Bioethanol: Fermentation efficiency of glucose vs maltose by *Saccharomyces cerevisiae*

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Introduction

In an effort to reduce global dependency on fossil fuels, renewable biofuels have been intensively researched. These fuels must compete with the price, producibility, and efficiency of fossil fuels in order to effectively replace them. Once they do, biofuels could reduce greenhouse gas emissions by, among other things, replacing ~30% of vehicular gasoline consumed globally (Dale et Seungdo 2004).

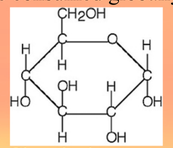


Fig 1.1: Chemical structure of glucose.

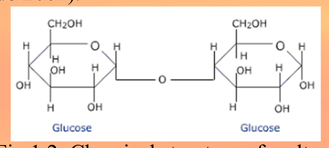


Fig 1.2: Chemical structure of maltose.

Research Question: Is there a difference between the ethanol production rates of glucose vs maltose media fermented by *S. cerevisiae* over 22 hours?

The objective of this experiment was to compare the bioethanol production rates of glucose(fig 1.1) and maltose(fig 1.2) media fermented by *S. cerevisiae*(fig 1.3). The purpose was to determine whether these rates were significantly different. Based on chemical complexity, it was hypothesized that the glucose treatments would have the greater fermentation rate. Higher amounts of ethanol were predicted to be found in the glucose media.

S. cerevisiae was chosen as the fermenting species due to its high ethanol tolerance (Bandera et al 2010).

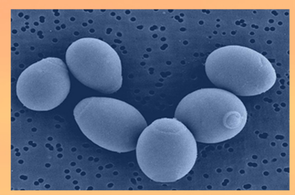


Fig 1.3: *S. cerevisiae* yeast cells.

Methodology

Media with maltose or glucose as a carbon source were prepared and heated to an ideal growth temperature of 30 °C(fig 1.4). After yeast innoculation, samples developed for 22 hrs in shake flasks at 200 rpm. pH levels, sugar and ethanol content were measured at 3 hr intervals starting at 10 hrs until 22 hrs.

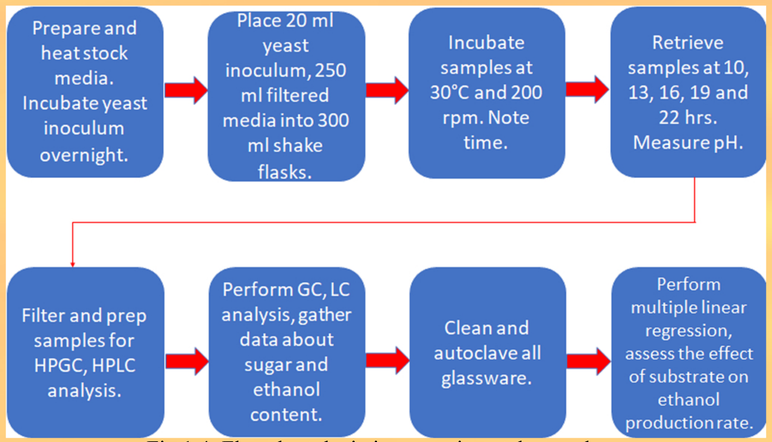


Fig 1.4: Flowchart depicting experimental procedure.

Multiple linear regression was used to statistically test the significance of the effect of glucose vs maltose on bioethanol produced over 22 hrs by *S. cerevisiae*.

Results

HPLC (High Performance Liquid Chromatography) and HPGC (High Performance Gas Chromatography) indicated the amount of sugar and ethanol (fig 1.5, 1.6) present in media at each time point. The results suggest that glucose was fermented at a greater rate than maltose media, producing more ethanol over 22 hours.

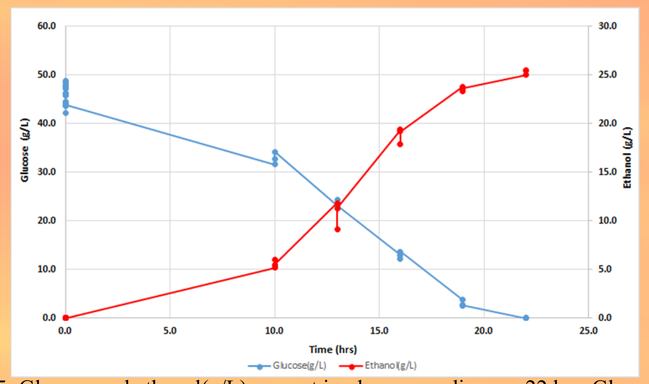


Fig 1.5: Glucose and ethanol(g/L) present in glucose media over 22 hrs. Glucose content in the 22 hr samples was below the detection of HPLC.

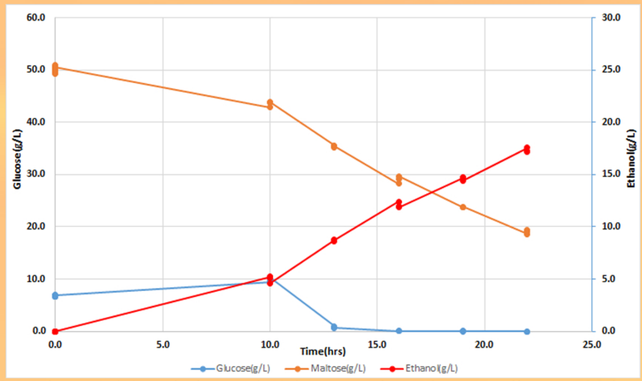
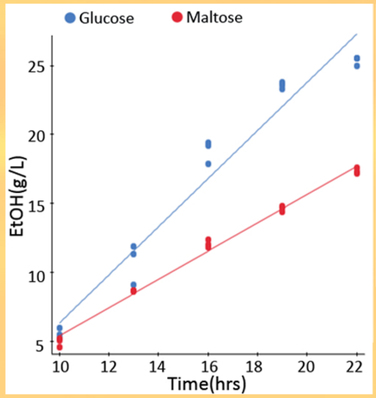


Fig 1.6: Maltose (g/L) and glucose(g/L) present in maltose media over 22 hrs. At 22 hrs, maltose was present in media but glucose content was measured by HPLC to be 0.0 g/L.



Multiple linear regression results:
Dependent Variable: EtOH(g/L)
Independent Variable(s): Treatment, Time, Treatment * Time
Y = -11.10 + 6.229 Group + 1.744 Time + -0.7189 Group * Time

Parameter	Estimate	Std. Err.	Alt.	DF	T-Stat	P-value
Treatment	6.229	1.833	≠ 0	26	3.399	0.0022
Time	1.744	0.07829	≠ 0	26	22.28	<0.0001
Treatment * Time	-0.7189	0.1107	≠ 0	26	-6.493	<0.0001

Summary of fit:
Root MSE: 1.286
R^2: 0.9683
R^2(adjusted): 0.9646

SLR for glucose group: -11.10 +1.744 time
SLR for maltose group: -4.869 + 1.025 time

Fig 1.7: Regression analysis indicates a significanct difference in ethanol production rates of glucose vs maltose media.

Discussion

The results show that glucose media produce a greater amount of ethanol over a 22 hr period, confirming my hypothesis and predictions. Multiple linear regression analysis confirms that the type of sugar(principle carbon source) used has an effect on how much ethanol is produced via fermentation by *S. cerevisiae*. The sample size for this experiment (3 flasks/ timpoint) should be improved in future work.

- Glucose, the simpler carbon source, is metabolized by *S. cerevisiae* faster.

- In time, maltose will produce/exceed the bioethanol concentration in the glucose media, but it is less efficient.

- Industrial bioethanol plants rarely use pure monosaccharide carbon sources. Impure, complex waste products such as cellulosic plant matter are common.

- Improving the fermentation efficiency of impure, complex substrates is an active area of research where future efforts should be focused.

- Efficient self-cycling methods (Wang et al 2017) are an innovative, effective method for improving bioethanol yields.

- Addition of enzymes to solutions often increases bioethanol yields (Wang et al 2017), but, at the industrial scale, are expensive treatments to apply.

Conclusion

In the absence of enzymes and efficient cycling methods, a pure monosaccharide substrate has a greater ethanol production rate than a pure disaccharide substrate when fermented by* S. cerevisiae *over 22 hours.

-Chemical complexity of the substrates in media must be accounted for to maximize bioethanol production.

- Glucose is an **expensive, impractical carbon source** for bioethanol production.

- Pretreatment methods are being extensively researched(Kumar et al 2016) to improve yield.

- Enhanced cycling methods (Wang et al 2017) also promote greater ethanol yields.

- Many factors require optimization before bioethanol can compete with fossil fuels as a practical power source.

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Citations

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