Optimized microbial conversion of bituminous coal to methane for in situ and ex situ applications

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Abstract

Although production of methane from coal through biogasification has been a commercial reality in several parts of the world, little work has been done on methane production from bituminous coal. Thus, this project seeks to maximize methane productivity from bituminous coal in the Illinois basin. To achieve this goal, we aim to: 1) Simplify the composition of the nutrient solution designed for biostimulation. This simplification will reduce the cost of the developed recipes; 2) Maximize methane yield by investigating individual and interactive effects from different parameters, such as coal particle size, temperature, pH, mixing, and addition of surfactants, solvents and electron donors, in microcosm setups; 3) Investigate methane production through biogasifciation in a fed-batch cultivation mode; and 4) Investigate methane production using our established microbial consortium in pressurized reactors simulating in situ pressures.

Upon completion of this project, biogasification processes suitable for ex situ or in situ applications will be developed. The low-cost, efficient and highly productive processes developed from this project will: 1) address the challenges facing the current Coal Bed Methane operations in the field, which are high cost and low productivity for high rank coals; 2) contribute to our technical know-how regarding biogasification of bituminous coal; 3) provide an abundant supply of natural gas to our society; 4) enable coal to be used in an environmentally-friendly and sustainable way; and 5) develop a means to utilize coal waste, thus converting a waste to a resource.

Objective 1: Simplify the nutrient recipe

Basin	Recipe	Number of added compounds	$/gal	Cost decrease (%)	Yield (ft^3/ton)	Yield increase compared to the controls
IL	Initial	16	0.63		200	50 x
	Final	5	0.05	92.6	1067	267 x
SJ	Initial	16	0.63		100	44 x
	Final	6	0.06	91.2	1042	458 x

Fig. 1: Site for formation water collection.

Objective 2: Optimize methane yield

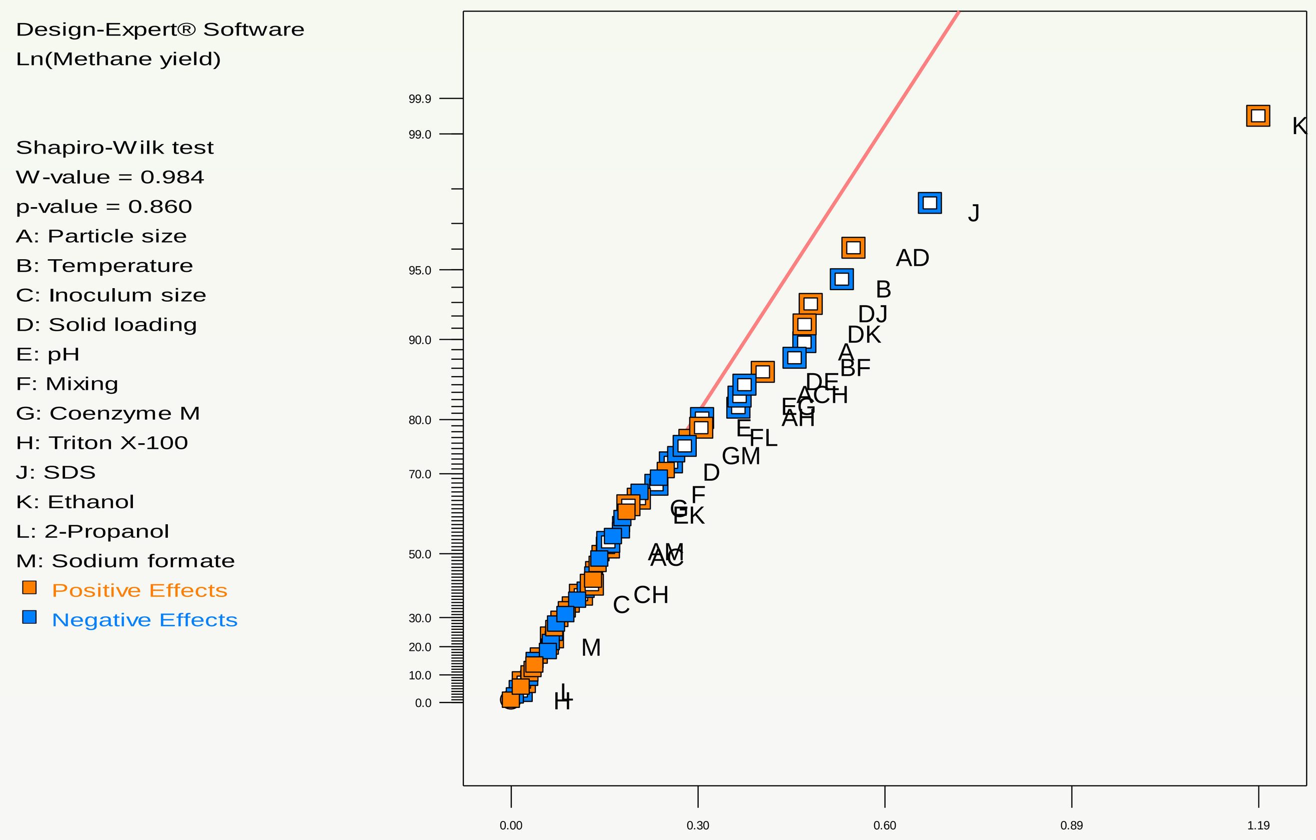


Fig. 2:Half normal probability plot for methane productivity (ft^3/ton).

Table 1: ANOVA test for Response Surface Reduced Quadratic Model.

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	32.94	8	4.12	4.8	0.0021	significant
A-Temp	13.26	1	13.26	15.45	0.0008	
B-particle size	1.8	1	1.8	2.09	0.1636	
C-ethanol	0.83	1	0.83	0.97	0.3366	
D-solid loading	4.51	1	4.51	5.25	0.0329	
AB	3.18	1	3.18	3.7	0.0687	
BC	3.46	1	3.46	4.03	0.0585	
B^2	3.55	1	3.55	4.13	0.0556	
D^2	3.18	1	3.18	3.7	0.0688	
Residual	17.17	20	0.86			
Lack of Fit	9.82	16	0.61	0.33	0.9492	not significant
Pure Error	7.34	4	1.84			
Cor Total	50.1	28				

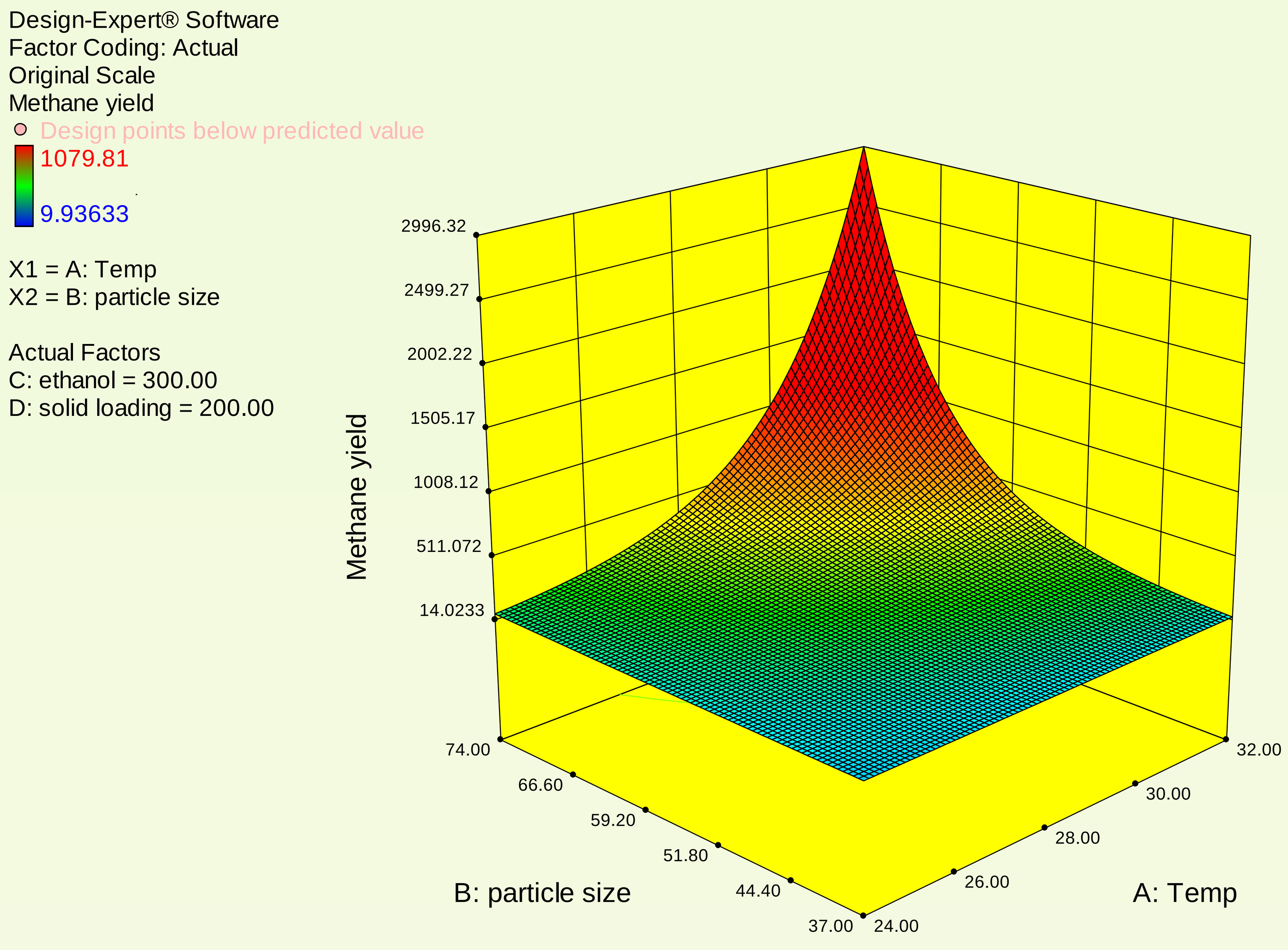


Fig. 3: 3-D response surface for methane yield.

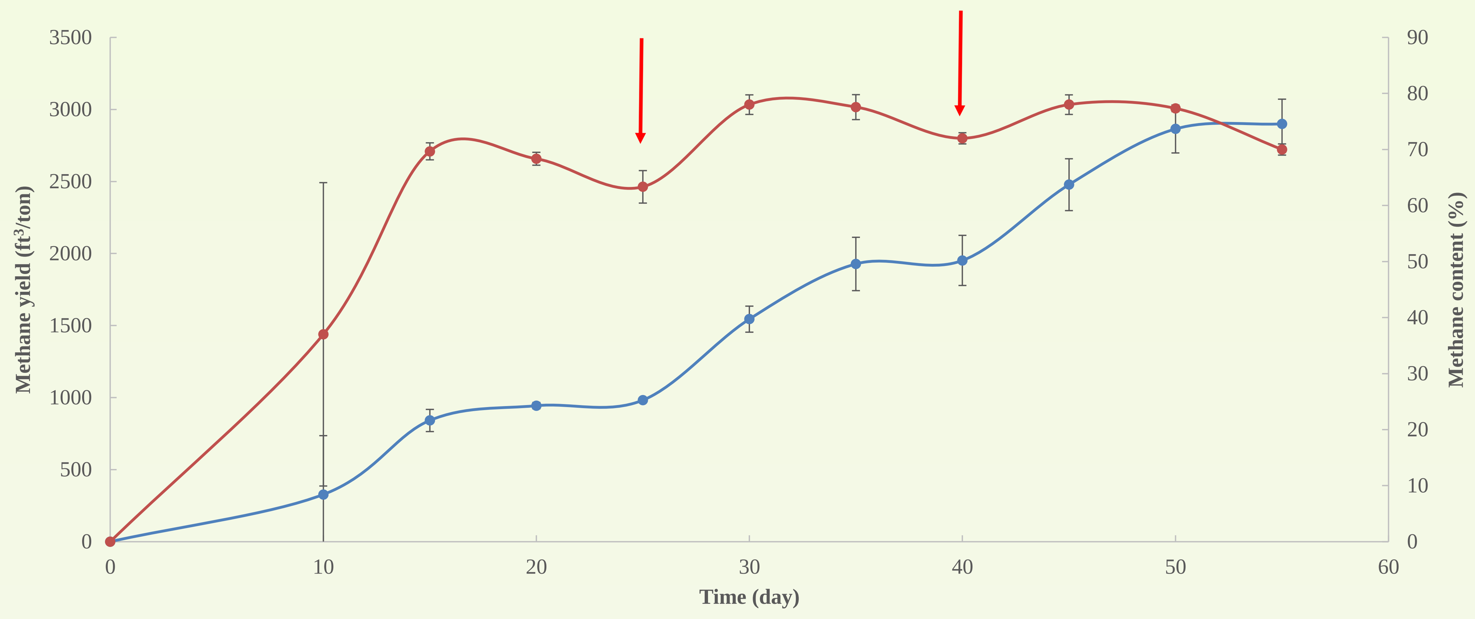


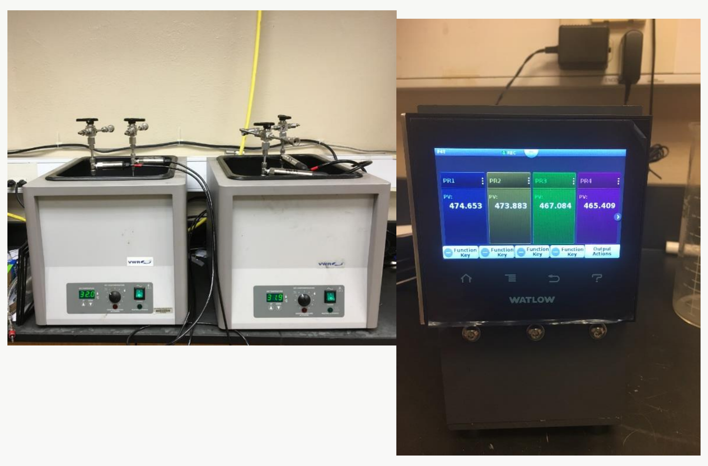
Fig. 4: Verification experimental results.

Objective 3: Coal bioconversion in fed batch mode

Table 2: Methane production in a fermentor over time.

Date	Action	Methane content	Gas volume (mL)	Methane volume (mL)	Methane production (ft^3/ton)	Culumative methane production (ft^3/ton)	Methane lost (mL)
4/20/2016	Setup the fermentor	0	0	0	0	0	0
5/21/2016	Collected the gas in the gas bag	32%	270	486.40	188.32	188.32	0.00
5/22/2016	**Added nutrients to the fermentor and purged the reactor with N_2**	/	/	0.00	0.00	0.00	0.00
6/21/2016	Collected the gas in the gas bag	61.20%	1340	1585.08	613.70	802.02	820.08
7/21/2016	Collected the gas in the gas bag	67.20%	683	2119.06	820.44	1008.76	458.98
8/25/2016	Collected the gas in the gas bag	62.70%	575	2423.33	938.24	1126.56	360.53
9/8/2016	**Added nutrients to the fermentor and purged the reactor with N_2**						
10/10/2016	Collected the gas in the gas bag	65.10%	1968	3734.50	1445.89	1634.21	1281.17
11/10/2016	Collected the gas in the gas bag	72.50%	1821	5147.22	1992.86	2181.18	1320.23
1/10/2017	Collected the gas in the gas bag	78.00%	2013	6636.35	2569.40	2757.72	1459.43

Objective 4: Methane yield in pressurized reactors



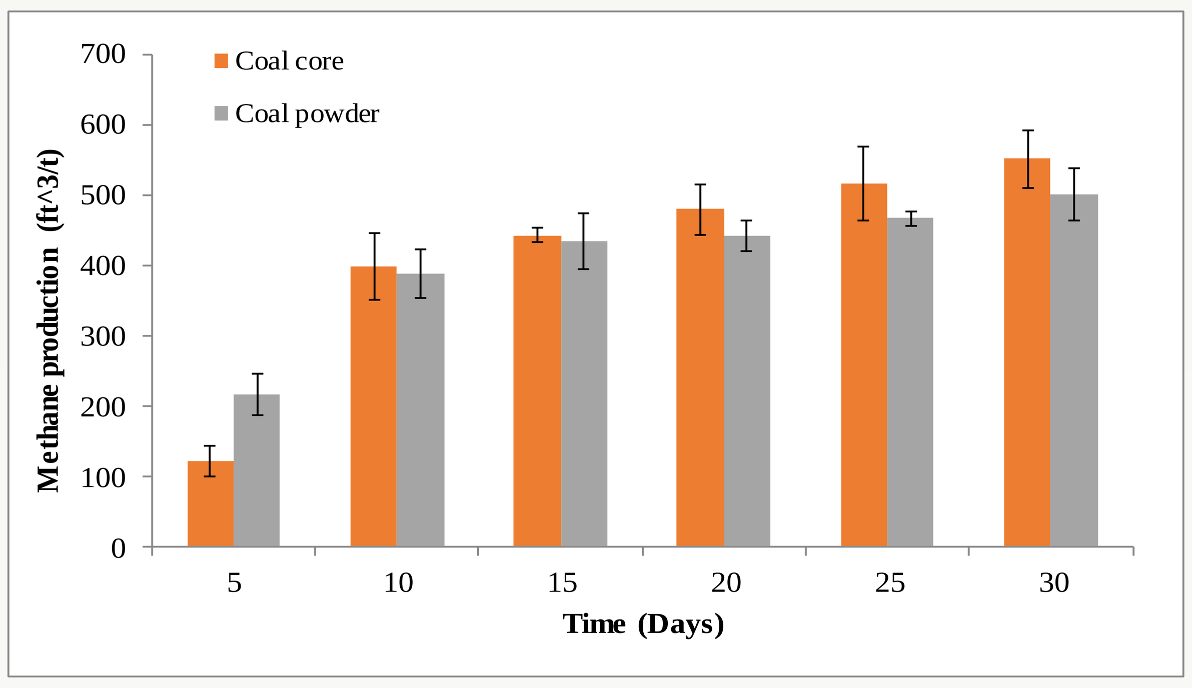


Fig. 6: Methane yield over time for pressurized reactors containing coal cores or coal powder.

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