1	1	37.50	13.40
0	0	0	0	36.50	12.00	0	0	2	0	38.60	12.40
0	0	0	0	36.50	12.00						

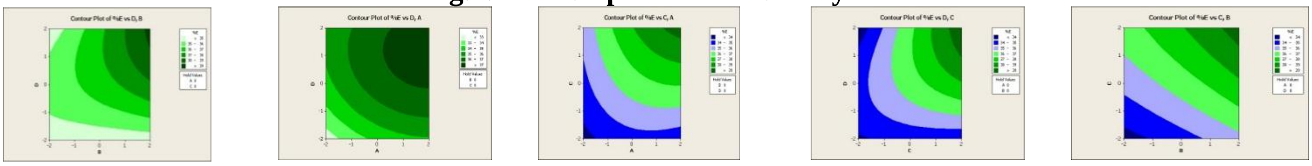
3.1. Response surface estimation for maximum yield of cellulose: As discussed in previous section, an experimental design model [the central composite face-centered experimental design] and response surface methodology were used with four process variables to evaluate their effect on the pretreatment process. The response equation was obtained in Eq.1 for the yield of cellulose. To investigate the interactive effect of two factors on the percentage pretreatment of the banana sheath, the response surface methodology was used and surface plots were drawn. The inferences so obtained are discussed below. In general according to the data obtained from RSM, it is evident that yield of cellulose increases with increase in various parameters. For instance few effects were discussed below.

3.2. Effect of size and time: The above figure shows the effect of size on the yield percentage of cellulose under the different time period. Graphs show that the maximum yield percentage of cellulose occurs under the size of 60 mesh at 3 hr .The cellulose yield was nearly 38% at this condition which is comparatively higher than that obtained under the size of 12 mesh at 1 hr.

3.3. Effect of size and concentration: The above figure shows that with increase in size, the yield efficiency of cellulose increases with concentration. For instance, the yield efficiency was 31% which increased to 34% with concentration 6% and time 2hr, further the efficiency was increased to 38% by increasing the concentration as 10% and time 3hr. The Regression equation for lignin is

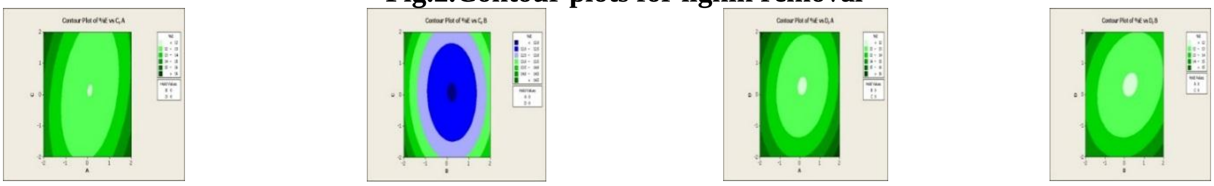
$$Y = 12 - 0.113792A - 0.169958B - 0.033125C - 0.193625D + 0.618323A^2 + 0.386948B^2 + 0.207323C^2 + 0.384948D^2 + 0.212813AB - 0.187812AC - 0.149687AD + 0.0128125BC - 0.175313BD + 0.200313CD \quad (2)$$

Fig.1.Contour plots for cellulose yield



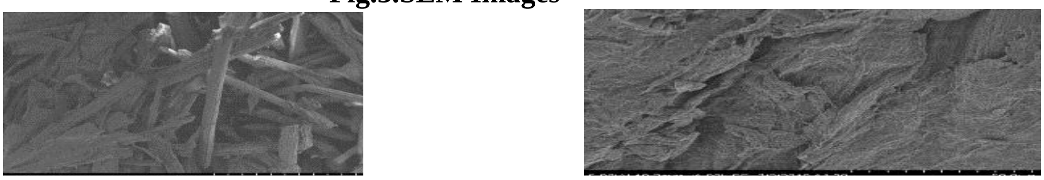
3.4. Response surface estimation for maximum removal of Lignin: As discussed in previous section, an experimental design model [the central composite face-centered experimental design] and response surface methodology were used with four process variables to evaluate their effect on the pretreatment process. The response equation was obtained from Eq. 2 for the percentage removal of lignin. To investigate the interactive effect of two factors on the percentage pretreatment of the banana sheath, the response surface methodology was used and surface plots were drawn. The inferences so obtained are discussed below. In general according to the data obtained from RSM, it is evident that removal of lignin increases with increase in various parameters, for instance few were discussed below:

Fig.2.Contour plots for lignin removal



3.5. Effect of concentration and time: To investigate the combined effect of size and concentration, the RSM was used and results was shown in the form of surface plot. The above figures shows that with increase in concentration, the removal efficiency increases with time. For instance at 2% concentration and 1 hr time, the removal efficiency was 11.5% which increased to 14% with concentration 10% and time 3hr. The optimum value of both the factors, viz, concentration and time can be analyzed by saddle point or by checking the maxima formed by the X and Y coordinates. Effect of size and concentration: The above figures shows that with increase in size, the removal efficiency increases with concentration. For instance, the removal efficiency was 10.5% which increased to 12% with concentration 6% and time 2hr, further the efficiency was increased to 13.5% by increasing the concentration as 10% and time 3hr.

Fig.3.SEM Images



4. CONCLUSION

Because of its high carbohydrate content, relatively low lignin content and its availability as an agricultural waste product, sheath is a particularly appropriate substrate for bioconversion to ethanol. Conventional optimization studies are time consuming and expensive. To overcome these problems, a central composite design (CCD) was used for the optimization of process conditions. From the experimentation, it is evident that the use of statistical process condition optimization approach, response surface methodology has helped to locate the most significant conditions with minimum effort and time. In addition, it has also proved to be useful in increasing ethanol concentration.

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