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Evaluating the Efficiency of Sugarcane and Corn Flour as Biofuels as Alternatives to Fossil Fuels

Introduction

With the estimated timeframe for complete fossil fuel depletion projected to be just within the middle of the 21st century–in just a few decades–the need for finding alternatives to fossil fuels has become tremendously important. Scientists have particularly spent the last few decades researching biofuels, an alternative energy source that can be derived from resources that are plentiful and renewable.

Examples of biofuels include ethanol and biodiesel (*Biofuels Basics*, n.d.). Ethanol, specifically, can be made by the fermentation of plant materials such as corn and sugarcane, some of the most abundant crops grown in the world (*Most Grown Crops | Statista*, 2023).

Fermentation is a metabolic process performed by organisms in anaerobic environments where there is an absence of oxygen. The organism converts a carbohydrate (such as corn or sugarcane) into alcohol or an acid. Yeasts, such as *Saccharomyces cerevisiae*, convert carbohydrates into alcohol during fermentation. From a biochemical perspective, this is achieved when Pyruvate molecules produced from Glycolysis are broken down to produce carbon dioxide and ethanol molecules (Maicas, 2020).

$$C_6H_{12}O_6 \text{ (glucose)} \rightarrow 2\ C_2H_5OH \text{ (ethanol)} + 2\ CO_2 \text{ (carbon dioxide)}$$

Ethanol produced by this process is of great importance since it can be used as a biofuel to power human activities. Additionally, since it is produced from yeast and carbohydrate sources like corn and sugarcane, it is renewable and a viable alternative to fossil fuels.

The major question, however, becomes how efficient this process is as well as how the source of the carbohydrate (corn or sugarcane) affects the efficiency of ethanol production. Answers to this question could help scientists and industrialists choose the most efficient way to incorporate biofuels into production systems.

Thus, this study will investigate the efficiencies of using corn versus sugarcane as organic sources for ethanol fermentation. It is predicted that sugarcane will be metabolized into ethanol faster than corn and will produce the most carbon dioxide since corn is known to be indigestible by many organisms which could indicate that it is a harder carbohydrate to break down. This study will include an experiment using these organic sources as well as *Saccharomyces cerevisiae* as the yeast by combining them in an anaerobic environment in a fermentation flask, and finally measuring the production of CO_2. A final result of the more efficient source will be deduced.

Materials & Methods

1. 2.0 grams of active yeast culture (Fleischmann's Active Dry Yeast) was weighed and poured into a bottle with 125 mL of deionized water and mixed.
2. The bottle was closed and incubated in a 37°C water-bath for 20 minutes.
3. 4 beakers were prepared with 1.5 grams of each reactant condition. Glucose was used as the positive control as it is a known carbohydrate that becomes metabolized into ethanol, and water was used as a negative control as it does not.
    a. Zulka Morena Pure Cane Sugar (sugarcane)
    b. Maseca Instant Corn Masa Flour (corn flour)
    c. Glucose - Carolina Biological (positive control)
    d. Water (negative control)
4. 15 mL of warm yeast solution was added into each beaker, mixed, and then transferred into a fermentation flask.
5. The opening of the flask was covered with parafilm and then inverted several times until the calibrated end was filled with solution. The flask was then transferred to a water-bath.
6. The time was started on an iPhone stopwatch and volume recordings of CO_2 in mL were taken in 3-minute intervals for 21 minutes with a sharpie on the flask.

7. This was repeated 3 other times by other groups for a total of 4 trials for each condition.

8. The rate and volume of CO_2 production (dependent variable) were measured over time (independent variable).

Results

Table 1: Raw data of CO_2 volume (mL) over time for each condition

	Volume of CO2 in mL for each condition at each time-point																							
	Sugarcane						Corn flour						Glucose(+)						Water(-)					
Time (m)	T2	T2	T3	T4	Avg	STD	T1	T2	T3	T4	Avg	STD	T1	T2	T3	T4	Avg	STD	T1	T2	T3	T4	Avg	STD
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.4	1.3	0.4	0.5	0.0	0.00	0.2	0.00	0.1	0.1	0.0	0.0	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.7	0.5	2.2	0.9	0.8	0.1	0.02	0.2	0.00	0.1	0.1	0.2	0.7	0.4	0.4	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0
9	0.2	1.5	1.3	3.5	1.6	1.2	0.2	0.03	0.2	0.05	0.1	0.1	0.4	1.4	0.7	0.8	0.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0
12	0.3	2.4	1.9	4.9	2.4	1.7	0.2	0.06	0.2	0.10	0.1	0.1	0.5	1.9	1.1	1.0	1.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0
15	0.5	3.1	3.1	5.0	2.9	1.6	0.3	0.09	0.2	0.30	0.2	0.1	0.7	2.4	1.8	1.6	1.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0
18	0.8	4.2	4.1	5.0	3.5	1.6	0.4	0.10	0.2	0.30	0.3	0.1	1.2	3.1	2.3	2.2	2.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0
21	1.1	5.0	5.0	5.0	4.0	1.7	0.4	0.10	0.2	0.30	0.3	0.1	1.8	4.0	3.0	2.9	2.9	0.8	0.0	0.0	0.0	0.0	0.0	0.0

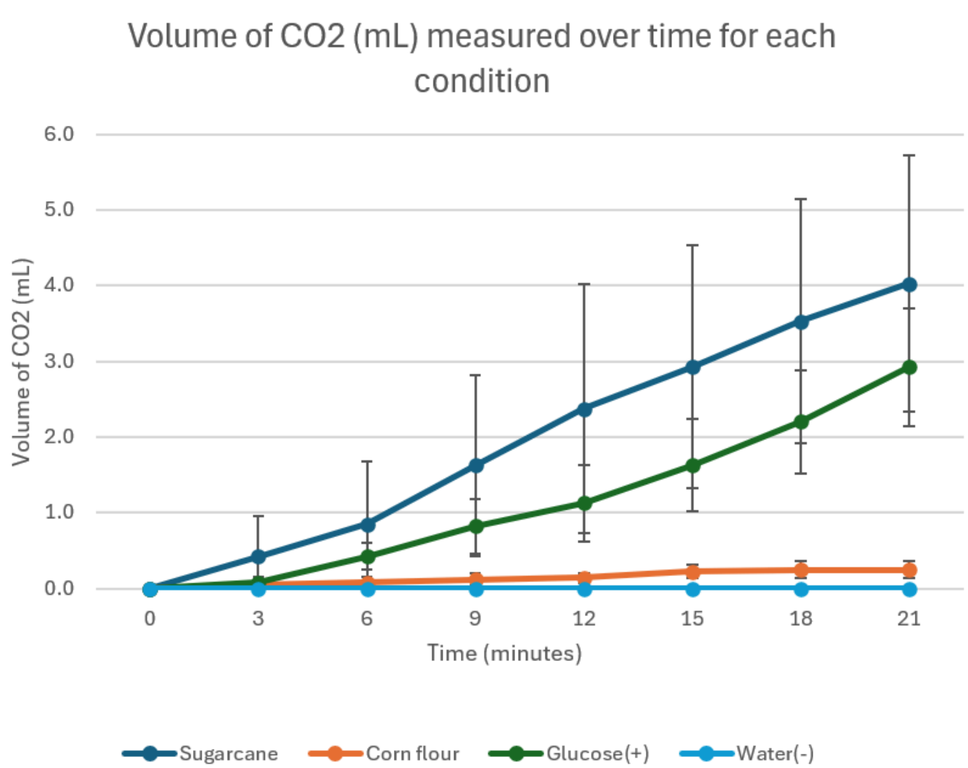

Figure 1: CO_2 production over time for each condition in mL

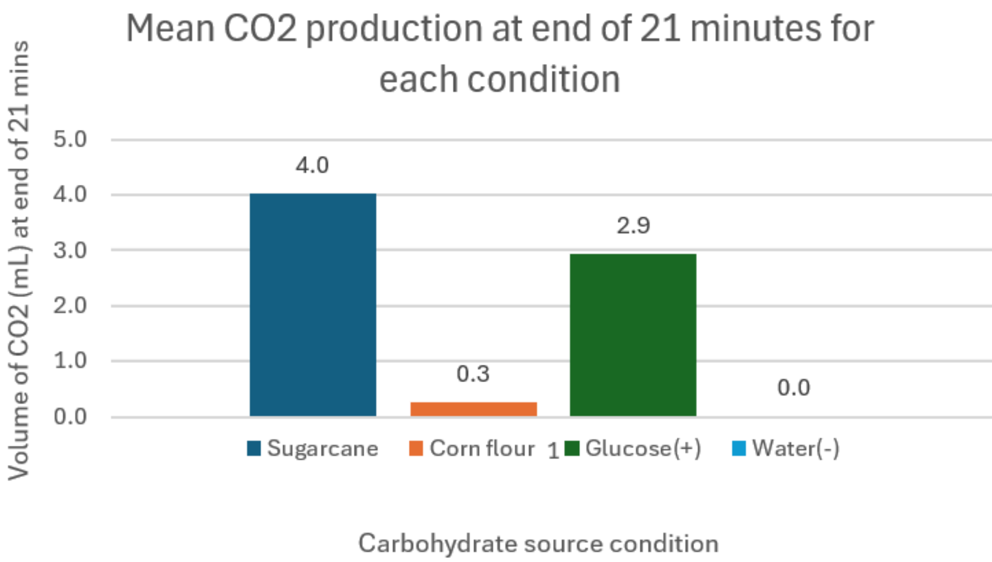

Figure 2: Average rate of CO_2 production in mL for each condition at the end of the 21 minutes

The averages and standard deviations of all trials for each condition were computed in Table 1. Additionally, the negative control (water) column had all zero values and the positive control (glucose) section had positive values, indicating that the experiment went according to plan. The figures following Table 1 (Figure 1 and Figure 2) visualize the results.

Discussion

As evident by the line in Figure 1, sugarcane had the largest increase in the volume of CO_2 produced in the fermentation reaction. Following this was glucose, the positive control, and then the corn flour with a very low amount of CO_2 produced. Water, the negative control, produced expected results of no carbon dioxide production.

The results here are interesting. First, it supports the hypothesis that sugarcane produces the most CO_2 and at the fastest rate since the rate of CO_2 production was greater in the sugarcane condition than in the corn flour one. Figure 2 also shows that the sugarcane condition had the highest overall production of CO_2 at the end of the 21 minutes, with 4.0 mL produced compared to 0.3 mL by the corn flour condition. The glucose and water control conditions also produced expected results in Figure 2. Interestingly the rate and the final amount of CO_2 production was significantly weaker in the corn flour by a large margin than in the sugarcane. In other words, it wasn't very close.

While the gap between sugarcane and corn flour was very large, measurements could have been improved and error kept to a minimum with the aid of a computer and a camera. A camera could be used to take accurate measurements of the volume of CO_2 rather than a sharpie and eyesight.

According to the literature, juices containing free sugars such as fructose, sucrose, and glucose, prove to be more efficient in producing ethanol compared to starchy sources like grains (Zabed et al., 2014). This is validated by the fact that free sugar solutions can be used in fermentation without prior treatment compared to starch feedstocks with complex carbohydrates that require conversion (Bai et al., 2007). As a result, other papers also confirm the result that sugarcane is a more efficient biofuel compared to corn (Bušić et al., 2018).

In this case, the sugarcane utilized was already in the form of simpler carbohydrates (cane sugar) which supports the idea that it would be easier for the *Saccharomyces cerevisiae* to ferment. The corn flour was in a more complex form (starch) which would require more pre-processing into simpler sugars to be efficient.

With these results, it is clear that sugarcane is the superior source considering rate of production and overall amount of production of carbon dioxide (which is tied to a higher ethanol production). Firms and scientists can take this into consideration when considering which biofuel to use to maximize efficiency and economic benefit for switching out of fossil fuels and minimizing environmental harm. However, further experimentation must be done to verify if sugarcane is truly the most efficient biofuel source. Other studies have shown that while sugarcane is an efficient source for ethanol fermentation, it may not be enough to completely replace fossil fuels (Canilha et al., 2012).

Future experiments of this area of study can include investigating the effect of the type of yeast or bacteria on ethanol fermentation as it is unclear at this moment whether *Saccharomyces cerevisiae* is the best organism to extract ethanol from organic sources or is a bottleneck in the process.

Conclusion

Overall, this study successfully demonstrated that sugarcane is a more efficient source for ethanol production compared to corn flour, as supported by the significantly higher rates of carbon dioxide production during fermentation. The findings support the hypothesis that simpler carbohydrates, such as those found in sugarcane, facilitate a more rapid and efficient fermentation process by *Saccharomyces cerevisiae*. The steep contrast in CO_2 output between the two carbohydrate sources highlights the importance of selecting appropriate sources for biofuel production as a way to shift from fossil fuel usage.

References

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