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Utilization of Soft Wood Wastes as a Feed Stock to Produce Fuel Ethanol

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Abstract: Problem statement: The current research investigated the utilization of soft wood waste as a feedstock to produce a value-added product-fuel ethanol. **Approach:** The main issue in converting soft wood waste to fuel ethanol is the accessibility of the polysaccharides for breaking down into monosaccharides. This study focused on the use of steam as the pretreatment method. The governing factors for the effectiveness of steam pretreatment are steam temperature and retention times. Following steam pretreatment, soft wood waste was subjected to acid hydrolysis. The sugars released by acid hydrolysis were fermented in series chemical reactions that convert sugars to ethanol. The fermentation reaction was caused by yeast, which feed on the sugars. **Results:** Steam pretreatment was able to improve both glucose yields from acid hydrolysis and ethanol yields from fermentation. The results obtained from this study showed that steam pretreated soft wood waste are a heterogeneous material. So biomass goes through a size-reduction step to make it easier to handle and to make the ethanol production process more efficient. Steam treatment on soft wood waste increased the hydrolysis of cellulose by acid hydrolysis. Following 24 h of diluted or concentrated acid hydrolysis, a maximum cellulose conversion of 20.5% was obtained. Similarly, sugars to ethanol conversions were improved by steam treatment. Maximum sugar to ethanol conversion of 40.7% was observed. **Conclusion:** It was recommended that the hydrolysis process be done for 40 min to obtain the maximum sugars yield in a reasonable period of time.

Key words: Fuel ethanol, wastes, soft wood, agriculture residue, biomass crops

INTRODUCTION

Ethanol is now the most important renewable fuel in terms of volume and market value[6]. Ethanol is referred to as an "oxygenated" fuel because of its higher oxygen content. The incomplete combustion of gasoline produces carbon monoxide (CO_2), hydrocarbons and particulates. The addition of ethanol or other oxygenated fuels to gasoline reduces CO production by providing more oxygen and promoting complete combustion. A study showed a 14% CO reduction as a result of oxygenated fuel usage in winter.

Energy and environmental issues are among the major concerns facing the global community today[7]. In view of the environmental benefits and the decreasing supply of crude oil, industry has been moving towards greater ethanol fuel usage. Automobile manufacturers such as ford, Honda and Chrysler have begun to manufacture limited supplies of E85 (15% ethanol with 85% gasoline) and E95 (5% ethanol with 95% gasoline) cars.

Currently, about 90% of ethanol is produced from wood. However, research is being done using other sources of biomass, such as sawdust, soft wood and wastepaper[2].

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The current research investigates the utilization of soft wood waste as a feedstock to produce a value-added product-fuel ethanol. The feedstock consists of cellulosic fibers, including soft wood, agriculture residues, biomass crops and lignocellulosic wastes. The three main chemical constituents are cellulose, hemicellulose and lignin[5].

Cellulose and hemicellulose are polysaccharides of primarily fermentable sugars, glucose and xylose respectively. Hemicellulose also includes small fractions of arabinose, galactose and mannose, all of which are fermentable as well[3].

Lignin is a complex polymer, which provides structural in planets. It makes up 10-24% by weight of biomass. It remains as residual material after the sugars in the biomass have been converted to ethanol. It contains a lot of energy and can be burned to produce steam and electricity for the biomass-to-ethanol process[4].

The main issue in converting soft wood waste to fuel ethanol is the accessibility of the polysaccharides for breaking down (de-polymerizing) into monosaccharides. This study focused on the use of steam as the pretreatment method.

The governing factors for the effectiveness of steam pretreatment are steam, temperature and retention time.

Following steam pretreatment, soft wood waste was subjected to acid. The sugars released by acid hydrolysis were fermented in series chemical reactions that convert sugars to ethanol. The fermentation reaction is caused by yeast, which feed on sugars.

Cell wall constituents: As a whole, soft wood waste should be considered a lignocellulosec material. Lignocellulosic materials consist of there main groups of polymers: Hemicellulose and lignin. Cellulose and hemicellulose are polysaccharides of the desired fermentable sugars. Cellulose is a polymer of glucose, a 6-carbon sugar. Hemicellulose is more diverse, consisting of a mixture of 5-carbon and 6-carbon sugars such as xylose, mannose glucose, arabinose, galactose and uronic acids (Table 1 and 2). Lignin is a phenolic polymer and therefore cannot be utilized by ethanol fermenting microorganisms[5].

The basic structures, organization and interactions between these molecules largely determine the physical and chemical characteristics of the overall plant. Some extractives such as waxes and lipids are also present in cell walls, but serve no structural purpose.

Another component, made up of inorganic materials such as calcium, potassium and silicone.

Table 1: Typical levels of cellulose, hemicellulose and lignin in biomass (www.bio.org)

Component	Percent dry weight
Cellulose	40-60
Hemicellulose	20-40
Lignin	10-25

Table 2: results for 2000 g wastepaper sample which pretreated

Material	Six-carbon sugars (%)	Five-carbon sugars (%)	Lignin (%)
Hardwoods	39-50	18-28	15- 28
Softwoods	41-57	8-12	24-27
As residues	30-42	12-39	11-29

Research overview and objectives: The general objective of this research is to investigate, at the laboratory scale, the use of soft wood and paper wastes for the production of fuel ethanol. Soft wood waste, composition, biomass pretreatment and fermentation are addressed with an emphasis on the effects of pretreatment on ethanol production.

The specific objectives are:

- To characterize the chemical composition of raw material and steam pretreated soft wood waste and wastepaper
- To apply and study the effects of steam pretreatment on biomass sugar recovery, acid hydrolysis yields and ethanol yields
- To ferment the released sugars to ethanol using bacteria and yeast

MATERIALS AND METHODS

The clinker samples were supplied by Cement Industries of Malaysia Limited (CIMA Limited) located at Bukit Keteri, Perlis, Malaysia. The samples were taken from a various place in kiln that have different section of temperature zone during production of cement. The samples were taken from four sections, which are section A (15 m from end of kiln), section B (10 m from end of kiln), section C (5 m from end of kiln) and section D (at the end of kiln). Each sample was divided into three for different analysis. Samples were prepared according to ASTM procedure before investigated under optical microscope and SEM JEOL 6460 LA with 12 kV acceleration volt. Samples for microstructure analysis need to be molded in resin and polished down to 0.05 µm. Samples were also etched with nital for 20 s before analyzed using optical microscope and SEM.

Screening and size homogenization: Two different stocks were used in the experiments; sawdust and waste paper.

It was observed that the sawdust consists of different sizes, big wooden parts and many undesirable particles like some small metal object, so it was homogenized by passing through a screening process and 25 mesh number screen was used.

The second stock-wastepaper-was passed through a process which cut the sheets of many kinds of paper and turned it into small thin parts and any colorized papers, or any papers which contain dyes was avoided because of the bad effect in the next processes Which the paper will be applied, like hydrolysis, fermentation.

Steam pretreatment of the stocks: The stocks were treated inside a high-pressure steam unit; every different stock was treated separately. Liquid hot water pretreatment uses pressure to keep water in a liquid state at elevated temperatures. Flow-through processes pass the liquid water at elevated temperatures through the cellulosic material[7].

First, the sawdust stock was treated and it was fed as batches, every batch contains 2000 g of screened sawdust, the pressure was constant during all the treatment process for all the batches. The pressure and temperature, which were applied, are 2 atm and 150°C; they remained constant.

The retention time for every batch was different, the first batch was treated for half an hour and the final batch was treated for 4 h, 8 batches were used, 30 min difference between every two batches.

Every batch was hold on a metal grid inside the unit, then the high pressure steam will penetrate the particles causing the wood fibers to be separated and get away all the lignin fibers which surrounding the cellulose fibers.

The wastepaper was also treated but at low retention time due to the difference in properties, so 8 batches every batch is 2000 g were used. First batch was treated for 10, 20, 40 min and the final batch for 80 min, 10 min difference between every two batches.

A simple diagram for the steam pretreatment unit is shown in Fig. 1.

Hydrolysis process of the pretreated stocks: Every pretreated batch then passes through a hydrolysis process using diluted (2 N) hydrochloric acid[7]:

- Sawdust stock: Every batch, which equaled 2000 g and pretreated at different retention times, as mentioned before is partition to 8 sections, every one equals 250 g, then every section has subjected to diluted hydrochloric acid with 2 N concentration at different retention times, the first section was subjected to the diluted acid for 10, 20 min and the last section for 40 min, 5 min difference between every two batches:
    - Temperature is remained constant at 95°C
- Wastepaper stock: Different retention times, as mentioned before is partition to 8 sections, every one equals 250 g, then every section has subjected to diluted hydrochloric acid with 2 N concentration at different retention times, the first section was subjected to the diluted acid for 10.20 min and the last section for 40 min, 5 min difference between every two batches:
    - Temperature is remained constant at 95°C
- After finishing the hydrolysis process, all the solid and liquid material (remaining slurry) is subjected to filtration
- Sugar solution which is prepared by dissolving the sugar obtained by the hydrolysis process in 200 mL boiling water (the dissolved oxygen will be driven out), then few drops of a diluted acid as hydrochloric acid is added to adjust the pH, meanwhile the optimum pH range is 6. Then the activated yeast is mixed with the previous prepared solution inside the fermenter and agitator is switched on to start blending, the temperature is remained at the range (23 ~ 26)°C:
    - Every batch requires 120 h (5 days)
- After the fermentation process finished, the liquor conveyed to a reflux distillation

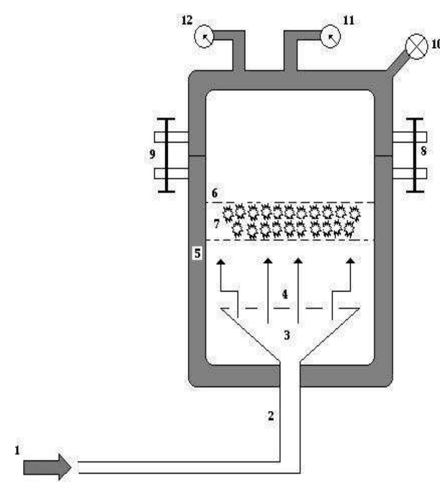

Fig. 1: The high-pressure steam pretreatment unit. (1): High-pressure steam from the boiler; (2): Stainless steel pipe; (3): Distribution grid; (4): Steam; (5): Stainless steel vessel; (6): Holding grid; (7): Sample (sawdust or paper-wastes); (8 and 9): Opening-closing section of the unit; (11): Pressure indicator; (12): Temperature indicator

RESULTS

According to the results, which are gained form the experiments, producing ethanol from waste-wood (sawdust, wastepaper) depends on many factors, which must be taken in consideration.

DISCUSSION

The effect of the sort of stocks: Results show that the final ethanol yield obtained from the wastepaper stocks (which consists of pure cellulose fibers only) is more than the ethanol yield obtained form the sawdust stock.

The effect of pretreatment retention time: The retention time of steam pre-treating of the sawdust samples with high pressure and temperature steam does not show any results until the retention time reaches 210 min, this due to the mechanical effect of the steam pretreatment which completely separate thee wood fibers from each other (Cellulose, Hemicellulose, Lignin) and simplify the next hydrolysis process which mainly depends on the accessibility to the cellulose and memicellulose fibers[1].

So the 210 min is the minimum value, which must start with under the same conditions (150°C, 2 atm).

The results of the wastepaper were totally different, all the retention time values-starting with 10 min until reaching 80 min shows slight increment of the ethanol yield as the retention time of the steam pretreatment increases. The optimum steam pretreatment retention time is 20 min.

The effect of pressure and temperature: Temperature and pressure have a significant effect during the steam pretreatment process. Temperature also has a good effect during the hydrolysis process; so using diluted acid solution must be companied with elevated temperatures (95°C), which increase the accessibility of the acid ions to the glycosidic bonds by reducing the viscosity of the acid solution and increase the rate of reaction to cleave the bonds.

The effect of hydrolysis retention time: Hydrolysis retention time is considered one of the most important factors that effect the final ethanol yield. At the initial stages of the hydrolysis reaction, larger pore volumes do correspond to faster reaction rates. However, after limited hydrolysis, the reaction rate slows down considerably. The glycosidic bonds most susceptible to hydrolysis are those either at the surfaces or in the inside regions of cellulose. Rapid hydrolysis rates reflect hydrolysis activity in these regions and can be seen as a decrease in the Degree of Polymerization (DP).

Table 3: Results for 2000 g sawdust sample which pretreated

Steam pretreated sample for 210 min:			
Hydrolysis retention time at 95°C (min)	10.00	20.00	40.00
Sugar yield after the Hydrolysis process (g)	6.32	9.96	10.71
Sugar recovery (%)	2.53	3.98	4.28
Ethanol after the fermentation process (mL)	2.60	4.50	4.70
Ethanol yield (%)	32.54	35.65	34.62
Steam pretreated sample for 240 min:			
Hydrolysis retention time at 95°C (min)	10.00	20.00	40.00
Sugar yield after the Hydrolysis process (g)	5.02	8.78	11.03
Sugar recovery (%)	2.00	3.50	4.41
Ethanol after the fermentation process (mL)	1.90	3.70	4.60
Ethanol yield (%)	29.86	33.25	32.90

Table 4: Results for 2000 g wastepaper sample which pretreated

Steam pretreated sample for 10 min:			
Hydrolysis retention time at 95°C (min)	10.00	20.00	40.00
Sugar yield after the hydrolysis process (g)	8.49	19.83	25.61
Sugar recovery (%)	3.40	7.93	10.24
Ethanol after the fermentation process (mL)	2.70	7.80	11.40
Ethanol yield (%)	25.09	31.00	35.12
Steam pretreated sample for 20 min			
Hydrolysis retention time at 95°C (min)	10.00	20.00	40.00
Sugar yield after the hydrolysis process (g)	15.62	26.41	34.20
Sugar recovery (%)	6.25	10.60	13.68
Ethanol after the fermentation process (mL)	4.70	11.70	20.10
Ethanol yield (%)	23.77	34.80	46.37
Steam pretreated sample for 40 min:			
Hydrolysis retention time at 95°C (min)	10.00	20.00	40.00
Sugar yield after the hydrolysis process (g)	16.38	32.80	38.67
Sugar recovery (%)	6.55	13.12	15.47
Ethanol after the fermentation process (mL)	5.20	15.30	22.20
Ethanol yield (%)	25.05	36.80	45.30
Steam pretreated sample for 80 min:			
Hydrolysis retention time at 95°C (min)	10.00	20.00	40.00
Sugar yield after the hydrolysis process (g)	19.31	46.68	48.11
Sugar recovery (%)	7.70	18.67	19.30
Ethanol after the fermentation process (mL)	8.30	23.10	25.10
Ethanol yield (%)	33.90	39.00	41.10

The sawdust samples' results show that after 20 min, the hydrolysis retention time has no effect on the sugars yield and increasing the retention time which results with slightly increment of the sugars yield. Economically, it is desired that the hydrolysis retention time will be carried out at 20 min because increasing the time will not effect the sugars yield. This is shown in Table 3.

The wastepaper results show that after 20 min, the hydrolysis retention time has no effect also on the sugars yield and the sugars yields remain constant. This is shown in Table 4.

CONCLUSION

Ethanol has been regarded as one of the main liquid transportation fuels that can take the place of fossil fuel. Energy and environmental issues are among the major concerns facing the global community today .this paper suggest promising techniques worthy of further exploration for commercialization this techniques.

Suggest:

- 210 min is the minimum value, which must start with under the same conditions (150°C, 2 atm)
- The optimum steam pretreatment retention time is 20 min

Economically, it is desired that the hydrolysis retention time will be carried out at 20 min because increasing the time will not effect the sugars yield.

Increasing the retention time more than 20 min will not effect the sugars yield in both sawdust samples and wastepaper samples, so it is recommended that the hydrolysis process be done for 40 min to obtain the maximum sugars yield in a reasonable period of time.

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