TiO2/UV based Photocatalytic Pretreatment of Post Harvest Canola Stalks for Cellulosic Ethanol Production

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Research Question

Is canola stalk a viable source for glucose to produce biofuel? If so is titanium dioxide pretreatment with UV irradiation efficient?

Hypothesis

The hypothesis for this research was to investigate the effectiveness of a photocatalytic pretreatment on canola stalk as a source of biofuel.

Introduction / Background Research

According to President María Fernanda Espinosa Garcés of Ecuador there is only 10 years left to stop the irreversible catastrophe that is climate change. Earth's greenhouse affects an important piece in maintaining the climate of the Earth but it can also increase Earth's temperature. Converting to biofuel is one solution that can be done to combat climate change.

Biofuel is a fuel source that is made from living materials, which makes it a better alternative to fossil fuels for many reasons. Obtaining fossil fuels is about as harmful for the environment as it is to use them. Fracking has been linked to dangerous levels of toxic air contaminants that can heavily contribute to air pollution in populated areas. This is part of why it is so important to find a good source for biofuel. In 2019 more than 7.2 billion pounds of canola were harvested in the United States alone.[4 Canola is grown in different geographical regions because it is known for its ability to adapt to temperature changes. A previous study revealed theoretical calculations that a 1000 acre canola field could produce 5,000 L of biofuel(site me). The sources of biofuel is not the only variable that is being experimented with, there is a constant search for a cost effective pretreatment. A pretreatment is necessary to decompose the lignin exposing the hemicellulose and cellulose to the enzymes for enzymatic hydrolysis to be carried out. Photocatalytic pretreatment is a process using UV light and a catalysis. The most commonly used catalysis is titanium dioxide because of its high reactivity and low cost.

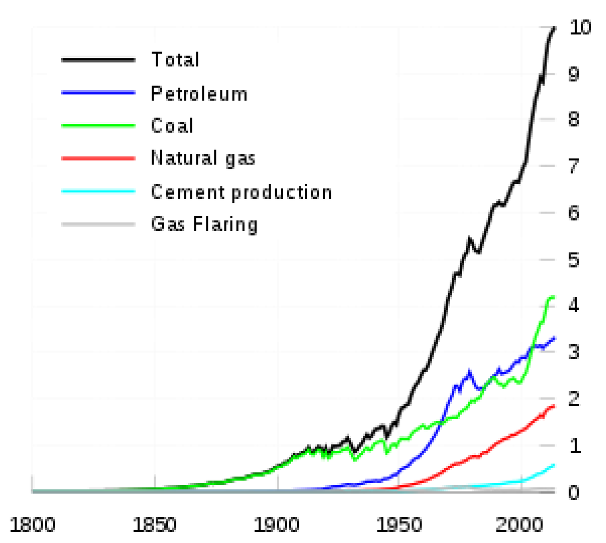

Figure 1: Metric tons of carbon produced by fossil fuels.

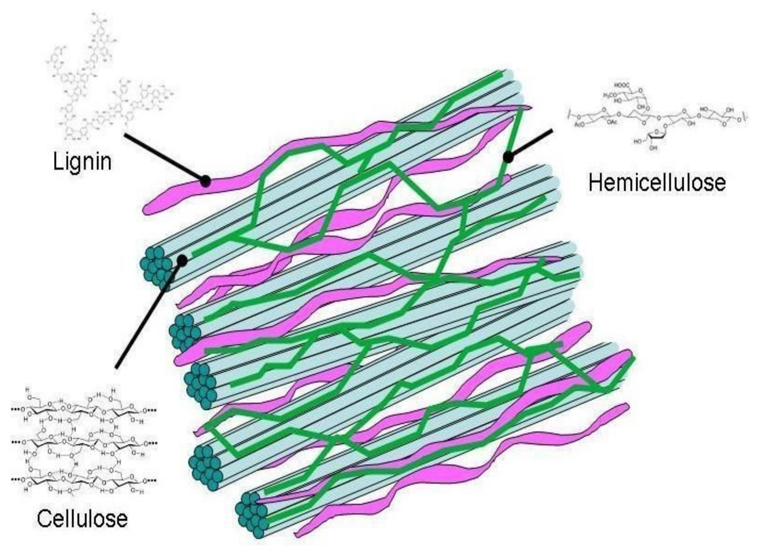

Figure 2: The cellulose and hemicellulose behind the wall of lignin.

Results

Using 0.04g of canola stalks with no pretreatment had an average of 30.03 mL ± 1.35 mL of CO2 was produced. Using 0.04g of canola stalks with titanium dioxide as a pretreatment had an average of 42.87 mL ± 9.1 mL of CO2 was produced.

Table 1: Average CO2 volume in milliliters with standard deviation.

Pretreatment (72hr)	HCL(1M)	NAOH(1M)	HCL(1M) w/ chipping	NAOH(1M) w/ chipping
Average CO_2 Volume (mL)	30.53	39.90	21.50	17.53
± SD	16.99	25.31	12.69	8.62
Average Canola Mass (g)	0.40	0.40	0.08	0.08
± SD	0.00	0.00	0.00	0.00

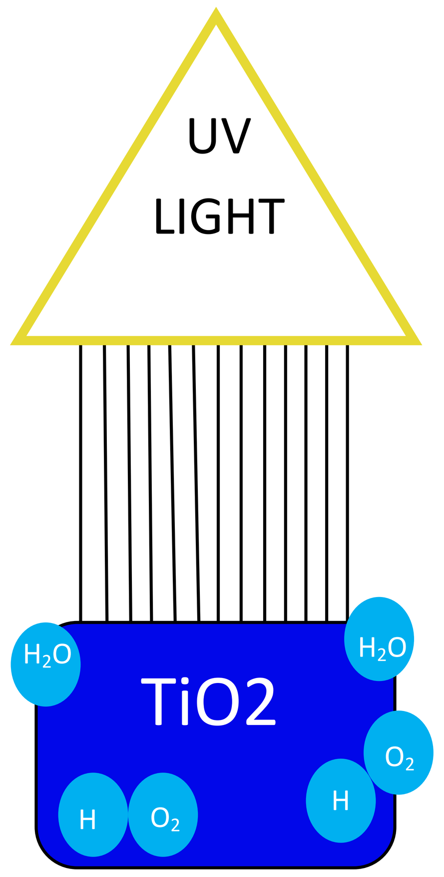

Figure 11: Creating and storing titanium dioxide solution.

Figure 12: Making the tetracycline solution.

Equation 1:

IDEAL GAS LAW

P = Pressure (kPa) V = Volume (L)

n = Moles (mol)

R = Gas Constant (8.315 kPalL/mollK T = Temperature (K)

$$n = \frac{P*V}{R*T} \quad n = \frac{100\ kPa*.0399\ L}{8.315*295.15\ K} \quad n = \frac{100\ kPa*.0399\ L}{8.315*295.15\ K} \quad n = n =$$

$$n = \frac{P*V}{R*T}$$

Equation 2:

STOICHIOMETRY

$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$

$$\frac{1\ mol}{181.116\ g} \quad \frac{0.00081 mol}{\mathbf{0.147\ g}} \quad \frac{1\ mol}{46.07\ g} \quad \frac{0.00163 mol}{\mathbf{0.0748\ g}} \quad \frac{1\ mol}{44.01\ g} \quad \frac{0.00163\ mol}{X}$$

Discussion

The hypothesis for this research was to investigate the effectiveness of a physical pretreatment on canola stalk as a source of biofuel. The hypothesis was accepted because CO_2 was produced using canola stalks. Using 0.4 g of canola stalk with a 1M HCL pretreatment yielded a theoretical 0.06 g of ethanol. Using 0.4 g of canola stalk with a 1M NaOH pretreatment yielded a theoretical 0.07 g of ethanol. Using 0.08 g of canola stalk with a 1M HCL and chipping pretreatment yielded a theoretical 0.04 g of ethanol. Using 0.08 g of canola stalk with a 1M NaOH and chipping pretreatment yielded a theoretical 0.03 g of ethanol. A 1000 acre canola field could theoretically produce 5,000 L of biofuel.

Table 2: Theoretical output glucose, ethanol, and percent yield with different pretreatments.

Pretreatment	HCL (1M)	NAOH (1M)	HCL(1M) w/ chipping	NAOH(1M) w/ chipping
Theoretical Glucose (g)	0.11	0.15	0.08	0.06
Theoretical Ethanol (g)	0.06	0.07	0.04	0.03
Theoretical % Yield	28.20	36.80	99.20	80.90

Figure 13: Theoretical glucose, ethanol, and %

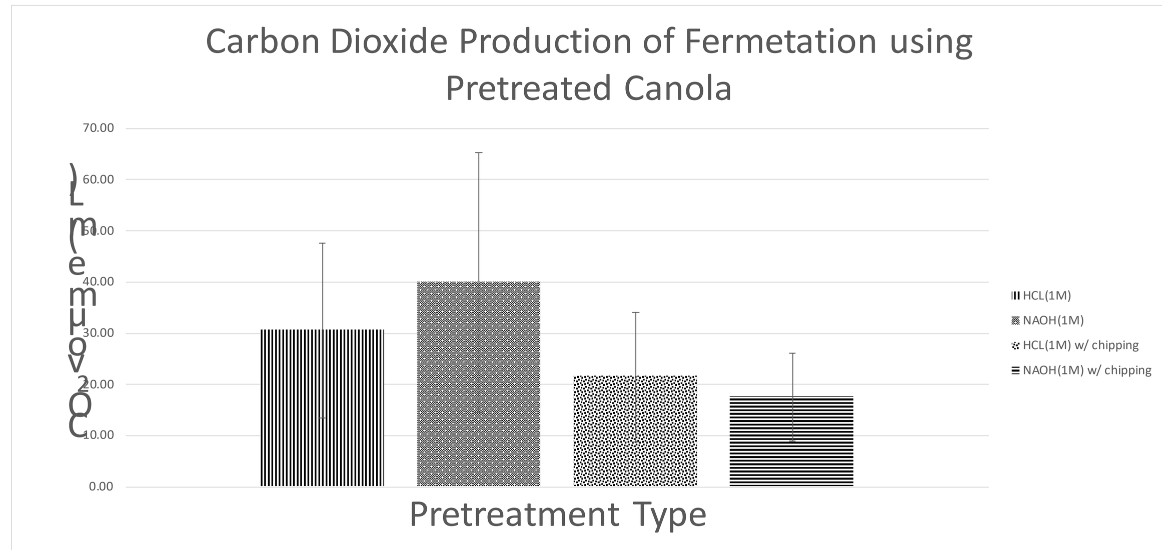

Figure 14: CO_2 volume produced by different pretreatments.

Materials / Methodology

Figure 4: Canola stalks were harvested then cut into 0.4 cm strands and stored in separate plastic bags. Different pretreatments were implemented such as, chemical; photocatalysis, and a combination with physical; chipping.

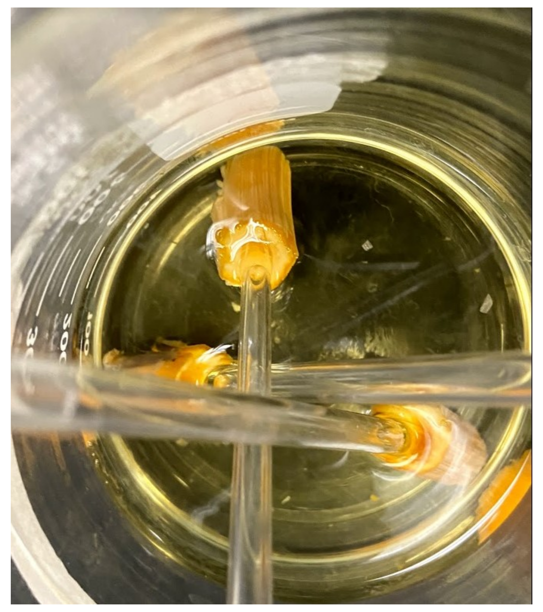

Figure 5: The samples were pretreated using titanium dioxide with 0-2 hours of UV irradiation.

Figure 6: The canola underwent enzymatic hydrolysis. Tetracycline, sodium citrate buffer, and the enzymes Beta glucosidase and xylanase were used to convert the cellulose to glucose.

Figure 7: The enzymes were deactivated by raising the temperature to 90°C.

Figure 8: Fermentation was done by adding 5g of yeast to the trials. The CO_2 produced was captured using balloons that were secured with parafilm.

Figure 9: The CO_2 produced was measured using a eudiometer and equalized. The volume of CO_2 was placed into Ideal Gas Law (Equation 1) to convert to mols, then stoichiometry (Equation 2) was used to calculate theoretical glucose and ethanol production

Conclusions

The hypothesis was accepted because CO_2 was produced using canola stalks. Canola stalks is a viable source of biofuel but there is no significant difference in pretreatments shown with the amount of trials executed. The sample sizes for this experiment were very small resulting in a high standard deviation. This project could have been improved by using a higher sample size. When comparing the average CO_2 produced by fermentation using the HCl pretreatment or the NaOH pretreatment, there was no significant difference at the 99.9% confidence level (two-tailed t-test, $t>2.77$, $p < 0.001$, $df = 4$). At this time, hydrochloric acid is nearly twice as expensive as sodium hydroxide, therefore it is concluded that NaOH should be used as a reliable pretreatment while decreasing the overall cost of biofuel.

Figure 12: Canola Field..

Future Study

The same pretreatments will be explored with lower molarities to reduce costs such as .5 M and .25M. The amount of time will also be reduced such as; 24 hr, 12 hr, 6 hr, and 1 hr pretreatments. Other pretreatments will also be explored such as a 24 hour boiling pretreatment to test heats affect on the cellulose-lignin.

Literature Cited / References

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[2] Jackson Robert B., Vengosh A, et al.(2014) The environmental costs and benefits of fracking. Annual Review of Environment and Resources, Volume 39, p. 327-362.

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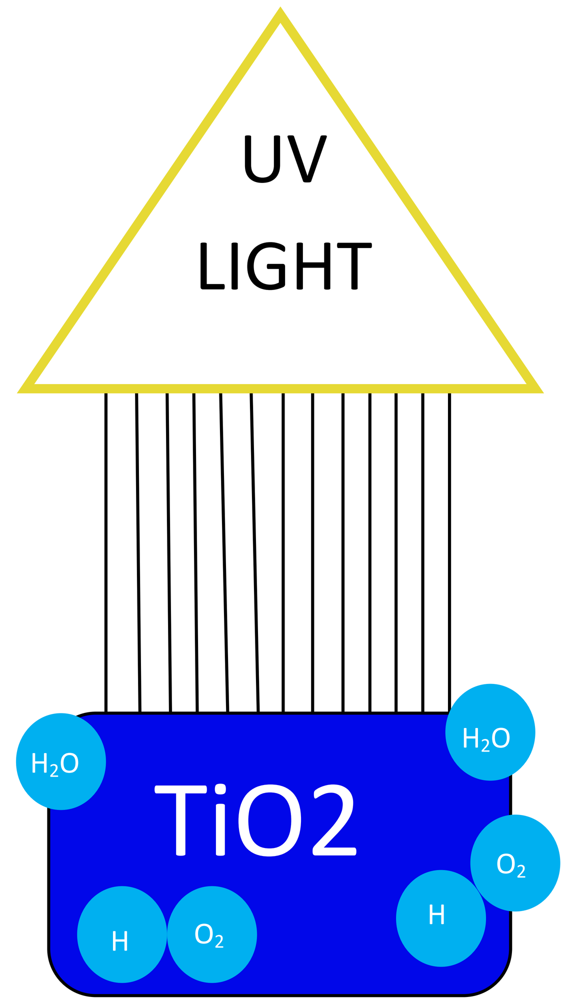
[4] The U.S. Canola Association. Crop production. https://www.uscanola.com/crop-production/

[5] Winkler C.(2020) Postharvest Canola Stalks for Cellulosic Ethanol Production. Advanced STEM Research Laboratory, Odessa High School, Odessa, WA p. 8.

[6] Alvarado-Morales, M.(2016) TiO2/UV based Photocatalytic Pretreatment of Wheat Straw for Biogas Production. Anaerobes in the microbiome, Anaerobe p. 155-161.

All Photographs, tables, and figures were taken or created by the researcher unless otherwise noted.


UV
LIGHT
TiO2
H_2O
H_2O
O_2
H
O_2
H