RECOVERY AND UTILIZATION OF VOLATILE FATTY ACIDS FROM ORGANIC WASTE FOR BIODIESEL PRODUCTION AND MICROBIAL INACTIVATION

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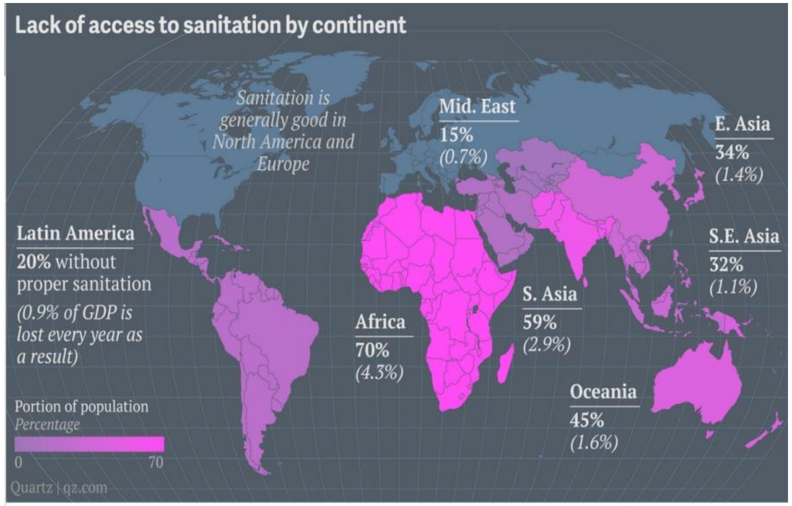
FSM3

Hanoi, Vietnam, January 21st, 2015



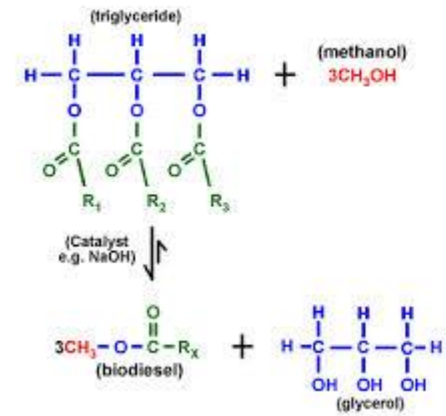
Lack of adequate sanitation is a global challenge

Is it possible to link sanitation with higher value chain biofuels and commodity chemicals?

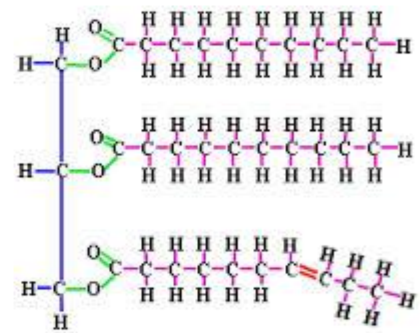
Often limited by access to reliable energy inputs and chemicals

Fecal sludge to biodiesel

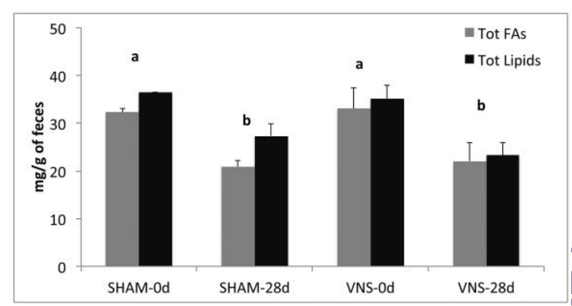
- Biodiesel

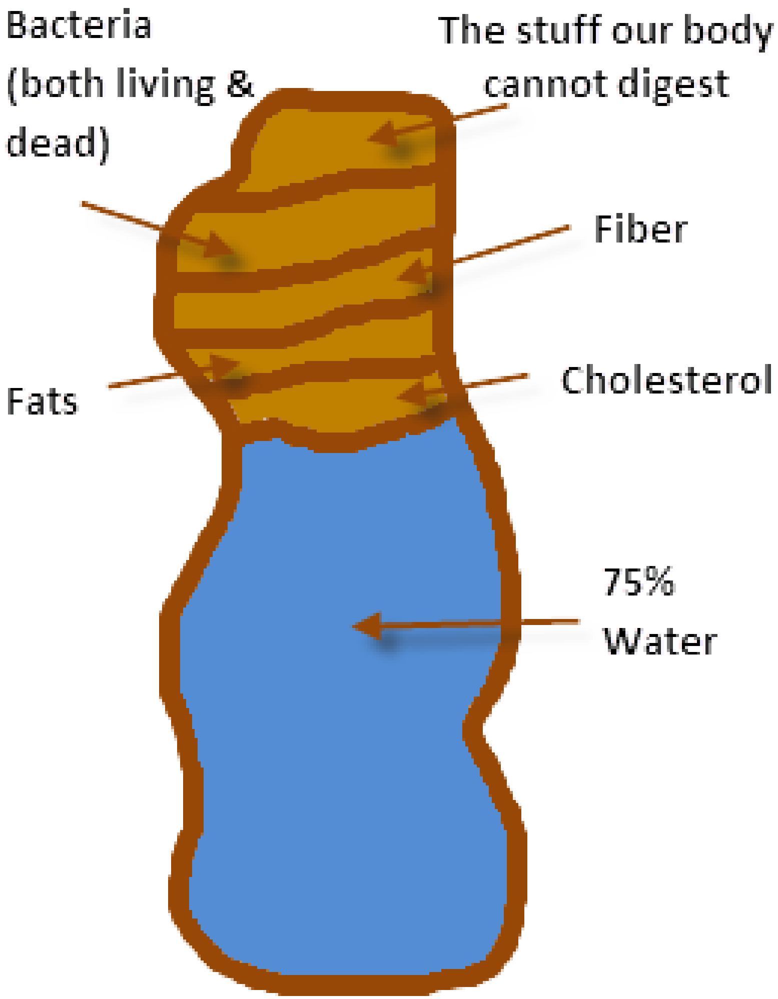


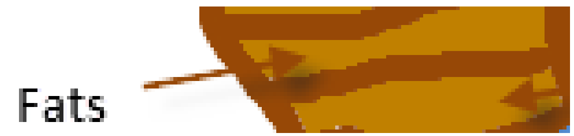
- Lipids

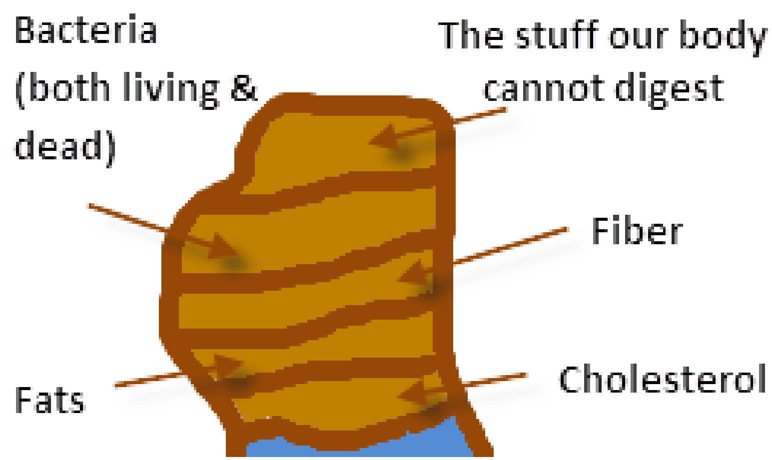


- Lipids in feces









- **Biodiesel process agnostic to 'waste' stream?**

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Domestic and Food waste

Faecal sludge

Municipal solid waste

Animal by-product waste

Channel through fermentation platform

Our approach

Commodity chemicals, lipids, biodiesel

BILL & MELINDA GATES foundation

Anaerobic Digestion

Complex organic polymers

↓ Hydrolysis

Sugars, amino acids

↓ Acidogenesis

VFA

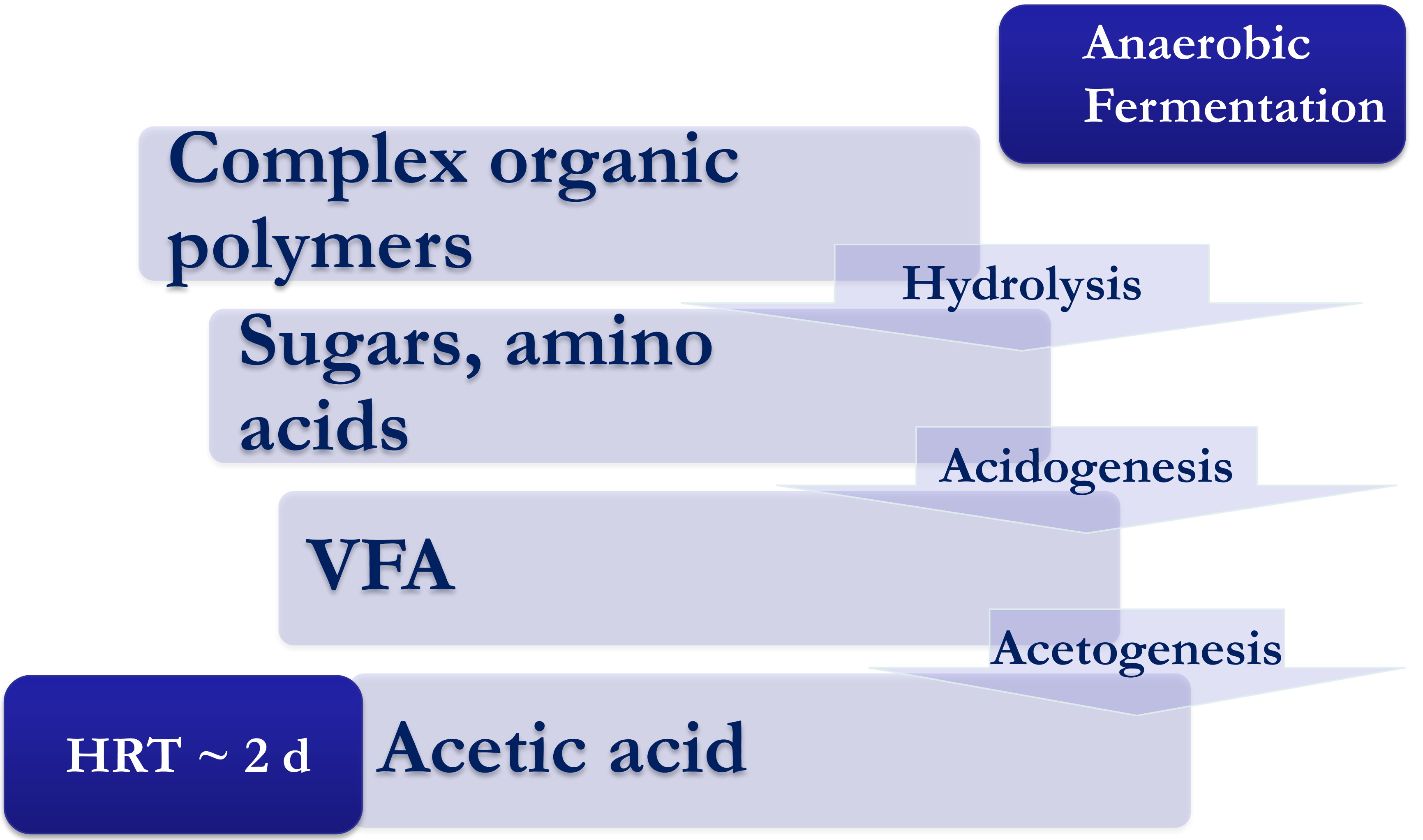
↓ Acetogenesis

Acetic acid

↓ Methanogenesis

Methane

HRT > 10 d



- Fermentation is more advantageous than just anaerobic digestion
- Fermentation can be incorporated into existing digestion processes

Overview of our process

Organic waste

Anaerobic fermentation to produce volatile fatty acids (VFA)

Convert VFA to lipids

Harvest and extract lipids

Convert lipids to biodiesel

Conversion of VFA to Lipids

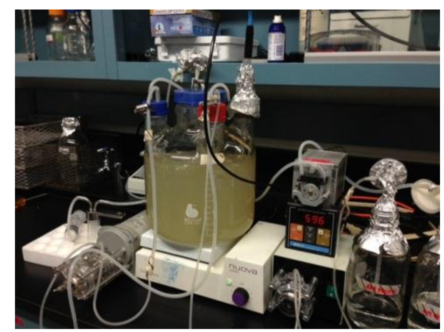
- **Different COD sources**
  - **VFA from food waste fermentation**
  - **Synthetic VFA**
  - **Glucose**
- **Different initial VFA concentrations**

6:1:3 acetate, propionate, butyrate. 2 day HRT

- **Different initial N concentrations**
  - **Excess N: COD:N = 5:1**
  - **Limiting N: COD:N = 25:1, 50:1, 125:1, 250:1**
  - **Stoichiometric COD:N supply =33:1**

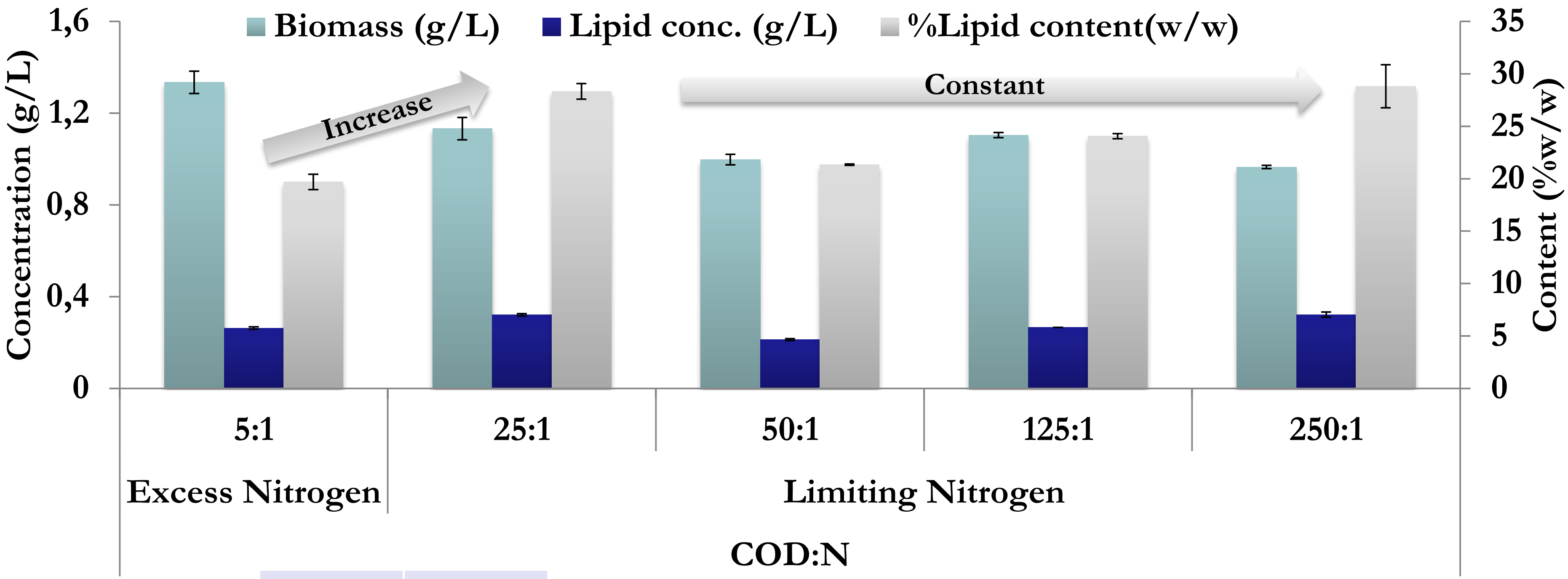
Lipid content of *C. albidus*

Batch reactor



Chemostat

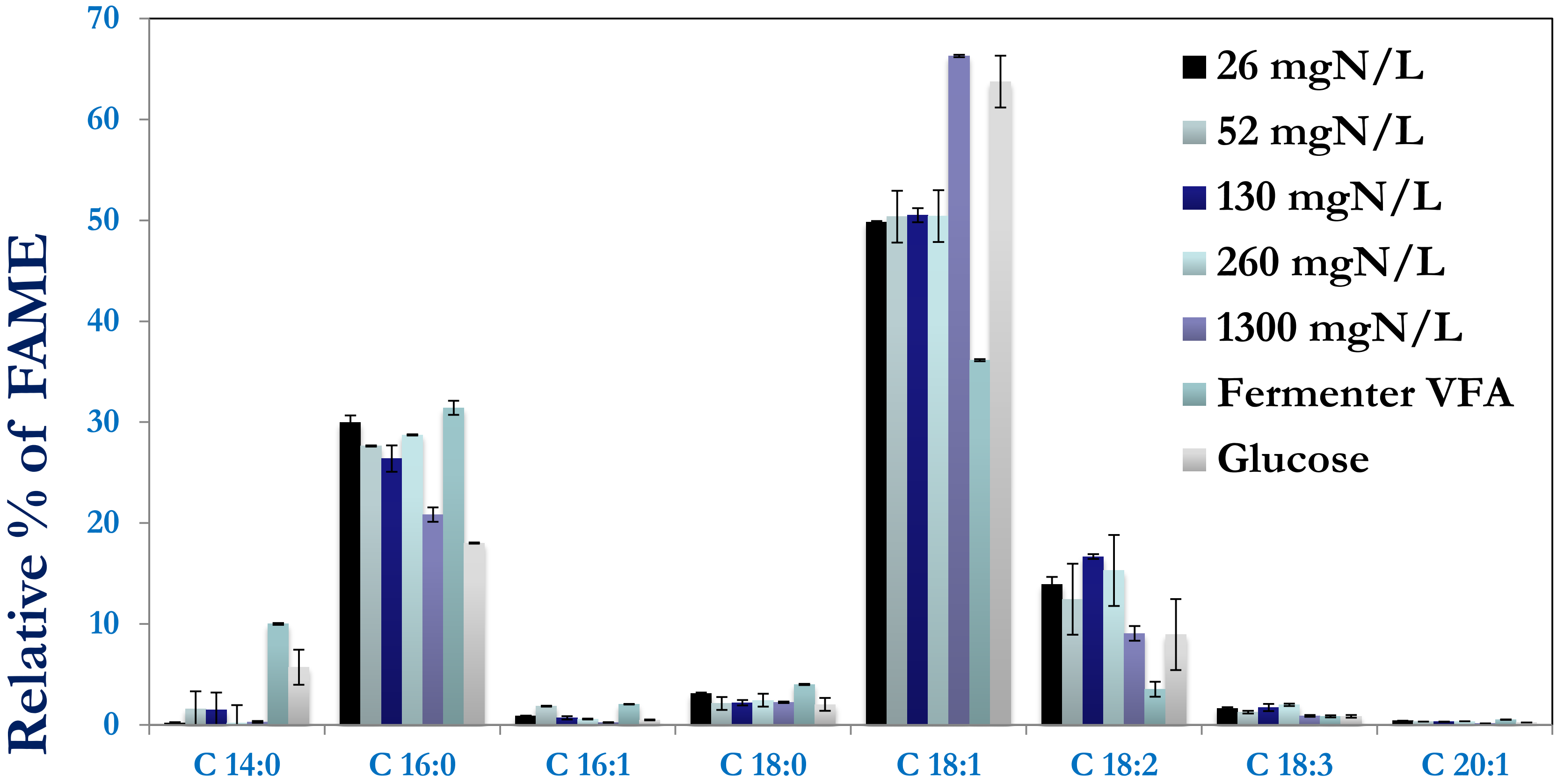
Effect of feedstock composition



	COD: N	μ_m (h^{-1})
	5:1	0.041
Limiting Nitrogen	25:1	0.043
	50:1	0.039
	125:1	0.036
	250:1	0.023

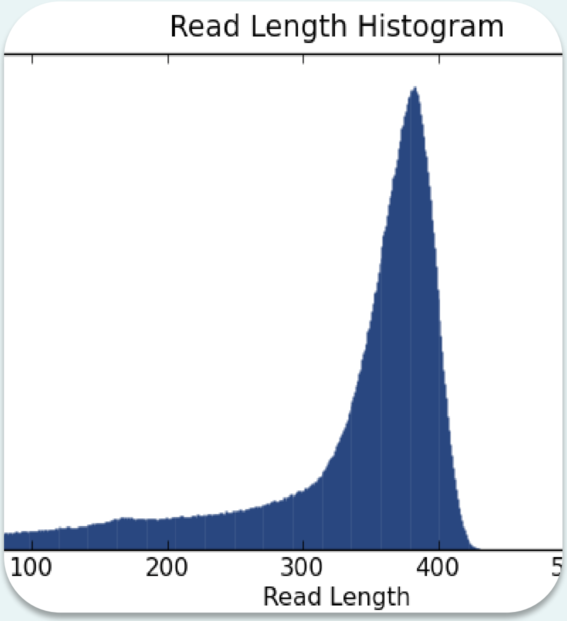
Process can handle variability in influent feedstock

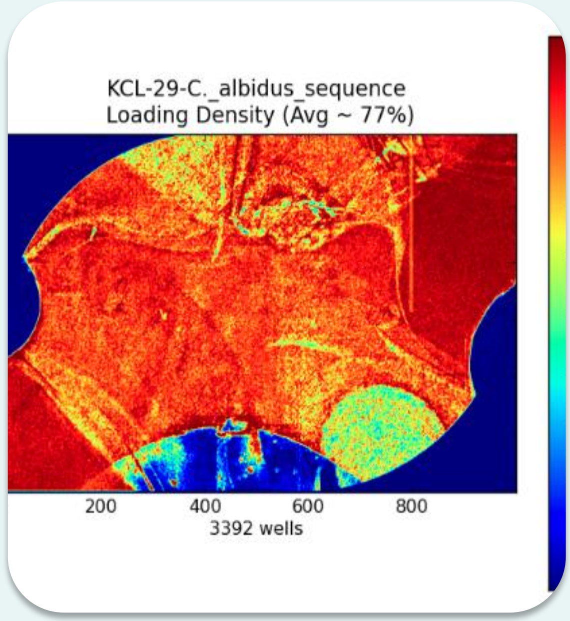
Lipid Composition

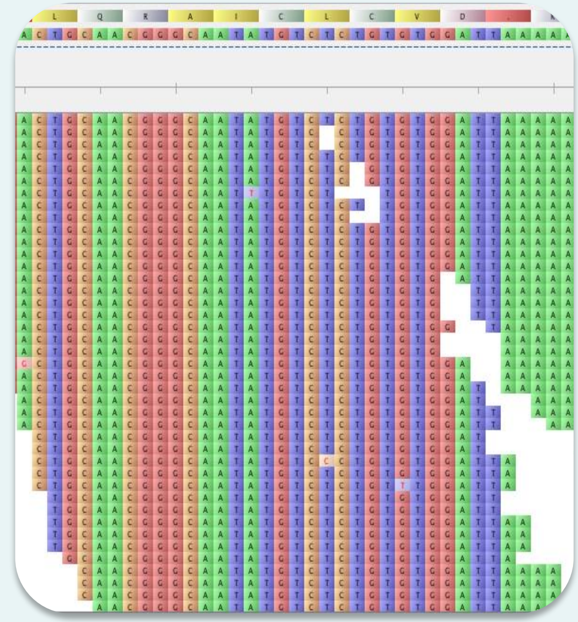


Major fatty acids accumulated are palmitic (C16:0), oleic (C18:1), and linoleic acid (C18:2)

Similar to soybean oil and jatropha oil, which are used as feedstock for biodiesel production in the US and the EU







Genome of

C. albidus

sequenced.

3million reads, 1G bases, 30x genome coverage

Assembly of library reads in to contiguous sequences (contigs). Consensus length 25MB, 915 contigs, N50= 83 kB

Allows understanding of mechanisms and metabolic pathways for lipid accumulation.

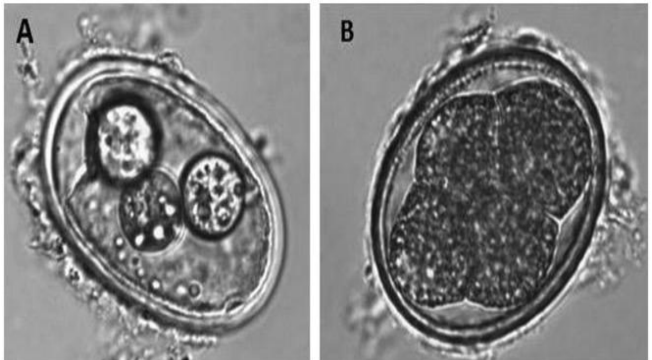
Can be used to increase lipid accumulation even further

Economic analysis

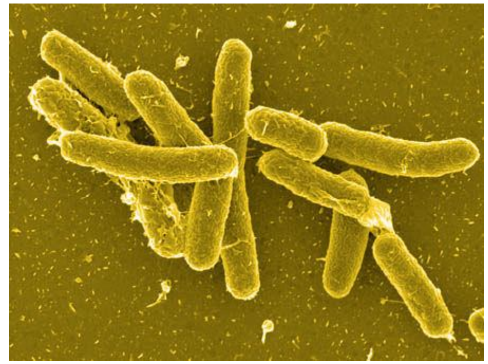
Cost of biodiesel production	
Carbon source cost	$30/ton (Much lower if sludge comes in pre-fermented, as in Kumasi, GH)
Lipid yield from *C. albidus* (kg lipid/ton VFA)	40.96 (lowest observed value during our studies)
Lipid cost ($/lb)	0.33
Gross cost ($/L biodiesel)	0.71
Gross cost ($/Kg biodiesel)	0.81

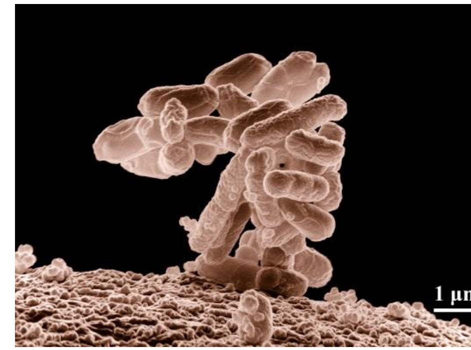
Not competing with biodiesel industry, rather making sanitation enterprise energy neutral or energy positive

Microbial inactivation using VFA



Butkus et. al


Salsali et. al



Wagner et. al

Ascaris sp.

High VFA conc.(60 g/L)
Low pH (4.75)

Salmonella sp.

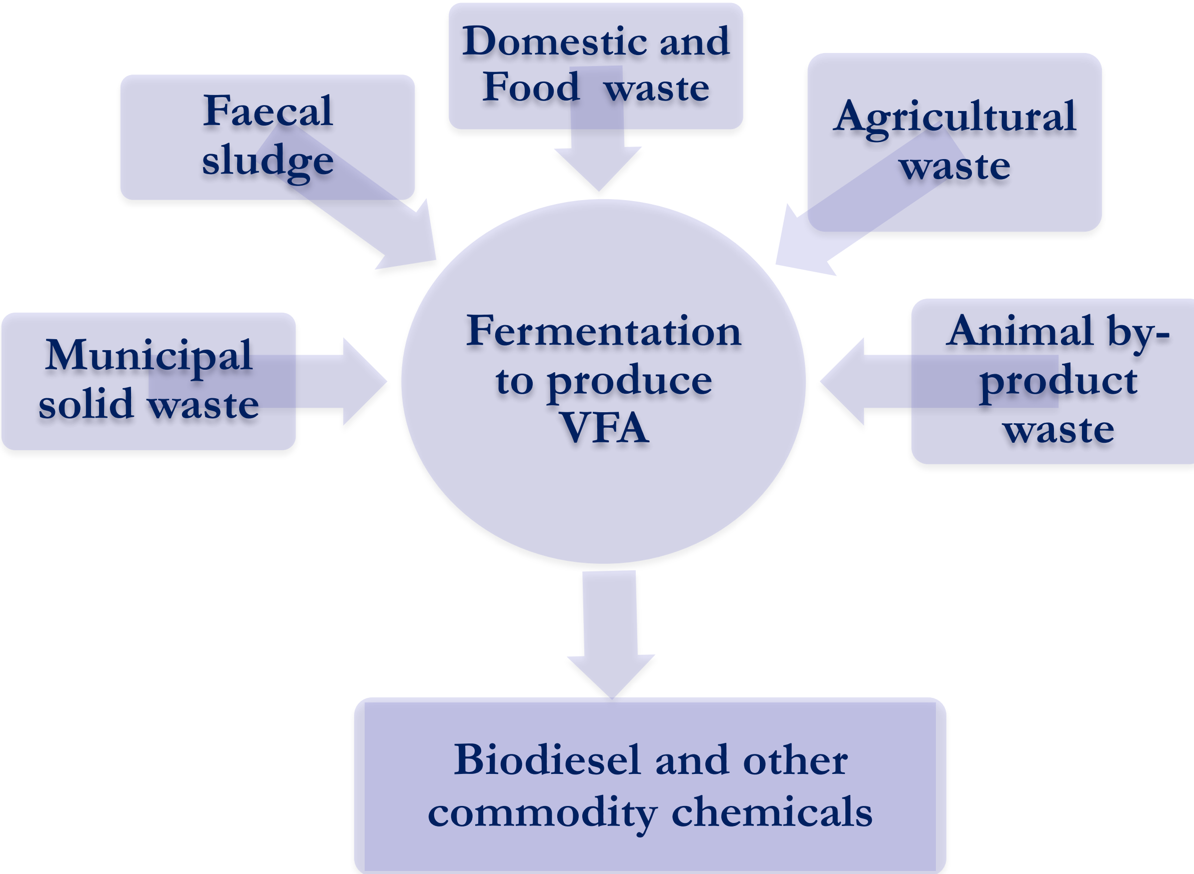
High temperature(49^{o}C)
Low pH (5.5)

E. coli

High temperature(55^{o}C)
Reduction after 7 days

What is the impact of exposure to VFA under extant conditions of anaerobic fermentation?

Conclusions and implications



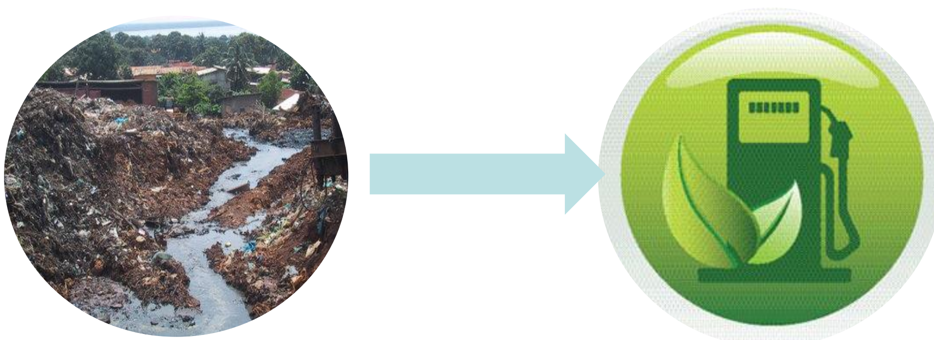
Novel and flexible platform to convert a variety of organic 'waste' streams to biodiesel or other lipid based commodity chemicals

Not reliant upon inherent lipid content- other organic classes can be converted to lipids

- For biodiesel as the preferred end point, reliance upon agricultural outputs is reduced or eliminated
- Links sanitation practice with energy and chemical recovery
- Microbial inactivation needs to be further characterized

DISCUSSION

BILL & MELINDA GATES foundation



Contact information

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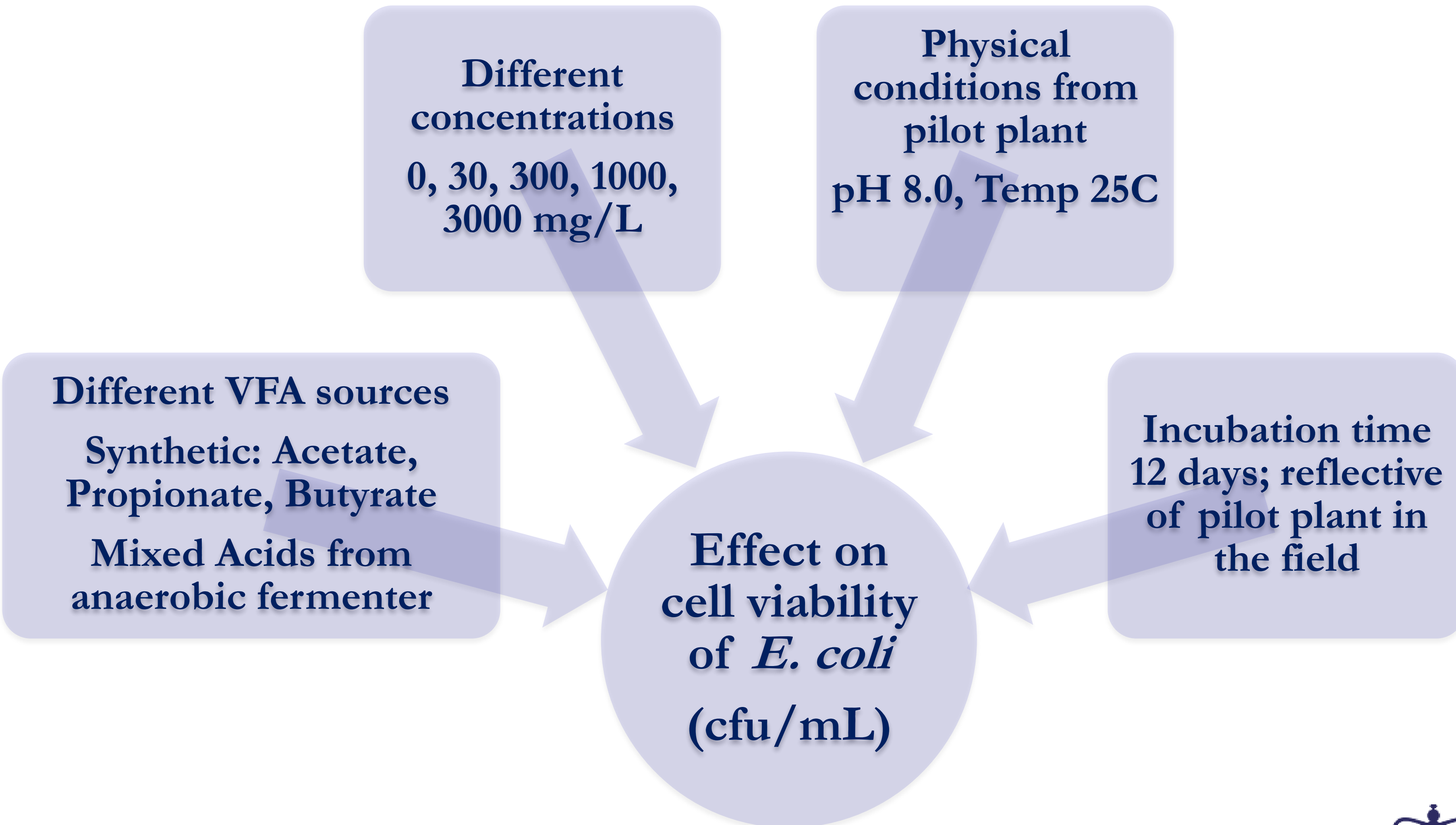
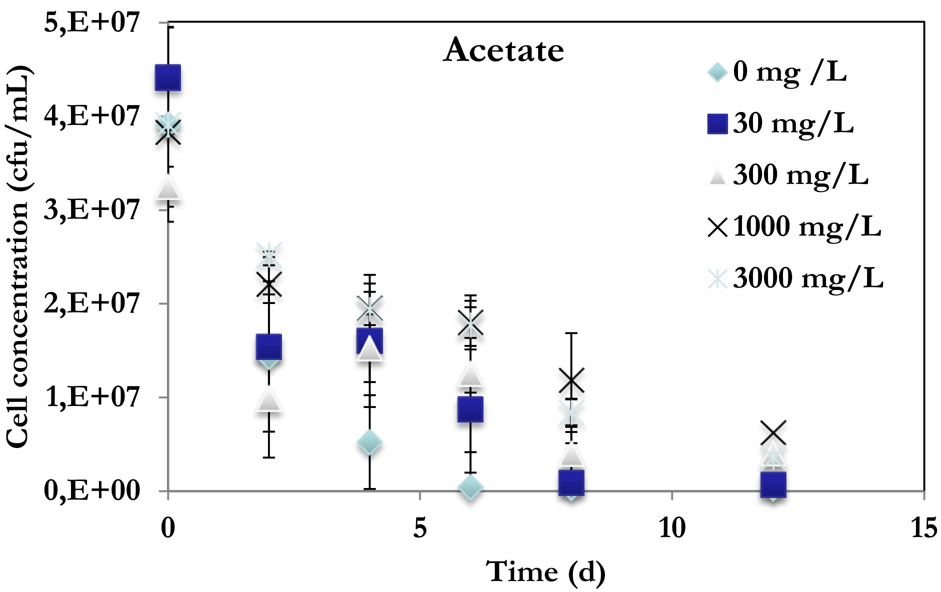
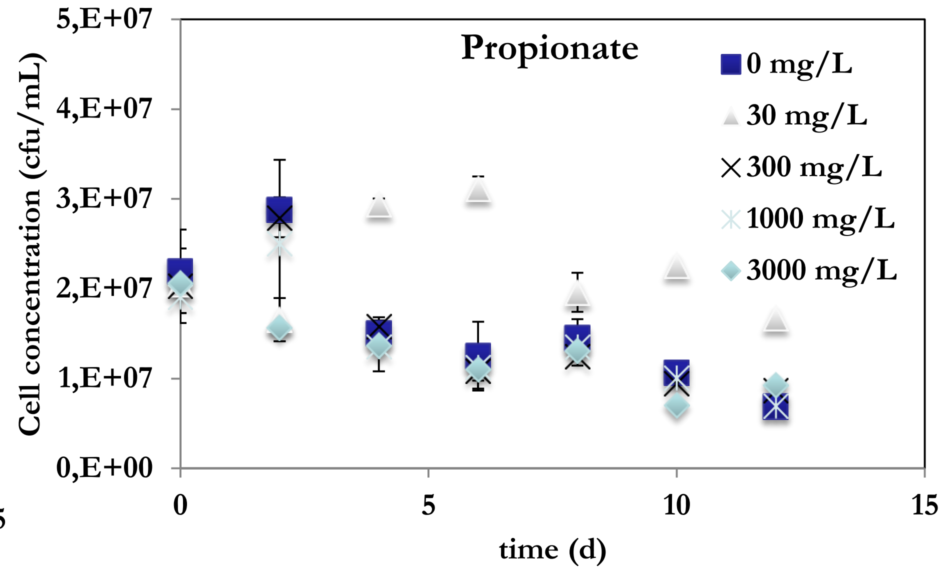
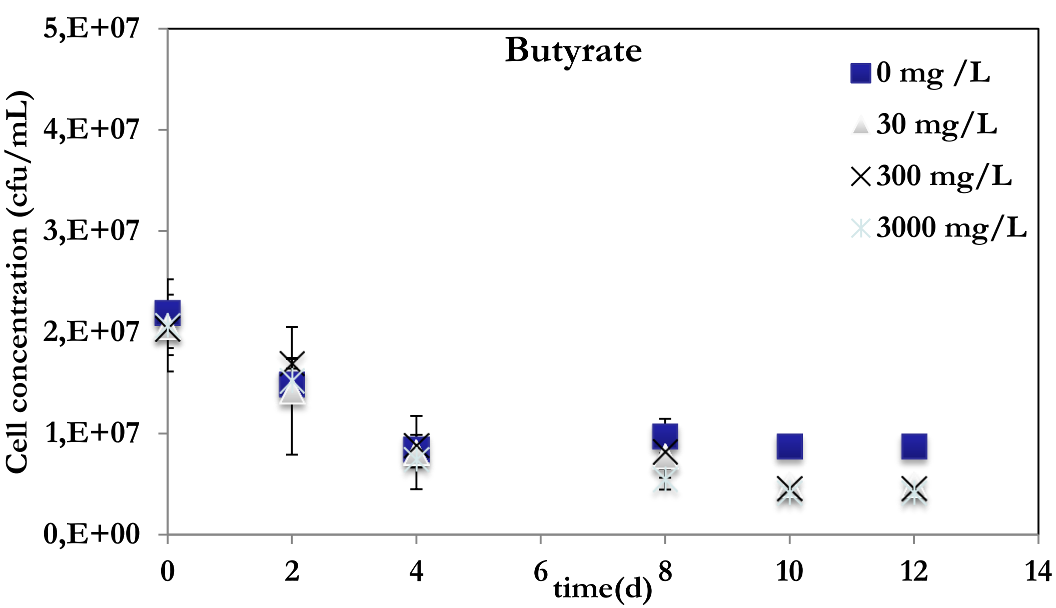
Microbial inactivation using VFA



EFFECT OF SYNTHETIC VFA

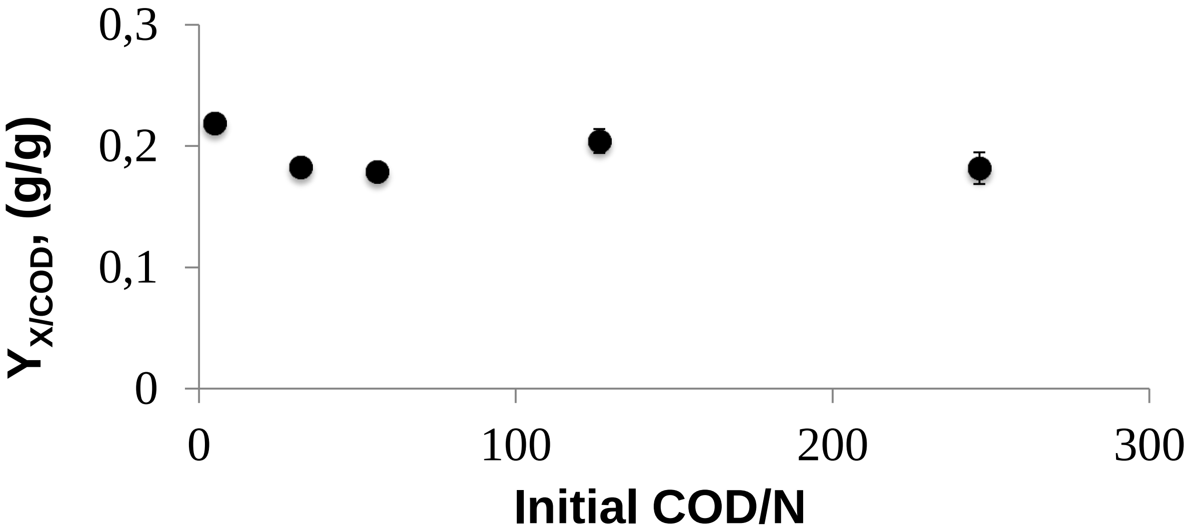




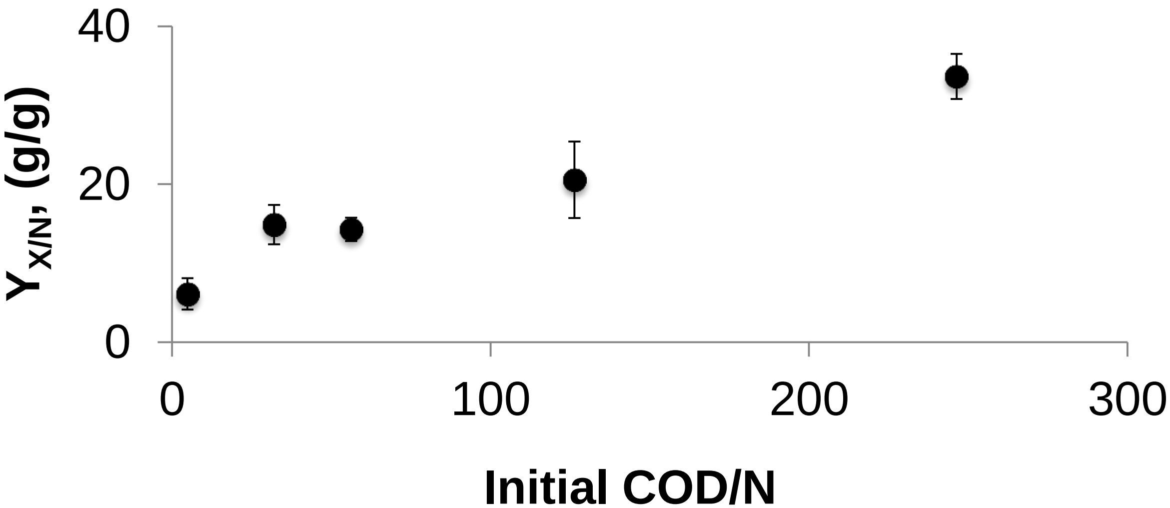


- Impact of added VFA not statistically different from endogenous controls
- Ongoing studies with food waste fermentate

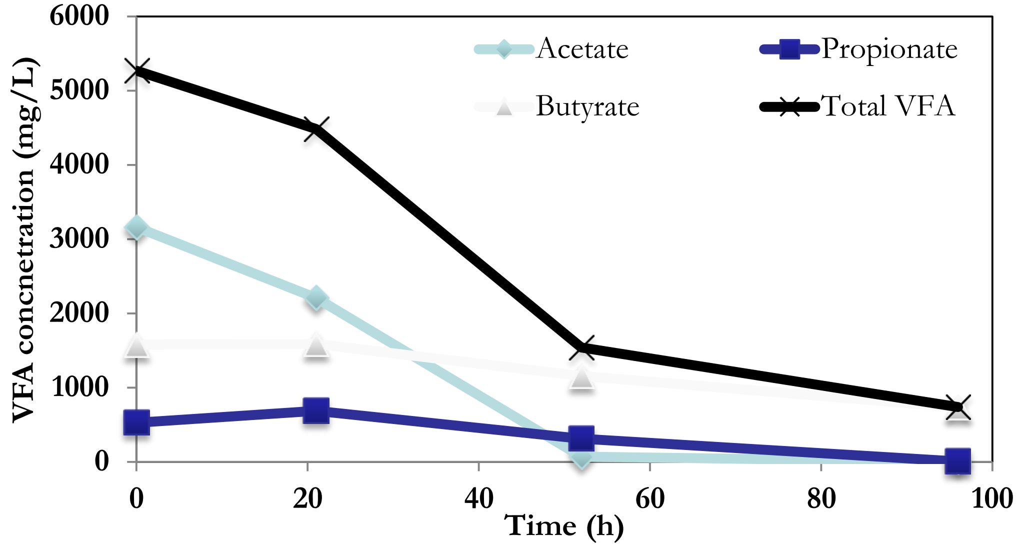
EFFECT OF NITROGEN CONCENTRATION ON YIELD COEFFICIENTS



Cultures become more efficient in carbon uptake and storage (as lipids) with increasing N-limitation



PREFERENTIAL CONVERSION OF VFA TO LIPIDS

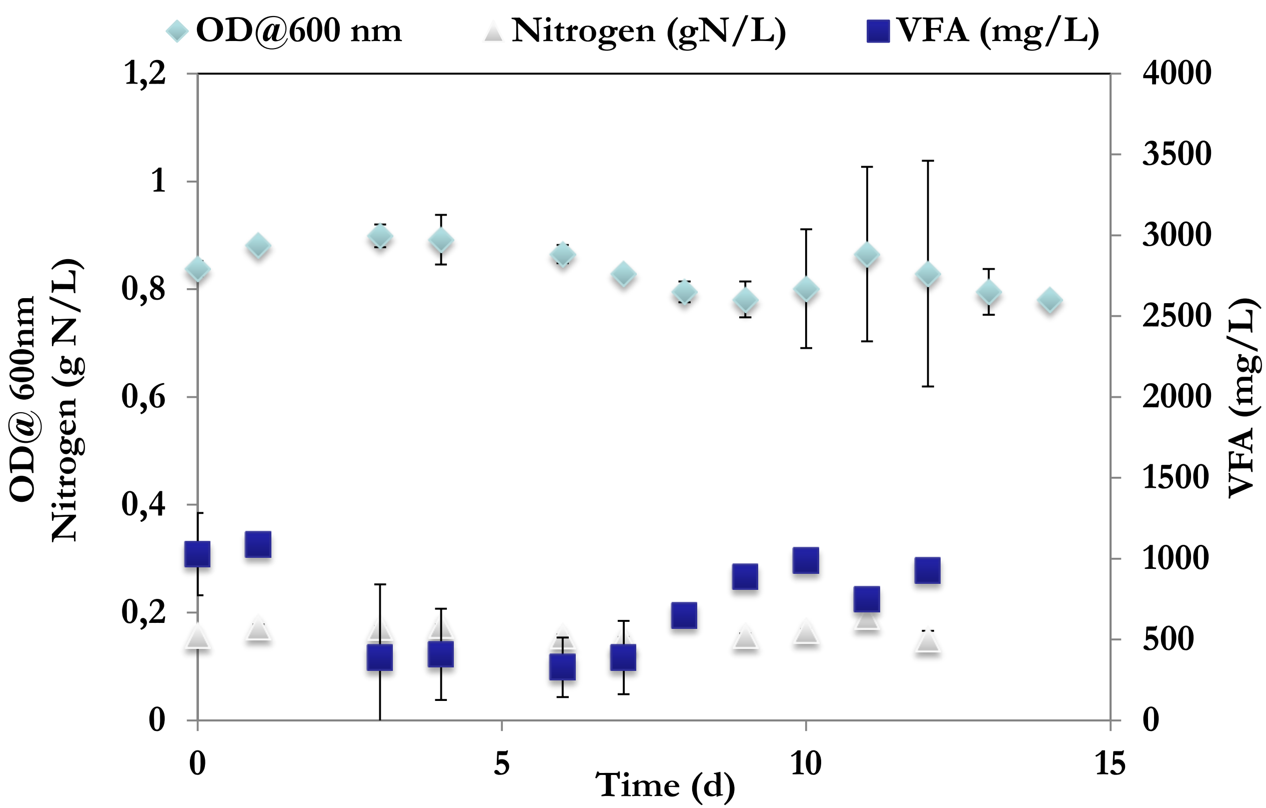


- ***C. albidus*** **exhibited higher preference for acetic acid before other VFAs *i.e.* propionic and butyric acid.**

VFA	Specific uptake rate (mg COD/g biomass/h)
Acetate	47.91±4.24
Propionate	3.97±1.54
Butyrate	7.42±3.01

- **Specific uptake rate for acetate was higher than other VFA**

BIOMASS AND LIPID YIELD IN CHEMOSTAT



Relative % as FAME	
C 14:0	0.52
C 16:0	36.81
C 16:1	0.96
C 18:0	2.67
C 18:1	37.36
C 18:2	19.14
C 18:3	2.26
C 20:1	0.29

- The steady state biomass concentration was 1.02 g/L and the intracellular lipid content increased to 29.88%.
- At this operational HRT of 3 days, the cells were able to assimilate all the influent carbon source.
- Slow growth rate resulted in increase in the saturated fatty acid content.

EFFECT OF DIFFERENT CARBON SOURCES AND CONCENTRATIONS

Carbon source	NH_3-N (mg/L)	Biomass (g/L)	μm (h^{-1})	Lipid content	$Y_{L/\Delta COD}$ (mg/g)
Pure VFA	260	1.13	0.043	27.8%	52
VFA from fermenter	260	0.96	0.021	14.9%	31
Glucose	1300	5.14	0.095	43.3%	110

VFA concentration

- 2600 mg-COD/L Carbon limiting
- 6500 mg-COD/L Optimal
- 10,000 mg-COD/L Substrate inhibition

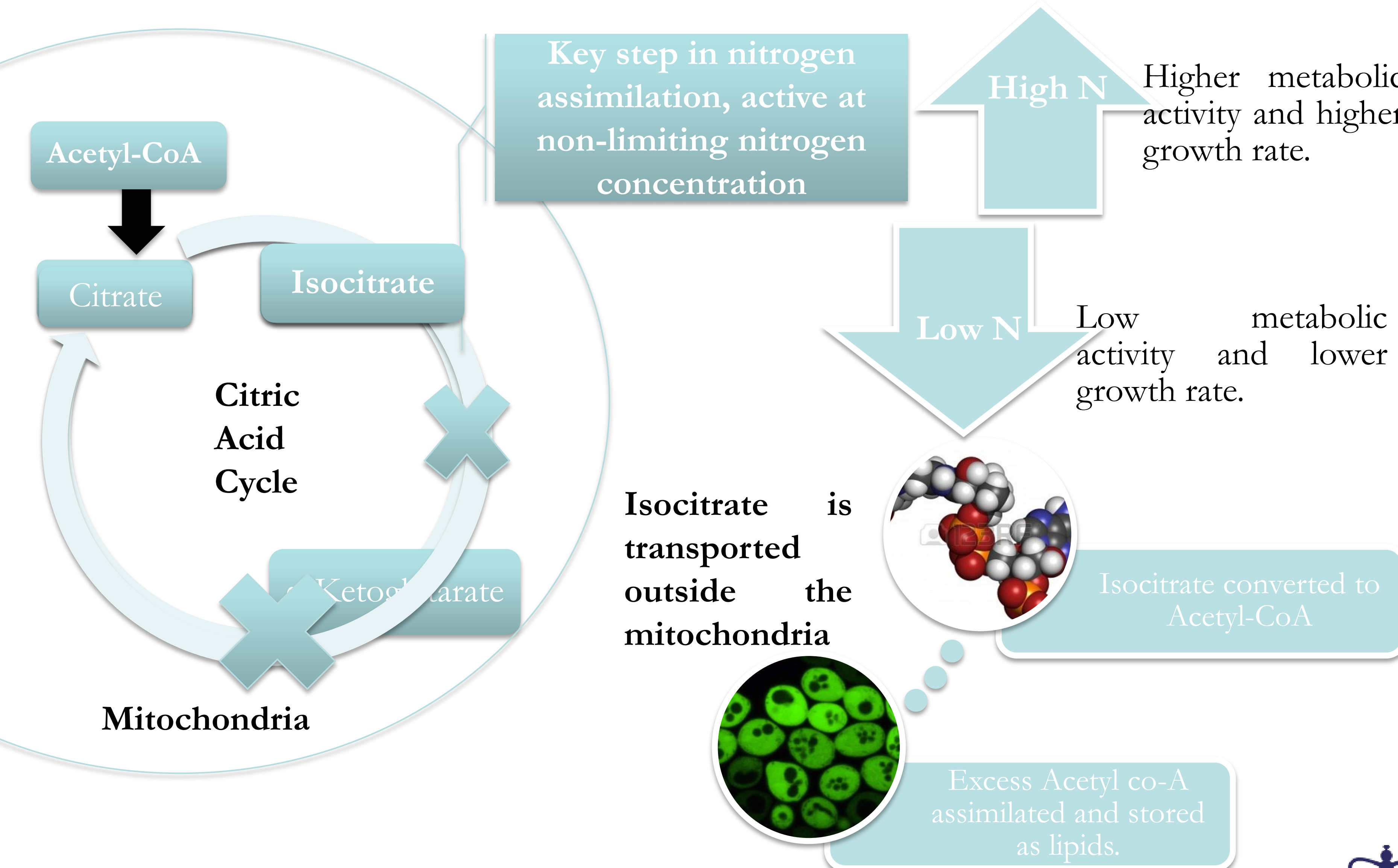
Glucose $500/ton

VFA $30/ton

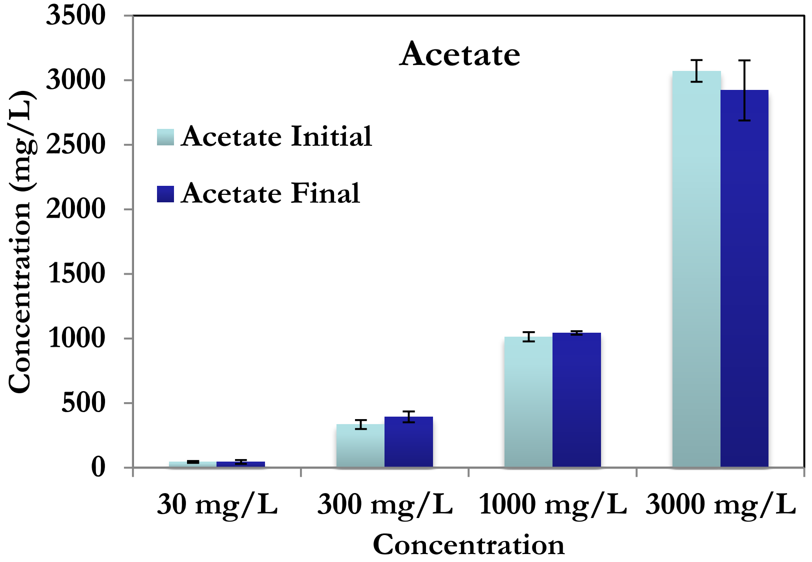
Cost*

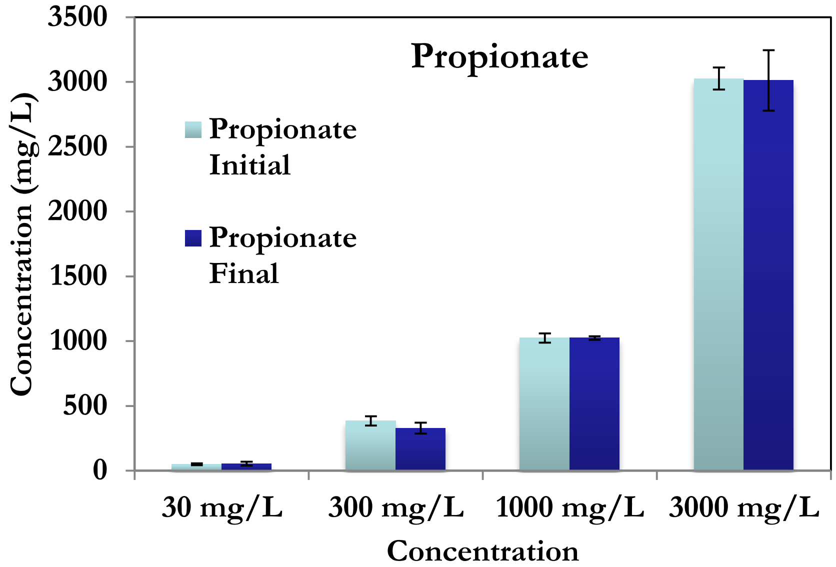
***Fei et al. 2011**

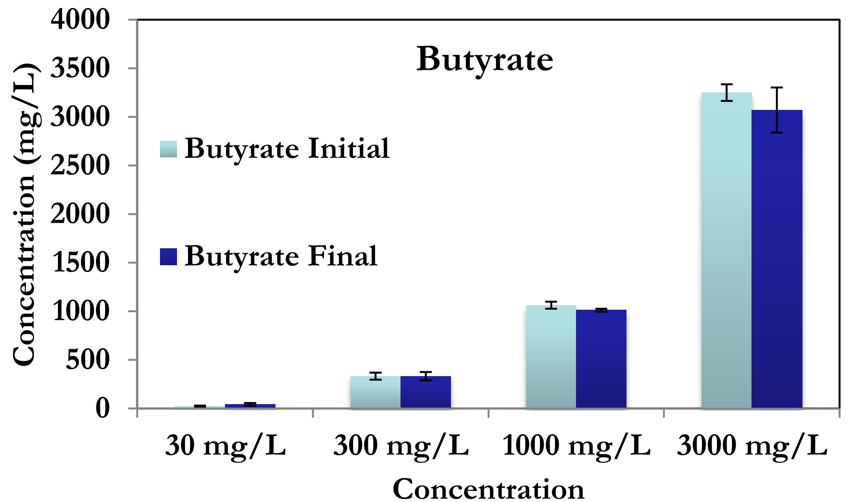
METABOLIC EFFECT OF NITROGEN CONCENTRATION



VFA consumption by *E. coli*





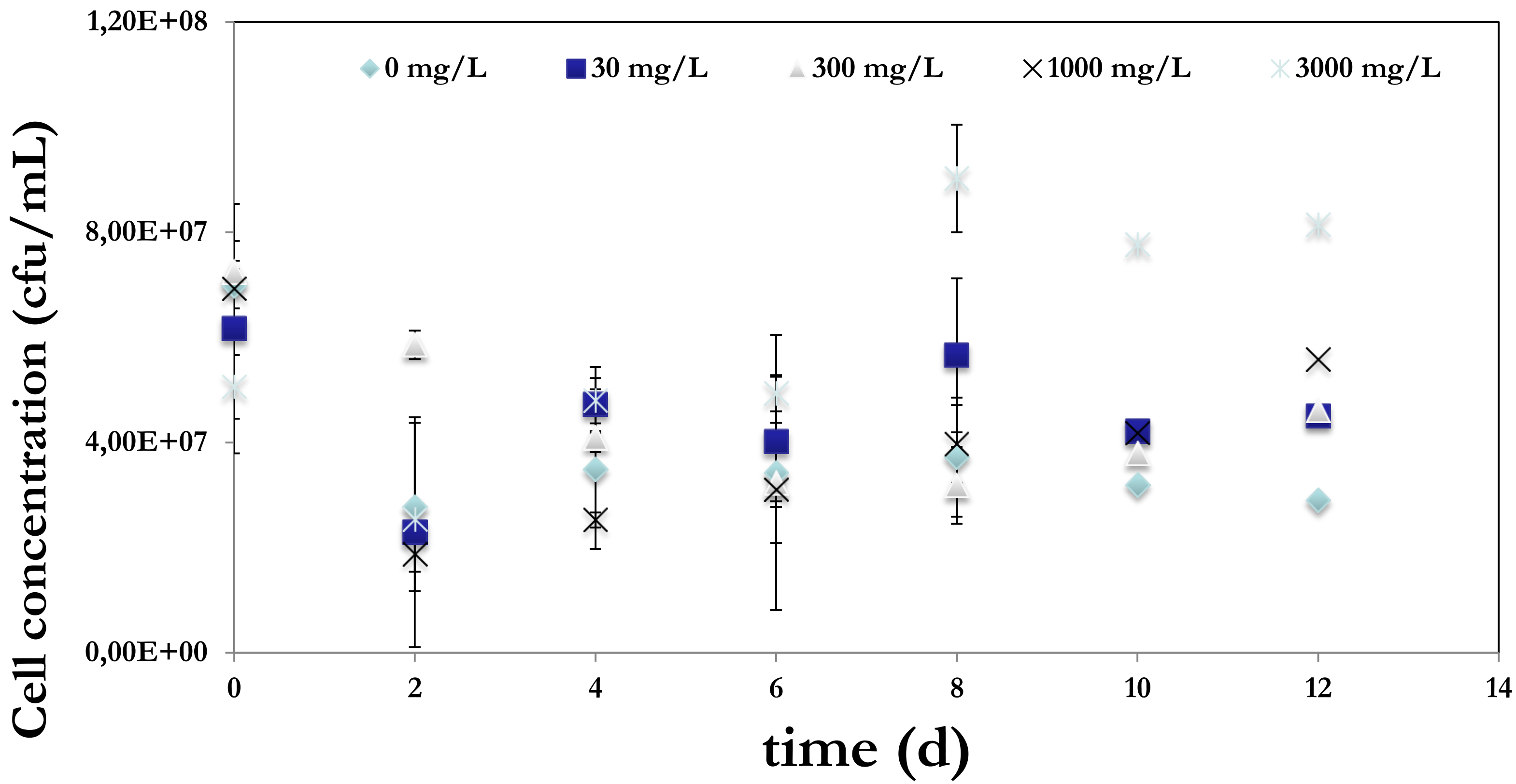


Water Chemistry

Acid	pKa	[A-]/[HA]
Acetate	4.75	1.78E+03
Propionate	4.88	1.32E+03
Butyrate	4.82	1.51E+03

At pH 8.0, >99.9% VFA exist as their conjugate base

EFFECT OF VFA FROM ANAEROBIC FERMENTATION OF FOOD WASTE



Impact of added VFA not statistically different from controls

Additional testing ongoing