This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

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The algae slaughterhouse - integrated conversion of algae biomass to fuels and chemicals using biocatalyst consortia

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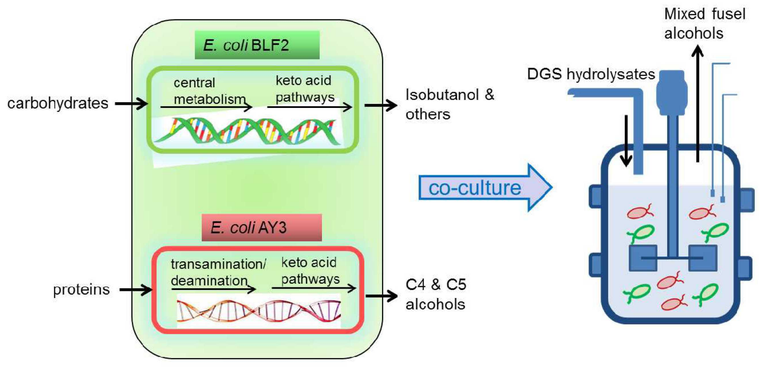
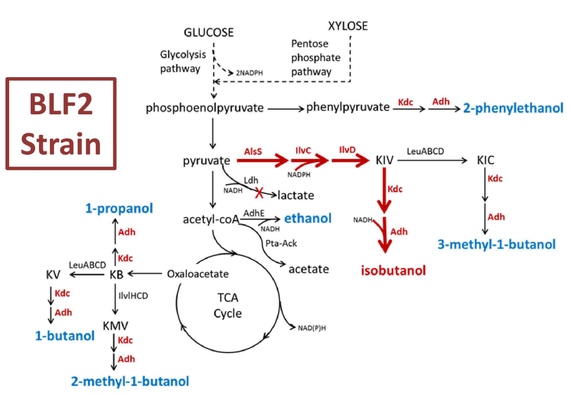
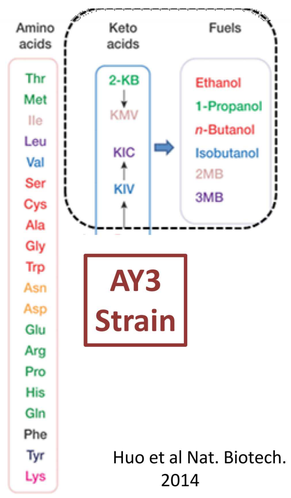
Background

A key challenge for use of algae biomass for renewable commodities is efficient utilization of all of the major biochemical fractions of the biomass, including carbohydrates, proteins, and lipids. Development of a combined algae processing biorefinery would facilitate co-production of petroleum displacing chemicals with the intermediate to high value products that are currently produced from algae. To overcome issues involved with highly variable feedstock composition, our group is developing means for single-pot bioconversion of amino acid and sugar oligomers from algae hydrolysates to generate a variety of petroleum-displacing end products. Various highlights from this work are discussed.



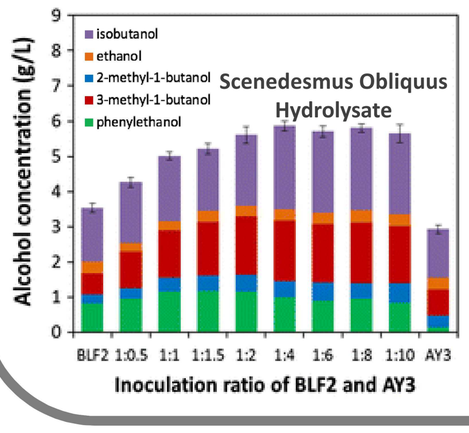
Strain Development/Optimization





AY3 Strain

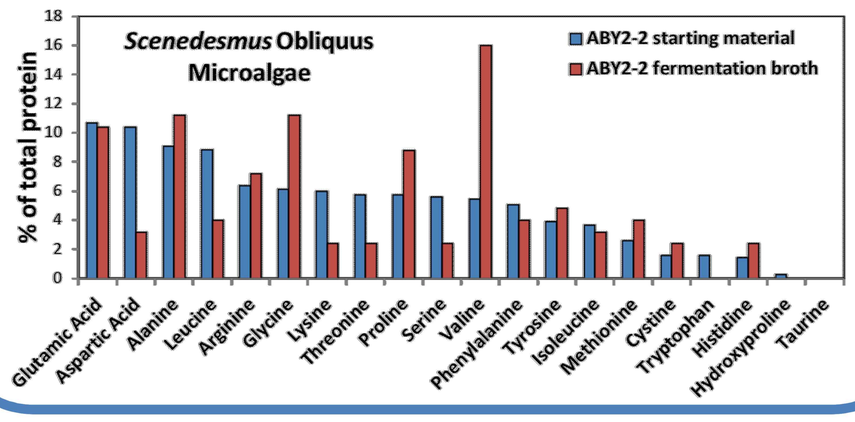
Huo et al Nat. Biotech. 2014



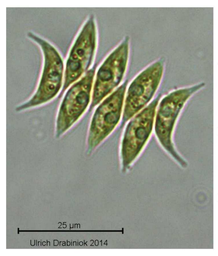
- Carbohydrate conversion strain **BLF2**: cloned the 2-keto acid pathway to *E. coli* ATCC 11303.
- Protein conversion strain **AY3**: engineered to deaminate proteins and able to utilize amino acids as the sole carbon source for growth.

Protein Enrichment

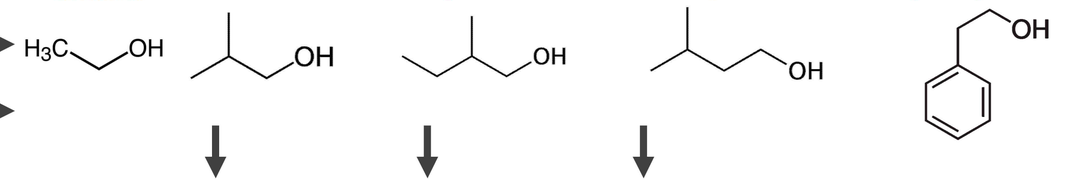
- High value AA such as Valine see a > 2X relative % increase in post fermentation broth
- Low value AA such as aspartate and leucine have their relative % dramatically reduced



Investigation of Fusel Alcohol Blends Under the Co-Optima Initiative

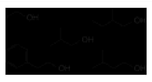


19% ethanol — 57% isobutanol — 5% 2-methyl-1-butanol — 11% 3-methyl-1-butanol — 8% 2-phenylethanol

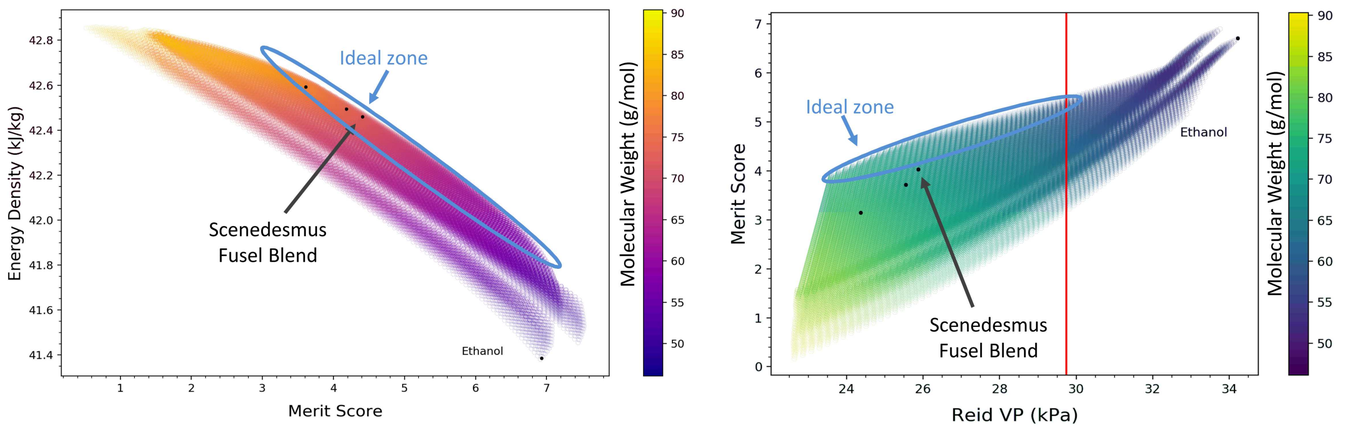


Use directly as blending agent in gasoline – Ranked as a "Top 10 Bioblendstock"

Strong Performance / Good Performance / Marginal Performance / Poor Performance

	Scenedesmus Fusel Alcohol Blend	Methanol	Ethanol	Isopropanol	Isobutanol	Prenol	Diisobutylene	Furan Mixture	Cyclo pentanone
Chemical Structure									
Blending RON	127	143	130	122	109	140	130	146	125
Blending Octane Sensitivity	32	44	35	17	25	38	29	41	22
Heat of Vaporization [kJ/kg]	691	1173	919	744	508	508	318.2	355	504
Particulate Matter Index	1.8	0.05	0.06	0.08	0.17	0.17	0.57	0.57	0.74
Sooting index	32.7	6.6	10.3	19.2	26.2	26.2	68.5	NA	22
Merit Function Score at 20 vol%	4.7	11.9	9.1	2.7	4.2	6.6	4.5	8.8	3.4
Energy Density [MJ/kg]	35.2	20.1	26.8	30.7	33.1	34.4	44.3	34	32
Blending Vapor Pressure	Low	High	High	High	Moderate	Moderate	Low	-	Low
Water solubility [g/L]	237	1000	1000	1000	85	17	0.004	2.2	60.8
Stability Issues	Minimal	Minimal	Minimal	Minimal	Minimal	Severe	Severe	Extreme	Moderate
Infrastructure Compatability	Average	Poor	Poor	Poor	Average	Average	Average	Average	Very Poor

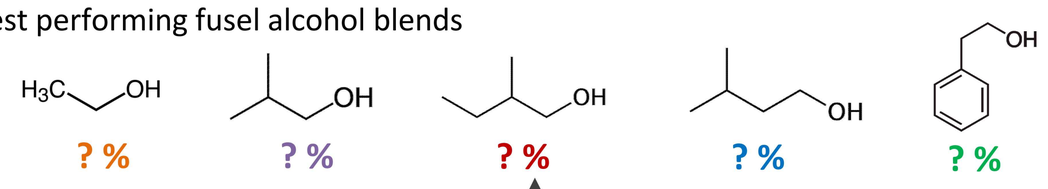
SNL development of computation tools to predict and optimize important fuel properties of fusel alcohol blends

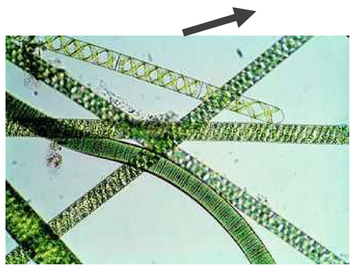


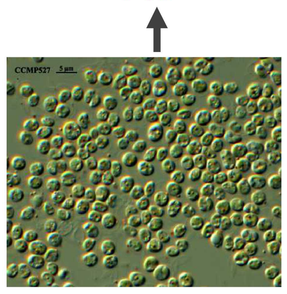
- **Merit Function score is a calculation that inputs a variety of measured fuel properties and calculates the expected thermodanmic efficiency gain of that fuel used in a boosted SI engine.**
  - **MF score of 5 means an expected 5% thermodynamic efficiency gain**
- **Significant room for "optimization" of fusel alcohol blends for maximum merit function score and energy density while keeping water solubility and Reid Vapor Pressure low**

Conclusions/Future Work

- Determination of which algal cultures (based on carbohydrate, protein, lipid content) lead to highest performing fusel alcohol blends







- Additional strain engineering to improve yields and selectively enrich for specific amino acids
- Technoeconomic Assessments of various upgrading strategies to determine most valuable product

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