Power Your Car – From Your Dinner Table
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Background, Purpose and Hypothesis

In the world's quest for greater energy security, biofuels such as bioethanol and biodiesel stand poised to take the place of gasoline to reduce our dependence on fossil fuel and to reduce pollution to improve our environment. Currently, farm-grown crops are the most commonly used feedstocks for biofuel production, but their use has reduced the world's supply of crop available for food, greatly increased food prices, and resulted in loss of large tracts of forests, wetlands and grasslands (Grunwald 30). The *goal* of this project is to use industrial organic waste such as potato peel, pineapple peel and core, overripe banana and apple pomace to produce a commercially viable biofuel. The *hypothesis* is that potato peel will yield the most cost effective bioethanol as it has the highest starch content by weight (23%), followed by overripe banana (22%), pineapple core and peel (13%) and apple pomace (11%).

Procedure and Results

Part 1: Preparation

1) Preparation of the Control Solution. 15 g of glucose powder was weighed and dissolved in 100 ml of distilled water.

2) Milling. Each of the apple pomace, overripe banana, pineapple peel and core, and potato peel feedstock was ground separately into small particles using a blender.

3) Preparation of the Fermentation Mixtures. ~700 g of each feedstock was weighed and transferred entirely into separately labeled pickle jars. 400 ml of 0.5 N sodium hydroxide was added to the jar containing the milled pineapple peel and core feedstock and 400 ml of distilled water was added to each of the jars containing milled banana, apple pomace and potato peel feedstock.

3) Autoclaving and Adjusting pH. All jars were mixed and autoclaved at 121˚C and 15 psi for 30 minutes. After the jars were allowed to cool, the pH of all substrates was adjusted to 4.5 with glacial acetic acid.

Part 2: Saccharification

1 g of cellulase enzyme was added to the pineapple peel and core feedstock, 1 g of invertase was added to the banana feedstock, and 1 g and 10 g of α-amylase was added to the apple pomace and potato peel feedstock respectively.

Part 3: Fermentation

1) Activating the Yeast. Five packs of the dried *Saccharomyces bayanus* (5 g per pack) were activated by adding each pack to 50 ml of warm distilled water and let stand for 15 minutes.

2) Adding the Activated Yeast Solution to the Mixtures. 50 ml of the activated yeast solution was then added to each of the feedstock solutions and the control. The jars were capped tightly, mixed, and left in a dark, constant temperature area (25˚C) to ferment. After seven days, the fermented mixtures were tested with glucose test strips to see whether all the glucose had been used up. If not, the feedstocks were left to ferment for a few more days. No harvesting was conducted until all glucose had been consumed.

Part 4: Harvesting the Ethanol

1) Filtering out the Solids. To harvest the ethanol, each of the fermented feedstock was first filtered through cheesecloth, then through #4 filter paper into separately labeled 500 ml conical flasks.

2) Isolating the Ethanol From Water. 200 ml of toluene was added to each flask and refluxed at 60˚C for 1 hour. The toluene-ethanol-water mixture was allowed to cool, transferred into a separatory funnel and the layers were allowed to separate. The toluene-ethanol mixture was transferred into a 500 ml Erlenmeyer flask.

3) Distillation. Boiling chips were added to the flask and distillation begun. The collection of the distillate in a calibrated measuring cylinder began when the temperature reached 77˚C, and stopped when the temperature reached 80˚C. The volume of distillate was noted and transferred to a tightly capped vial.

4) Adding the Molecular Sieve. ~1 g of molecular sieve (Type 3A, 4-8 mesh) was added to the distillate in the vial to remove the rest of the water molecules. After two days, the specific gravity of the distillate in each vial was determined at 25˚C.

Results

Results are summarized in Table 1.

Table 1: Yield and comparative cost of making biofuel from different feedstocks

Type of Feedstock	**15% Glucose Control solution**	**700 g of Potato Peel Feedstock**	**700 g of Overripe Banana Feedstock**	**700 g of Apple Pomace Feedstock**	**700 g of Pineapple Peel and Core Feedstock**
Specific Gravity	0.7998	0.8056	0.8021	0.8009	0.8033
Yield (y)	48.5 ml	42.8 ml	31.3 ml	29.8 ml	13.0 ml
Total cost (c)	$7	$407	$122	$47	$147
$ Cost per ml of bioethanol (c/y)	$0.14/ml	$9.51/ml	$3.9/ml	$1.58/ml	$11.31/ml

Conclusion

As seen from Table 1, potato yields the most ethanol as hypothesized, but apple is the most cost effective. With a fixed set-up cost, the cost-limiting factor in the production is the starch converting enzymes. Potato and apple were hydrolyzed with the least expensive enzyme but potato needs more enzymes to break down the starch to glucose. Apple pomace needs less; therefore it is the more cost effective feedstock to use (Table 1). As there are more than 1.3 million metric tons of apple pomace produced each year, it makes economic sense for each apple processing plant to set up its own biofuel producing facility to generate energy for its own use and for sale. Similarly, with the amount of organic waste generated by food processing plants each day, it would be both sensible and environmentally beneficial to harness these waste products for fuel production.

Acknowledgements

I would like to thank my uncle, Mr. Charles Ng, for letting me use the equipment and reagents from his laboratory, and Ms. Liisa Kukk for her guidance and advice.

References

1. Grunwald, Michael. "The Clean Energy Scam." TIME 7 April 2008: 30-35. Print.

Bibliography

1. Austin G., and Richards C.: *Maximizing Returns With Yeast*, Biofuels Business, October 2007.
2. Bekatorou A., Psarianos C., and Koutinas A.A.: *Production of Food Grade Yeast*. Food Technology Biotechnology, 44 (3), 407- 415, 2006.
3. Bries A.R.: *The Extraction of Bioethanol from Pineapple Peelings Through Simultaneous Saccharification and Fermentation Using the Yeast Saccharomyces cerevisiae*. Republic of the Philippines Cumhyriyet Filipinler 2007-2008.
4. Chandel A. K., Chan E.S., Rudravaram R., Narasu M. L., Rao L. V. and Ravindra P.: *Economics and Environmental Impact of Bioethanol Production Technologies: an Appraisal*. Biotechnology and Molecular Biology Review, Vol.2 (1), P. 014 – 032, February 2007.
5. Das Neves M., Kimura T., Shimizu N., and Nakajima M.: *State of the Art and Future Trends of Bioethanol Production*. Dynamic biochemistry, Process Biotechnology and Molecular Biology, April 2007.
6. Del Rosario E.J., and Pamatong F. V.: *Continuous-flow Fermentation of Banana Fruit Pulp Sugar Into Ethanol by Carrageenan-immobilized Yeast*. Biotechnology Letters, Vol 7, No. 11, P.819 – 820, November 1985.
7. Demirbas A.: *Bioethanol from Cellulosic Materials: A Renewable Motor Fuel from Biomass*. Energy Sources, 27:327-337, 2005.
8. Devrajan A., Joshi V.K., Gupta Kuldeep, Sheikher Chander S., and Lal B.B.: *Evaluation of Apple Pomace Based Reconstituted Feed in Rats After Solid State Fermentation and Ethanol Recovery*. Brazilian Archives of Biology and Technology, Vol. 47, No. 1 Curitiba, Mar. 2004.
9. Dr. M. Dharmadhikari: Active Dry Wine Yeast. Vineyard & Vintage View, Mountain Grove, Mo, undated.
10. Industrial Biotechnology and Biomass Utilization: Prospects and Challenges for the Developing World. United Nations Industrial Development Organization, Vienna, 2007.
11. Internet Journal of Microbiology Volume 5, No. 2: *Bioethanol Production from Apple Pomace left after Juice Extraction*.
12. Kautola H., Cardenas P., Kymäläinen M., Tokeensuu L., Alatalo T., Siukola K., and Näsi J.: Bioethanol From Different Finnish Agricultural Carbon Sources. Hamk University of Applied Sciences, 2004.
13. Li A., Ladislo B. A., and Kharidheh M.: *Bioconversion of Municipal Solid Waste to Glucose for Bioethanol Production*. Journal of Bioprocess and Biosystems Engineering, Volume 30, Number 3, May 2007.

14. Liimatainen H., Kuokkaner T., Tanskanen J., and Kääriäinen J.: *Development Steps in Potato Waste- Based Bioethanol Production*. Journal of Solid Waste Technology and Management, 31 (3), 122-9, August 2005.
15. Marszalek J. and Kaminski W.: *Environmental Impact of Bioethanol Production*, Proceedings of ECOpole, Vol. 2, No. 1, 2008.
16. Naresh S., Kalra K. L., Harinder S. O. and Barsal S.: *Optimization of Fermentation Parameters for Production of Ethanol from Kinnow Waste and Banana Peels By Simultaneous Saccharification and Fermentation*. Indian J. of Microbiology, Volume 47, Number 4, December 2007.
17. Natural Resources Canada: *Making Ethanol: The Green Gasoline*. November 19th, 2008
18. Sanchez O.J., and Cardona C.A.: Trends in Biotechnological Production of Fuel Ethanol from Different Feedstocks. Bioresource Technology, Volume 99, Issue 13, P. 5270 – 5295, September 2008.
19. Takenaka Corporation: *Bioethanol Using the Waste Materials from a Potato Starch Factory*. November 4, 2008.
20. Upper Canada Brewery Company: Making Your Own Fuel: Mashing and Fermentation. October 19th, 2008.
21. U.S. Department of Energy: *Energy Efficiency and Renewable Energy: ABC's of Biofuels*. January 2009.
22. USDA SR-21, Commodity Food A214: *Nutrition Facts and Analysis for Potatoes*.
23. White J.S., and White D.C.: Source Book of Enzymes. CRC Press, 1997.
24. Wilkins M.R., Widmer W.W., and Grohmann K.: *Simultaneous Saccharification and Fermentation of Citrus Peel Waste by Saccharomyces cerevisiae to produce Ethanol*. Process Biochemistry, Vol. 42, No. 2, P. 1614 -1619, 2007