

Sweet sorghum bagasse: an alternative for the production of second generation Ethanol in Colombia (Part I)¹

Bagazo de sorgo dulce: una alternativa para la producción de etanol de segunda generación en Colombia (Parte I)¹

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Abstract

Each lignocellulosic material is a new terrain to be explored, therefore, the physical chemical characterization of these materials is a fundamental step for the biotransformation process. The lignocellulosic composition of sweet sorghum bagasse was determined, values close to values reported in the literature were found. Pretreatment technologies were explored with steam, mild acid hydrolysis, alkaline delignification, NH₃ soaking, AFEX, ozonolysis, and alkaline peroxide; Being that the alkaline delignification with NaOH is the best option to pre-treat this substrate. The lignin content was decreased by 52% and ethanol productivity of 0.87 g / Lh was obtained, which equates to a yield of 114 L of ethanol / Ton bagasse of pre-treated dry sweet sorghum.

Keywords: sweet sorghum; lignocellulosic; ethanol; alkaline delignification.

Introduction

Nowadays the world worry for the conservation of the environment and the generation of energetic alternatives different from the obtained ones conventional from the exploitation of the oil they have led to the search of renewable sources of energy; it is for this that the utilization of the biomass opposite to the hydrocarbons, he presents comparative advantages that make her attractive for his utilization in processes of generation of heat, motive or electrical energy, well be in systems centralized, in systems of generation of distributed energy or for not interconnected zones (Alvira, Tomás-Pejó, Ballesteros & Negro, 2010; Morales, 2007; Rincón, 2009; Toquero & Bolado, 2014).

Colombia centers the economy on activities of the first level; due to its relief and the different climates that it possesses, its territory is suitable to generate a great variety of agricultural products, inside which they find the products of internal consumption and those of export (García, 2003). The principal agricultural zones of Colombia are located in the Andean region and in the plains of the Atlantic coast. According to the information brought by the Department of Agriculture, the surface sowed in Colombia for the year 2008 was 4,7 million distributed hectares like that: the transitory cultures occupy 40 % of the cultivated area and the permanent cultures occupy 60 % of the surface (Department of Agriculture and Rural Development, 2010). The agricultural production of the country carries to the joint production of agroindustrial residues of interest, such as the husk of rice, the residues of crop of the sugar cane, the flesh and coffee wood, remaining cocoa of the process of benefit, residues of crop of maize and bagasse of sweet sorghum, which might use for the generation of energy.

In previous works, there was realized a process of selection of lignocellulosic materials based on criteria as quantity generated of residue, location, periodicity of the crops, use, the composition of the solid counterfoil and theoretical performance to ethanol (Kafarov, 2010). This study threw the bagasse of sweet sorghum as the agroindustrial residue with major potential for the production of ethanol of the second generation.

The sweet sorghum has been widely used for the production of alcoholic drinks based on processes of fermentation of the juices extracted from the stem by means of a system of pressure similar to the employee in the extraction of juices of the sugar cane. The juices extracted from the sorghum contain a percentage of sugars equivalents found in the diverse varieties of sugar cane (Chuck-Hernández, Pérez-Carrillo, Heredia-Olea, & Serna-Saldívar, 2011; Morales, 2007). Nevertheless, the quantity of sucrose in relation to the glucose and fructose is high in the sugar cane (90 and 6 % respectively), whereas in the bagasse of sweet sorghum it is (69,21 and 14 % respectively). The quantity of sugar produced with the bagasse of sweet sorghum is 10 ton of sugar / hectare sowed against the 19 ton of sugar / hectare sowed for the sugar cane (Chuck-Hernández *et al.*, 2011; Reis, Damilano, Menezes, & of Morais, 2016). The bagasse obtained after the process of extraction of juices is a fibrous material, shaped basically by cellulose, hemicellulose, and lignin. It is possible to transform the fraction holocellulosic (cellulose and hemicellulose) of this bagasse of sweet sorghum, by means of chemical, physical and / or biological processes,

in monosaccharides, for his later conversion to ethanol. (Tejada *et al.*, 2010). One of the principal difficulties for the biotransformation of the lignocellulosic materials is its variability as for its composition, which demands its physicochemical characterization. The second obstacle is the definition of a technology of preprocessing that allows to disintegrate the fraction polysaccharide, without generating valuable concentrations of inhibitory substances. The correct conjugation of these two elements allows obtaining the best quantity of possible ethanol (Sanchez, 2010). In this work one presents the physicochemical characterization of the bagasse of sweet sorghum, as well as the selection and optimization of the best preprocessing for this material, simultaneously that evaluate the degradability and fermentability of the same one, to the opposing conditions of process.

Materials and methods

For the development of this work sweet sorghum was in use *Sorghum bicolor* L. Moench, supplied by the company Clayuca from the Valle del Cauca, Colombia. This material dried off up to reaching a dampness of approximately 10 % and later his size dampness up to obtain particles of a size between 10-30 mm according to the brought in the literature for Kumar & Wyman (2009).

Analytical methods

The cellulose quantities, hemicellulose, lignin and ashes of the raw material and pretreated were decided according to the protocols of National Renewable Energy Laboratory *NREL/TP-510-42618* (Sluiter *et al.*, 2012), *NREL/TP-510-42622* (Sluiter *et al.*, 2008a), respectively.

Sweeten total reducers:

The quantification of the sugars from the cellulose was realized by ART'S method (Total sugar reducers) using as reactivate the acid 3,5 dinitrosalicylic (DNS) (Miller, 1959).

Glucose

For the determination of glucose, it was used the enzymatic method based on the enzyme glucose oxidase, according to the kit of the company Biosystem S.A.

Selection del preprocessing

To select the preprocessing most adapted for the substratum bagasse and sweet sorghum they took as

parameters of evaluation: quantity of lignin removed, the degradability and its fermentability. There were evaluated seven pretreatments which summarize in Table 1.

Table 1. Experimental conditions for preliminary evaluation of pretreatments on the bagasse of sweet sorghum

Preprocessing	Temperature (°C)	Pressure (kPa)	Time (min)	Solid relation/ Liquid	Agent concentration of the pretreatment	Reference
Explosion with steam	210°C	1900	2 min	N/A	N/A	(Ballesteros <i>et al.</i> , 2008) (Hamelinck, Van Hooijdonk y Faaij, 2005) (Lynd, Weimer, Van Zyl, y Pretorius, 2002)
Acid diluted hydrolysis	90	Atmospheric	90	1/10	H ₂ SO ₄ 2%	(Hamelinck <i>et al.</i> , 2005) (Lynd <i>et al.</i> , 2002) (Sun y Cheng, 2002)
Alkaline with NaOH	120	200	30	1/15	1 % NaOH	(Hamelinck <i>et al.</i> , 2005) (Saha y Cotta, 2006) (Sun y Cheng, 2002)
Soaking with watery ammonia	60	Atmospheric	360	1/6	15 % NH ₃	(Lynd <i>et al.</i> , 2002)
Ammonia explosion (AFEX)	180	1900	5	1/7	NH ₃ 25 % (w/w)	(Lynd <i>et al.</i> , 2002) (Sun y Cheng, 2002) (Hamelinck <i>et al.</i> , 2005)
Ozonolysis	25	Atmospheric	60	1/6	5.4 mg ozono/minute	(Sun y Cheng, 2002)
Alkaline peroxide	35	Atmospheric	180	5% (w/w)	2% H ₂ O ₂ (v/v), pH 11.5	Sun y Cheng, 2002)

Source: the authors

Inhibitors

The inhibitors generated in the process of deslignification alkaline were quantified in the liquid obtained fraction, according to the procedure described in the protocols NREL/TP-510-42623, were analyzed by means of HPLC using a column type Biorad Aminex HPX - 87P (Sluiter *et al.*, 2008b).

Fermentability

It was decided across samples obtained from ethanolic fermentation in configuration SSF (saccharification and simultaneous fermentation) using the enzyme Accellerase 1500 of Genencor with an enzymatic activity of 52,88 FPU / mL and the commercial yeast Ethanol Red (*S. cerevisiae*) to the following conditions of process: temperature 37 °C, concentration of yeast 2 g/L and agitation 150 rpm and percentage biomass pretreated / liquid 10/90.

Gas chromatography

For the analysis of the type waited in this form of fermentation, the chromatographic analysis is one of the most common; for this one several configurations exist depending on the type of chromatography that is used: liquid chromatography (HPLC) and gaseous chromatography (GC), and the method of injection. For the development of this project the gaseous chromatography was in use, for the analysis of compounds from a fermentation it is necessary to use a method of separation or isolation, since the direct injection becomes unviable due to the fact that the present components in the broth of fermentation (sugars, salts) are harmful to the column in which the separation is effected.

To realize the sampling there was in use a device composed of a syringe and a special fiber. The most important part of the device is the fiber, which consisted of a metal needle that protects a pipe of silica of very small diameter, with a covering of a liquid polymer, which acts as stationary phase. During the sampling the fiber was exposed to the free space on the sample or the liquid sample, allowing the quantitative absorption of the analytes of agreement with his affinity the covering of the fiber. The analytes are then thermally desorbed in the port of injection of the chromatograph and are analyzed immediately in the equipment.

Precipitation of the lignin

The black liquor, a by-product of the preprocessing, surrendered to a process of acidification up to pH=2. To these conditions there is formed a precipitate, which was leaked and dried, this by-product was analyzed in the infrared detector, in order to confirm that it was the lignin withdrawn from the bagasse of sorghum.

Optimization of the deslignification alkaline

Once the selected the preprocessing most adapted for the bagasse of sweet sorghum, there decided the best conditions of this process. For this there was established an experimental design of the surface of response of the central type, composed of three central points, the variable response was the fermentability (g/L). The design bore four factors in mind: temperature (80-120) °C, time (1-2) h, relation solid liquid (15-20) g/mL and concentration of

NaOH (1-2) % w/w, the counterfoil of experiments can be see in Table 2.

Table 2. Experimental design for the study of the alkaline deslignification.

Exp.	T °C	T(h)	% NaOH	L/S
1	100.0	2.0	2.3	17.5
2	80.0	1.0	2.0	15.0
3	100.0	2.0	0.66	17.5
4	66.4	2.0	1.5	17.5
5	120.0	1.0	2.0	20.0
6	120.0	1.0	1.0	20.0
7	80.0	3.0	1.0	20.0
8	100.0	2.0	1.5	17.5
9	80.0	1.0	1.0	15
10	80.0	3.0	2.0	20.0
11	133.6	2.0	1.5	17.5
12	100.0	0.3	1.5	17.5
14	100.0	3.6	1.5	17.5
15	100.0	2.0	1.5	17.5
16	100.0	2.0	1.5	17.5
17	100.0	2.0	1.5	13.3
18	120.0	3.0	1.0	15.0
19	120.0	3.0	2.0	15.0
20	100.0	2.0	1.5	21.7

Source: the authors

Results and discussion

characterization of the material

As is since it was mentioned in the methodology for the determination of the structural polysaccharides there was in use the protocol (Technical Report NREL/TP-510-42618 (Sluiter *et al.*, 2012). The results obtained in the characterization of the bagasse of sweet sorghum bring in Table 3, in that one presents the cellulose composition, hemicellulose, and lignin obtained experimentally. Of this table it is possible to say that the composition of the bagasse of sweet raw sorghum obtained experimentally is similar to values brought in the literature by Barcelos, Maeda, Santa Anna & Pereira (2016); Chuck-Hernández *et al.*, (2011) and Fenalce (2002).

Table 3.Composition of the bagasse of sweet raw sorghum

Component	Experimental- percentage (%w/w)	Reported (%w/w)
Cellulose	29	34-44
Hemicellulose	22.68	25-27
Lignin	24.68	18-20
Ash	1.36	-
Moisture	8.55	-
Extractive	13.29	-
Others	4	2

Source: Chuck-Hernández *et al.*, (2011)

Another aspect that must be considered in Table 3, is the cellulose composition of the bagasse of sweet sorghum; the above mentioned composition turns this agroindustrial residue into a promising substratum, which might be in use in the production of ethanol of the second generation.

Selection of pretreatment

It is possible to observe, in the Tables 4 and 5, that the degradability and fermentability to ethanol they are better in the alkaline pretreatments (deslignification alkaline, soaking with NH₃ and alkaline peroxide, respectively),

Table 5. Fermentability to ethanol from sweet sorghum for different pretreatments

Pretreatment	Fermentability (g/L)	time (h)
Ozonolysis	3.43	6
NH ₃	6.82	8
NaOH	8.57	9
Acid diluted	2.83	7
Steam explosion	3.91	8
Peroxide Alkaline	5.65	22.5
AFEX	3.90	8

Source: the authors

this behavior gives itself principally due to the reactions of saponification and of solvation that appear in the bagasse of sweet sorghum when it surrenders to this type of treatments; what agrees with the brought in the literature by Lynd *et al.* (2002), which suggests that for substrata of type agroindustrial residues the best pretreatments are of alkaline type. With a base in the results presented in the Tables 4 and 5 the alkaline deslignification was chosen for being the process in which the values were obtained high of degradability and fermentability, in addition, his reagents are of easy access, economic and in comparison with the steam explosion that of minor energetic expense.

Table 4.Degradability of the sweet sorghum for different pretreatments

Pretreatment	Degradability (g/L)	time (h)
Ozonolysis	11.42	33
NH ₃	13.81	33
NaOH	19.11	34
Acid diluted	13.40	30
Steam explosion	11.37	30
Peroxide Alkaline	15.05	32
AFEX	14.70	43

Source: the authors

Optimization of the alkaline deslignification

The results obtained of degradability and fermentability for each of the pretreatments appears in Table 4, Figure 1. In general, it might be said that for all the experimental units bigger concentrations than 50 were reached g/L of ART. The major fermentability obtains with the experimental units numbers 5 and 19, where a temperature of 120 is used °C, time of 1 h, NaOH's concentration of 2 % and a relation (L/S) of 20. It is worth a sorrow highlighting that, for these

experimental units, values of degradability reached also ART'S major values and glucose. It is necessary to highlight that the time has great importance when one works to low temperatures, nevertheless, it loses importance when high temperatures are evaluated. In fact, the value more down of fermentability in (g/L), was obtained to the minor conditions of temperature and time (80 °C and 1 h). ANOVA's table of the statistical analysis for the study of deslignification alkaline can observe in Table 6.

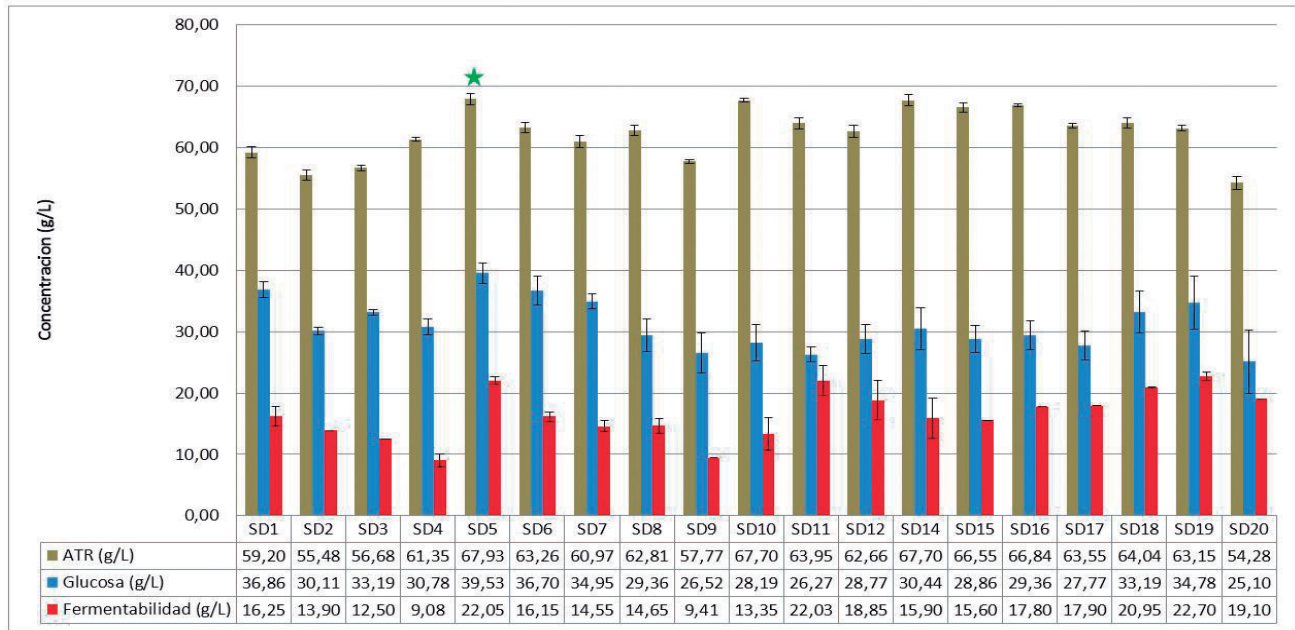


Figura 1. Estudio de deslignificación alcalina: resultados de fermentabilidad y degradabilidad del bagazo de sorgo dulce a diferentes condiciones de pretratamiento (SD: Muestra de Bagazo Sorgo Dulce)

Table 6. ANOVA for the process of deslignification alkaline on the bagasse of sorghum

Source	Sum of Squares	F Value	p-value Prob > F
Model	198.40	50.73	0.0009
A-T	2.65	9.47	0.0370
B-t	4.35	15.58	0.0169
C-NaOH	21.78	77.96	0.0009
D-L/S	0.72	2.58	0.1837
AB	0.71	2.56	0.1851
AC	2.38	8.51	0.0434
AD	15.06	53.92	0.0018
BC	12.10	43.32	0.0028
BD	32.80	117.41	0.0004
CD	0.30	1.06	0.3612
A^2	2.16	7.72	0.9342
B^2	5.60	20.04	0.0110
C^2	2.23	7.99	0.0475
D^2	14.54	52.06	0.0020
Residual	1.12		
Lack of Fit	0.36	0.48	0.6756
Pure Error	0.75		

Source: the authors

The statistical analysis, for this experimental design, was realized by a confidence interval of 95 %. Of the ANOVA it is possible to highlight that the quadratic model proposed by the program is significant, as well as that the variables temperature, time and concentration of soda caustic, whereas the variable (L/S) doesn't have a statistical influence inside the evaluated ranges, this can steady due to the fact that the values of the p-value are minor to 0,05. It is important to rescue that the time has a negative influence on the production of ethanol and is for this by what it was fixed the time in his low limit of the evaluated range. This model has an adjustment to the experimental information of 99,4 % (R²) and explains 97,48 % of the variations of the experimental information. The surfaces of response and the conditions of pretreatment thrown by the statistical model to obtain the best fermentability inside the selected limits 7 are presented in Figures 2, 3 and the Table.

In Figure 2 it is possible to observe, that too low temperatures in the process of deslignification alkaline do not favor the production of ethanol using the bagasse of sweet sorghum. This one meets favored when one works to high values of temperatures and relations low (L/S), is to say that for NaOH's fixed concentration the major quantity of ethanol would have. What coincides with the significance of the interaction temperature-L/S (AD) on the model.

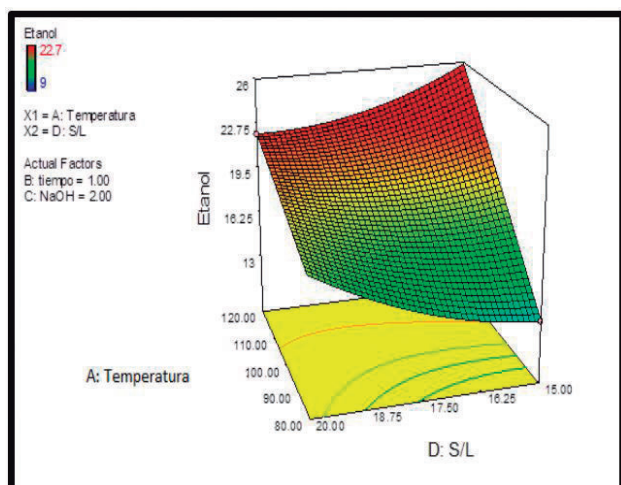


Figure 2. The surface of response fermentability to ethanol depending on the relation (L/S) and the temperature

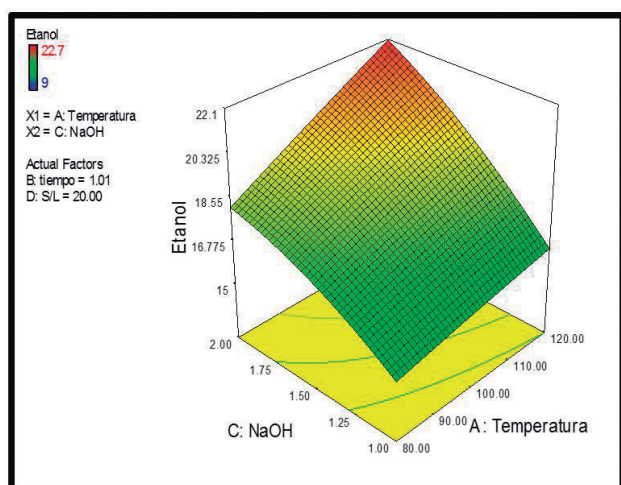


Figure 3. The surface of response fermentability to ethanol depending on NaOH's concentration and the temperature

Table 7. Conditions of pretreatment obtained (designification alkaline) for the bagasse of sweet sorghum

Pretreatment's optimal conditions	
Temperature (°C)	120
Time (h)	1
% NaOH	2
Relation (S/L) (g/g)	20
Ethanol (g/L)	22
Desirability	0,971

Source: the authors

In Figure 3, it is possible to observe that to low temperatures the production of ethanol is not favored for the bagasse of sweet sorghum, the production of ethanol is favored to high values of temperature and concentrations of caustic soda, being confirmed again that the caustic soda

in excess benefits positively the process of deslignification, as is confirmed by the significance of the interaction temperature - concentration of caustic soda (AC). NaOH's concentration seems to be an important variable, but this one does not see concerned high temperatures (120 °C) due to the fact that the differences between the diverse experimental units are not significant. Of the results of the experiments 5, 6, 18 and 19, it might infer that the temperature is one of the most important variables for the process of deslignification, which is identical with Alvira *et al.* (2010); Asgher, Ahmad, and Iqbal (2013); Cao, Sun, Liu, Yin, and Wu (2012). Cao *et al.* (2012) they bring for the bagasse of sweet sorghum that the best results are when the alkaline deslignification carries out to 121°C and one time of 60 min, Asgher *et al.* (2013) they bring conditions of pretreatment of 120 °C and time of 30 min, on the other hand Alvira *et al.* (2010) they indicate that the best values are obtained in ranges of temperature of 85 °C-150 °C and times between 3 and 13 h, that on having be compared with the values found in this work are similar 120 °C and 1 h. To determine the values of the factors that allow coming to a major concentration of ethanol, inside the evaluated ranges, the function was used desirability of the program Design Expert. The conditions thrown by the software for the maximization of the variable response can observe in Table 7.

The kinetic one of validation of the conditions predicted by the model is presented in Figure 4. For this validation, the values of the concentration of alcohol were determined by gaseous chromatography, the last point took to the 26 h of fermentation and his concentration of ethanol was of 22,70 g/L, this result approaches the obtained ones for Asgher, Ahmad, and Iqbal, (2013) which worked with bagasse of sugar cane and reached a concentration of ethanol of 18,2 g/L to a few conditions of temperature of fermentation of 37 °C, pH of 5,5 and one time of 72 h.

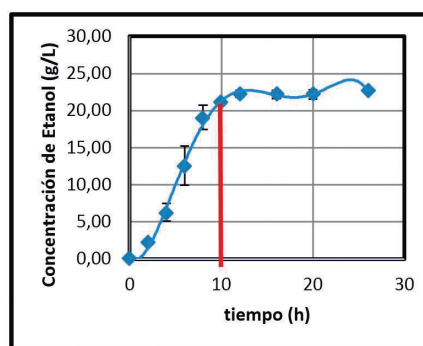


Figure 4. Kinetic of validation of the hydrolyzed of bagasse of sweet sorghum to the conditions predicted by the statistical model (NaOH (2 %), L/S (20), T (120 °C) and t (1 h)

The performance obtained in the fermentation with the conditions predicted by the model was of 0,203 g of ethanol / g of dry biomass pretreated. The productivity for this validation was of 0,87 g ethanol/L h, but if the Figure observes 4 one sees clearly that the time of fermentation might be diminished until 10 a.m. h and like that the productivity to increase up to 2,27 g ethanol/L h.

Effect of the alkaline deslignification on the bagasse of sweet sorghum

The bagasse of sweet sorghum pretreated surrendered again to the process of characterization in order to determine the effect of the pretreatment on the substratum, in this table also there appear the by-products that remain present in the black liquor. The opposing results show themselves in Table 8.

Table 8. Composition of the solid fraction and it liquidates of the pretreatment by-products of the bagasse of sweet sorghum

Solid phase	
Component	Percentage (%w/w)
Cellulose	54.4
Hemicellulose	24.8
Lignin	13.4
Moisture	7.4
Liquid phase	
Component	Concentration (mg/mL)
Glucose	0.28
Pentose	0.63
Acetic acid	1.44
Furfural	0.002

Source: the authors.

The formation of inhibitory substances could meet favored due to the high conditions of the temperature of the pretreatment since to extreme conditions one presents the degradation of the xylose to furfural. It is necessary to highlight that though there is presence of inhibiting his concentration is low, agreeing this way with Sun and Cheng (2005) which bring for pastures and straw of rye.

When the Tables are compared 3 and 8 it is possible to say that the content of lignin diminished in 45,7 % and the cellulose increased in 47 %, due to the action of the alkaline pretreatment agreeing with the brought for Asgher Ahmad, and Iqbal, 2013, which obtained a percentage of deslignification of 48,7 % for the bagasse of sugar cane with an alkaline deslignification using NaOH's concentration to 4 %. The authors Alvira *et al.*, (2010); Balat, Balat, & Öz

(2008); Balat (2011); Barcelos *et al.*, (2016); Cao *et al.*, (2012); Khalil, Abdelhafez and Amer (2015); Mosier *et al.*, (2002) and Reis *et al.*, (2016) bring similar values of removal of lignin with the alkaline pretreatment on different lignocellulosic materials.

The cellulose degradation and hemicellulose in the alkaline pretreatment are minimal, this can be affirmed on having observed the concentration of glucose and pentose in the black liquor (liquid fraction) that is obtained after the alkaline pretreatment.

The characterization realized to the black liquor shows that to the conditions to which it took place the alkaline deslignification appears a low formation of inhibiting compounds of the enzymatic activity (acetic acid and furfural), the fermentation capacity of the microorganism, therefore, the production of sugars reducers like the later transformation of these sugars to ethanol during the fermentation did not meet affected significantly.

By-products of the deslignification

Of the spectrum 5 IR of the Figure, can confirm the presence of the functional groups as the OH - (broadband between 2800 and 3400 cm⁻¹) the aromatic groups with several substitutions (strong band to 600 cm⁻¹ and multiple bands to 1600 cm⁻¹), the link carbon - oxygen (approximately to 1100 cm⁻¹), as well as the bands of the links carbon - hydrogen (the strongest to 1400 cm⁻¹). The non-presence of the carbonyl group to 1600 cm⁻¹ indicates the absence of the sugar from the hemicellulose in the sample (Martínez, Jiménez, Ramirez, and Rojo, 2007). The shoulder to 2900 cm⁻¹ corresponds to the group CH₂ guayacilo - siringilo (Raiskila, 2007).

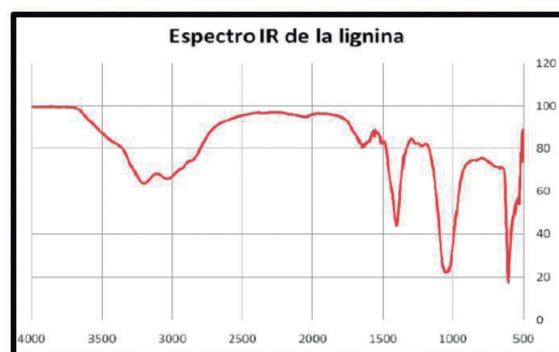


Figure 5. Spectrum IR of the solid precipitate of the liquid fraction of the alkaline deslignification

Source: the authors

The fingerprint of any infrared spectrum analyzes between 600 cm⁻¹ and 1800 cm⁻¹, the obtained results were compared by the brought ones by Frog, Langenfeld-Heyser, Finkeldey, and Polle (2010). This author realized a study of IR of lignin from wood isolated by different methods. If it is compared IR obtained of the sample we can infer that the present peaks to 1596, 1505 and 1270 cm⁻¹ correspond to present compounds in the lignin. To 1200 cm⁻¹ presents a peak that represents the uracil typical of the lignin (Derkacheva, & Sukhov, 2008).

The group's hydroxyl typical of the lignin, they appear to 1338 cm⁻¹, it is possible that this present peak overlapping between the own carboxyls of the lignin and the C=C of the aromatics (Raikila, 2007). The aromatic pole replaced groups are typical of 600 cm⁻¹. Nevertheless, 1 can be overlapped by a peak to 1100 cm⁻¹ corresponding to the links ether of the CH; nevertheless, the absence of the peak to 1600 cm⁻¹ (carbonyl group) allows to reject this possibility. Derkacheva and Sukhov (2008) bring that the lignin recovered of the pretreatment alkaline of the lignocellulosic materials presents an increase in the peaks of 1490 and 1188 cm⁻¹, when it is analyzed, which are very marked in Figure 5.

With a base in the previous analyses, it is possible to say that the spectrum generated by the material removed in the alkaline treatment corresponds to the fraction of lignin of the evaluated material, who presents a high composition of fractions guarafílicas of lignin. Additional, it is important to highlight that the method used in the recovery of lignin allows obtaining exempts from carbohydrates, which performs great importance if it is thought about a future application for the same one.

The analyses realized to the residual water of the deslignification, confirm the removal of lignin of the bagasse of sweet sorghum. It is important to highlight that due to the characteristics of the deslignification and the properties of the hemicellulose and the cellulose, it is not possible to obtain the pure lignin with a simple rainfall if it is thought about future applications.

Conclusions

The results obtained in the evaluation of the different types of pretreatments in the substratum bagasse of sweet sorghum, allow saying that the alkaline with NaOH is the best process for the above mentioned substratum.

The process of deslignification alkaline trebles the production of ethanol once the best conditions are identified for this stage (NaOH 2 %, 1 hour, 121 °C and L: S of 20).

The production of ethanol is favored to high conditions of temperature and concentration of caustic soda.

It is possible to diminish the time of fermentation with the conditions established by pretreatment. This decrease goes from 26 hours to 10 hours, which allowed to increase productivity by 260 %.

With the accomplishment of the alkaline deslignification on the bagasse of sweet sorghum, the content is diminished of lignin in 45,7 % and the cellulose content increased in 47 %, allowing with this that the enzymes and the yeast should have better access to the cellulose and the glucose respectively.

The quantity of ethanol obtained in this work allows concluding that the performance of the bagasse of sweet sorghum to ethanol is 114 L Ethanol / Ton is of sweet dry Sorghum pretreated with NaOH and fermentation in configuration SSF in 26 hours.

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