Maximizing Biofuel Quality and Yield Using DOE

Team Cisco Sustainability

CISCO COLLEGE CHEMISTRY

Jocalyn Meyer

McMurry University and Cisco College, Texas

MCMURRY UNIVERSITY

Purpose

The purpose of our project is to investigate factors that influence the output of biogas, produced by the anaerobic digestion of kitchen waste.

Importance

This project gives a hands - on exploratory experience concerning sustainable energy chemistry . It also challenges one to think out of the box

Background

Our goal is to generate a (i) high volume of biogas, along with (ii) good quality biogas. Biogas is made of 80-90%, methane and carbon dioxide. By good quality we mean a *high biofuel methane to carbon dioxide ratio*. Carbon dioxide is removed by passing it through a lime water scrubber. Using a statistical software, Minitab, Design of Experiment (DOE) we propose to determine the best value of pH level and Carbon:Nitrogen ratio of feedstock – in order to maximize quality and output of biogas

Sustainable Solutions to Fossil Fuels

- ❖Burning of fossil fuels is a predominant driver to Global Warming
- ❖Sustainable energy resources, unlike fossil fuels, (i) can be recycled (ii) they will not degrade the environment. A good example of sustainable energy is biofuel methane, from kitchen and animal waste.

C : N Ratio of Biogas

- ❖ We propose that to maximize Biogas quality and yield, an optimum Carbon to Nitrogen ratio of the recyclable waste is critical.
- ❖ To begin with, we propose to focus on Kitchen waste as a source of biogas

C:N Ratio in Composting [1]

Studies have shown that in the case of Composting - a 30-40 : 1 Carbon to Nitrogen ratio, was the most desirable range. We believe this to be a reasonable range for anaerobic bio digestion and propose to work with these values, as a starting point in our experiment

C:N Analysis of Kitchen Waste [2]

Nitrogen will be measured by the Total Kjeldhal Nitrogen method (TKN). It can help analyze the organic Nitrogen and Ammoniacal Nitrogen and their percentage amount in the kitchen waste

The amount of carbon can be determined by combustion. and the combustion method, that uses a furnace such as the leco 1000 CHN analyzer).

Experimental

In this project, the bio digester consists of a round-bottom reflux flask connected via a bent glass tube, to a biogas collector, composed of an inverted wash bottle.

Kitchen waste is characterized by a mix of lettuce and paper. Varying the ratio of paper to lettuce, is in effect varying the ratio of C : N

Temperature is kept constant at 38°C and the particle size is maintained uniform, by making a blended paste of the lettuce and paper, with minimum amount of water

MINITAB [3] : Design of Experiment & Analysis

Design of Experiments (DOE): A systematic statistics driven method to determine relationships between factors affecting a process and the impact of the factors on the output of that process

Table 1

Illustrative Minitab Randomized 2 level 2 factorial DOE

Trail Number	C:N	pH
1	20:1 (lettuce)	Buffer 6.50
2	40:1 (paper+ lettuce)	Buffer 8.50
3	40:1 (lettuce + paper)	Buffer 6.50
4	20:1 (lettuce)	Buffer 8.50

Illustrative Sample Experiment [3]

Baking a Cake : 2 level 3 factorial DOE

Three factors are studied: the brand of flour, the temperature of baking and the baking time. The associated lows and highs of these factors are listed in Table below. The output response is taste of the cake (3).

Table 2. Setting o input factors and taste response

Run Order	A: Brand	B: Time (min)	C: Temp. (C)	Y_1: Taste (rating)
1	Costly(+)	10(-)	70(-)	75
2	Cheap(-)	15(+)	70(-)	71
3	Cheap(-)	10(-)	80(+)	81
4	Costly(+)	15(+)	70(-)	80
5	Costly(+)	10(-)	80(+)	77
6	Costly(+)	15(+)	80(+)	32
7	Cheap(-)	15(+)	80(+)	42
8	Cheap(-)	10(-)	70(-)	74

MINITAB can provide hypothesis testing and give the actual value of variance, F

Table 3: ANOVA table for Taste Response

Factor	df	SS	MS	F	Effect	Contrast	p	F-crit at 1%
Brand	1	2.0	2.0	0.0816	-1	-4.00	0.82	16.47
Time	1	840.5	840.5	34.306	-20.5	-82.00	0.11	
Brand x time	1	0.5	0.5	0.0204	0.5	2.00	0.91	
Temp	1	578.0	578.0	23.592	-17	-68.00	0.13	
Brand x temp	1	72.0	72.0	2.9388	-6	-24.00	0.34	
Time x temp	1	924.5	924.5	37.735	-21.5	-86.00	0.10	
Brand x time x temp	1	24.5	24.5	1	-3.5	-14.00	0.50	
Error	1	24.5	24.5					
Total	7	2442.0						

F- Test and null hypothesis for taste Response

F critical within 1% was computed to be 16.47. The F-test for temperature and time of baking was 34.3 and 23.5 ; If F-test is higher than F critical - means the **null hypothesis** is valid. The ***two factors influence the taste***. The F value for brand was 0.082. This means the brand is not an influencing factor on cake taste.

References

1:Empirical Study on Factors Affecting Biogas Production Ravita Prasad, ISRN Renewable Energy, 2012 pp 1-7

2.Planet Natural Research Center https://www.planetnatural.com/composting-101/making/c-n-ratio/

3. Minitab: https://www.isixsigma.com/tools-templates/design-of-experiments-doe/design-experiments-%E2%90%93-primer/ ; *DOE Simplified Practical Tools for Effective Experimentation* (Productivity Inc., 2000) ; *Design and Analysis of Experiments* (John Wiley and Sons, 1997)

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