6-20-2019

Anaerobic digestion of the aqueous pyrolysis condensate

Franco Berruti
ICFAR, Western University, Canada, fberruti@uwo.ca

Cesar Miguel Moreira Valenzuela
ICFAR, Western University, Canada

Lars Rehmann
ICFAR, Western University, Canada

Connie Wen
ICFAR, Western University, Canada

Anaerobic Digestion of Aqueous Pyrolysis Condensate

Connie Wen, Franco Berruti, Lars Rehmann,
Institute for Chemicals and Fuels from Alternative Resources (ICFAR),
Western University, London, Ontario, Canada
Cesar Moreira Valenzuela
ESPOL, Ecuador

Outline of the Presentation

Aqueous Pyrolysis Condensate (APC)

Integrated Biomass Thermo- & Bio-Conversion

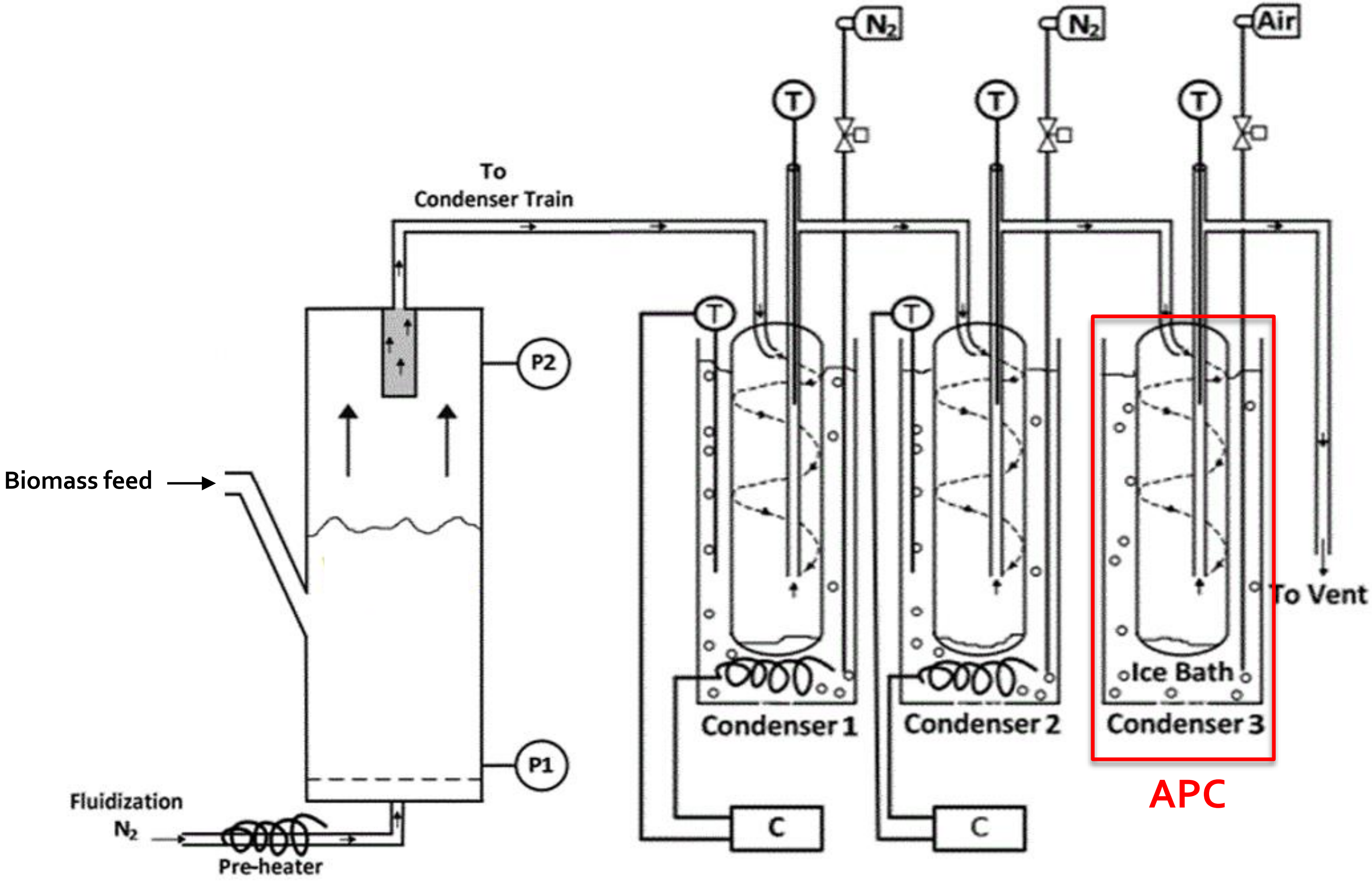
Experimental methods

Products characterization

Can bacteria metabolize APC to produce valuable products?

Effects of supplements (nutrient & biochar) in APC on Anaerobic Digestion

Pyrolysis & Fractional Condensation



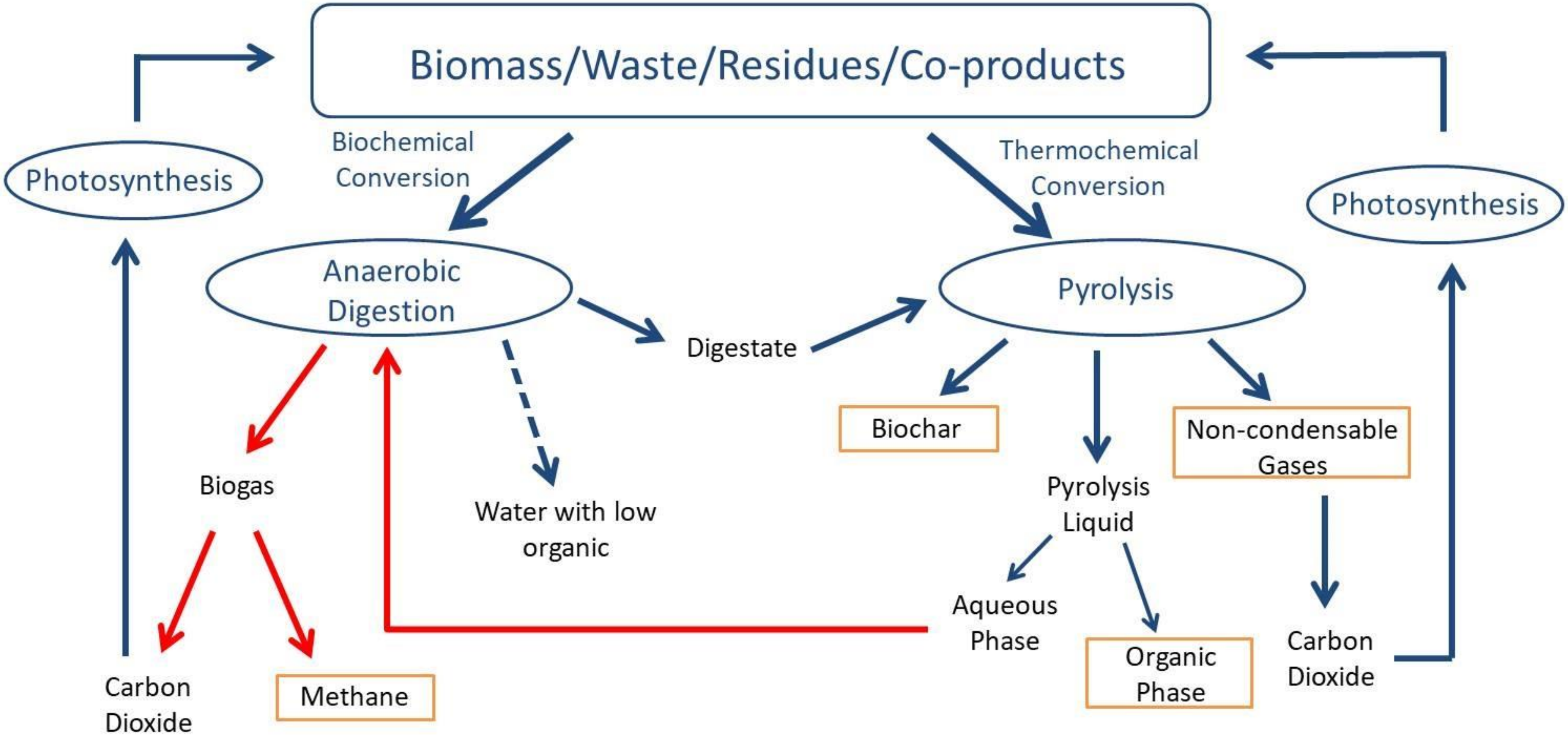
Aqueous Pyrolysis Condensate (APC)

- High water contents (low calorific value)

- High acid and organic contents (costly to dispose)

- A resource for alternative use?

Biomass Conversion – Integrated



A Circular Economy!

Research Objectives

- Confirm whether Anaerobic Digestion can degrade APC to:
  1. Reduce organic content of APC
  2. Produce biogas

- Study anaerobic microbial consortia adaptation to APC

- Study the effect of supplements in APC Anaerobic Digestion (i.e. on biogas production)

Anaerobic Digestion (AD)

Biological conversion of organic matter carried out by microbial consortia in the absence of oxygen generating Methane and CO_2

Influential factors:

- Temperature (optimum for mesophilic: 30 - 38 °C)
- pH (optimum: 6.5 - 8)
- Substrate & Nutrients (N, P, Co, Fe, Ni, S)
- Inhibitors

Anaerobic Digestion Process

Hydrolysis:

Insoluble organic polymers - Carbohydrate - Protein - Fat	→	Soluble monomers - Glucose - Amino acid - Fatty acid

Acidogenesis:

Soluble monomers - Glucose - Amino acid - Fatty acid	→	Short-chain organic acids (**acetic and propionic acids**) Alcohol (MeOH, EtOH)

Acetogenesis:

APC

Short-chain organic acids (**acetic and propionic acids**) Alcohol (MeOH, EtOH)	→	Acetate Hydrogen

Methanogenesis:

Acetate Hydrogen	→	Biogas (Methane & Carbon Dioxide)

Common Inhibitors of AD

Ammonia

Sulfides

Alkali and Alkaline Earth Metal Ions (Na^+, K^+, Ca^{2+}, Mg^{2+})

Heavy Metals

Organics (benzene ring compounds, phenolic compounds, aromatic compounds, aldehydes, ketones, furans, etc.)

Materials

APC (from pyrolysis of birchbark at 500 °C)

AD Inoculum from an industrial anaerobic digester (StormFisher, London, Ontario)

APC & AD Products Characterization

Total organic content (TS, VS, TSS, VSS, COD)

pH

Volatile Fatty Acids

Common AD Inhibitors (ammonia, sulfide, metals, other organic compounds)

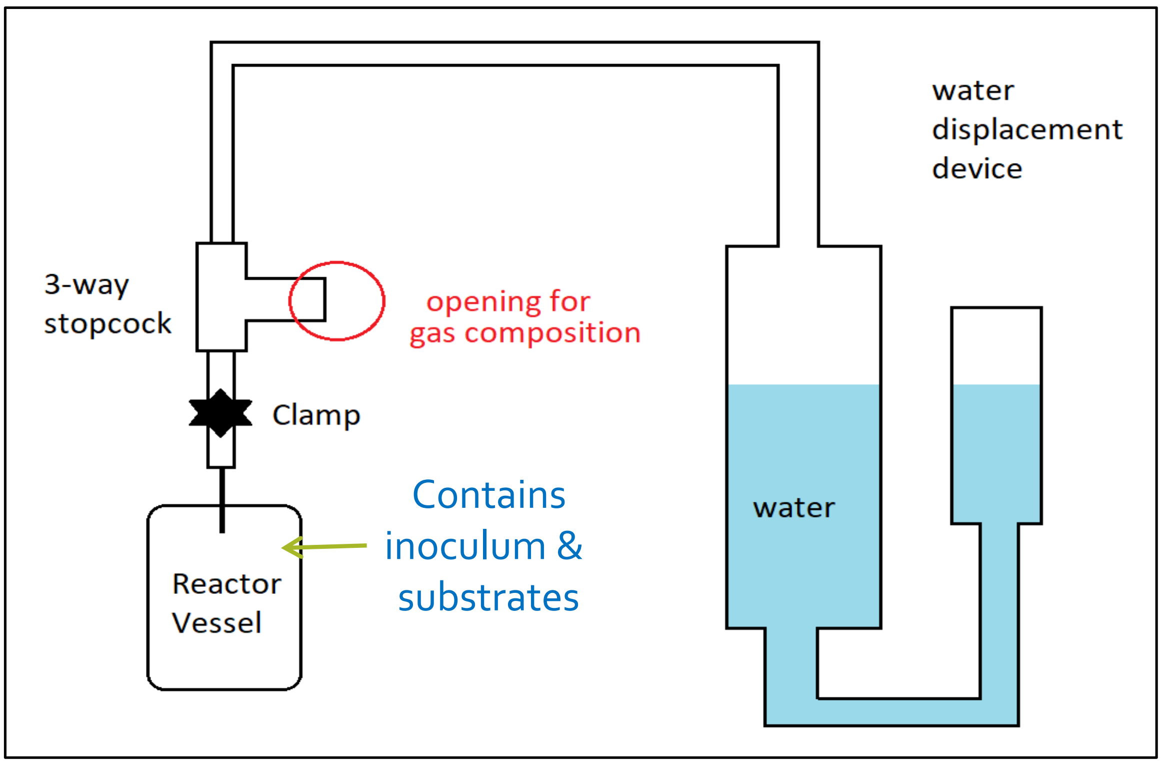
Gas composition

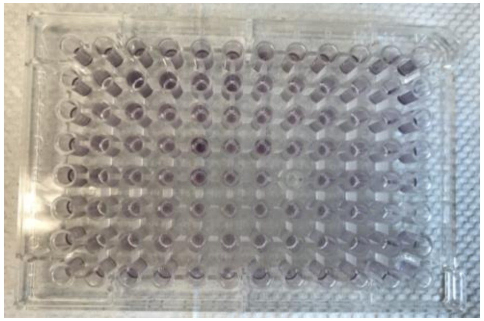
Experimental Method

Inoculum preparation & Inoculation

Gas volume measurement

Preliminary Community Level Physiological Profiling





Effects of Different Dilutions of APC on Biogas Composition

Bottles containing equal amounts of inoculum but with different amounts of APC corresponding to different **acetic acid equivalent (from 0 to 1 g/L)** concentrations

Adaptation of AD Inoculum to APC Batch 1

Bottles containing equal amounts of inoculum but with different materials added:

Sample	Content
Blank	Sterilized N_2-flushed diH_2O
Acetic Acid Control	1.0 g/L acetic acid
APC	1.0 g/L AA eq. APC

.....with 1.0 g/L of glucose was added on Day 27

Adaptation of AD Inoculum to APC Batch 2

Bottles containing equal amounts of inoculum but with different materials added:

Sample	Content
Blank	Sterilized N_2-flushed diH_2O
Acetic Acid Control	1.0 g/L acetic acid
APC (1.0 g/L AA)	1.0 g/L AA eq. APC
APC (0.5 g/L AA)	0.5 g/L AA eq. APC

Organic Content & Acids Analysis of Aqueous Pyrolysis Condensate (APC)

COD	TS	VS	TSS	VSS
499.0 g/L (0.48 gCOD/g)	81.0 g/L (7.7 % wt)	79.4 g/L (98 % of TS)	6.1 g/L (0.5 % wt)	5.8 g/L (95 % of TSS)

pH	Acetic Acid	Propionic Acid
2.12	**104.7 g/L**	**9.9 g/L**

Possible APC Inhibitors Analysis

Ammonia: below threshold

Sulfide: below threshold

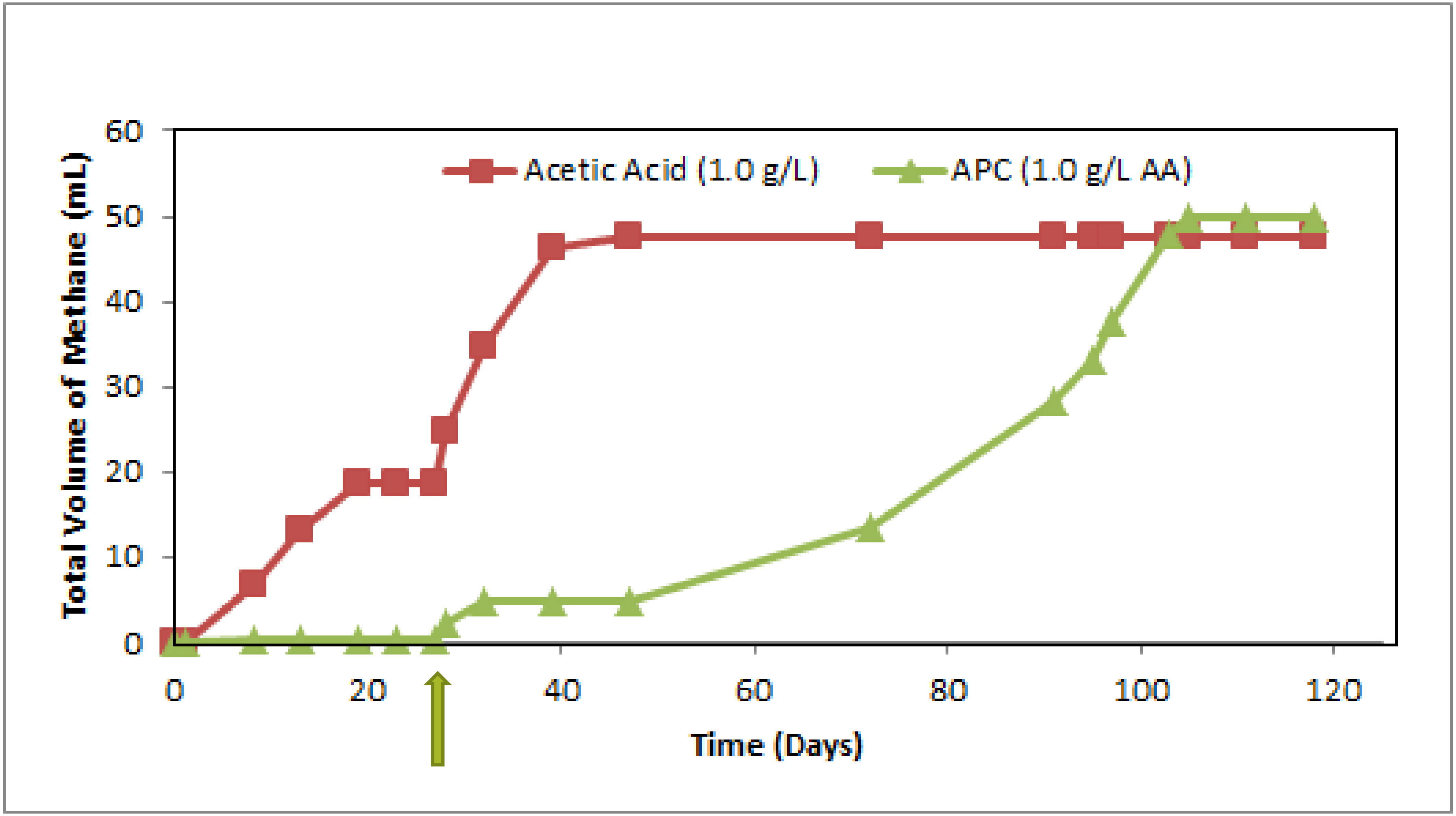
Alkali and Alkaline Earth Metals: below threshold

Heavy Metals: below threshold

Phenols: 25,530 mg/L (threshold: 1,700 mg/L*)!!

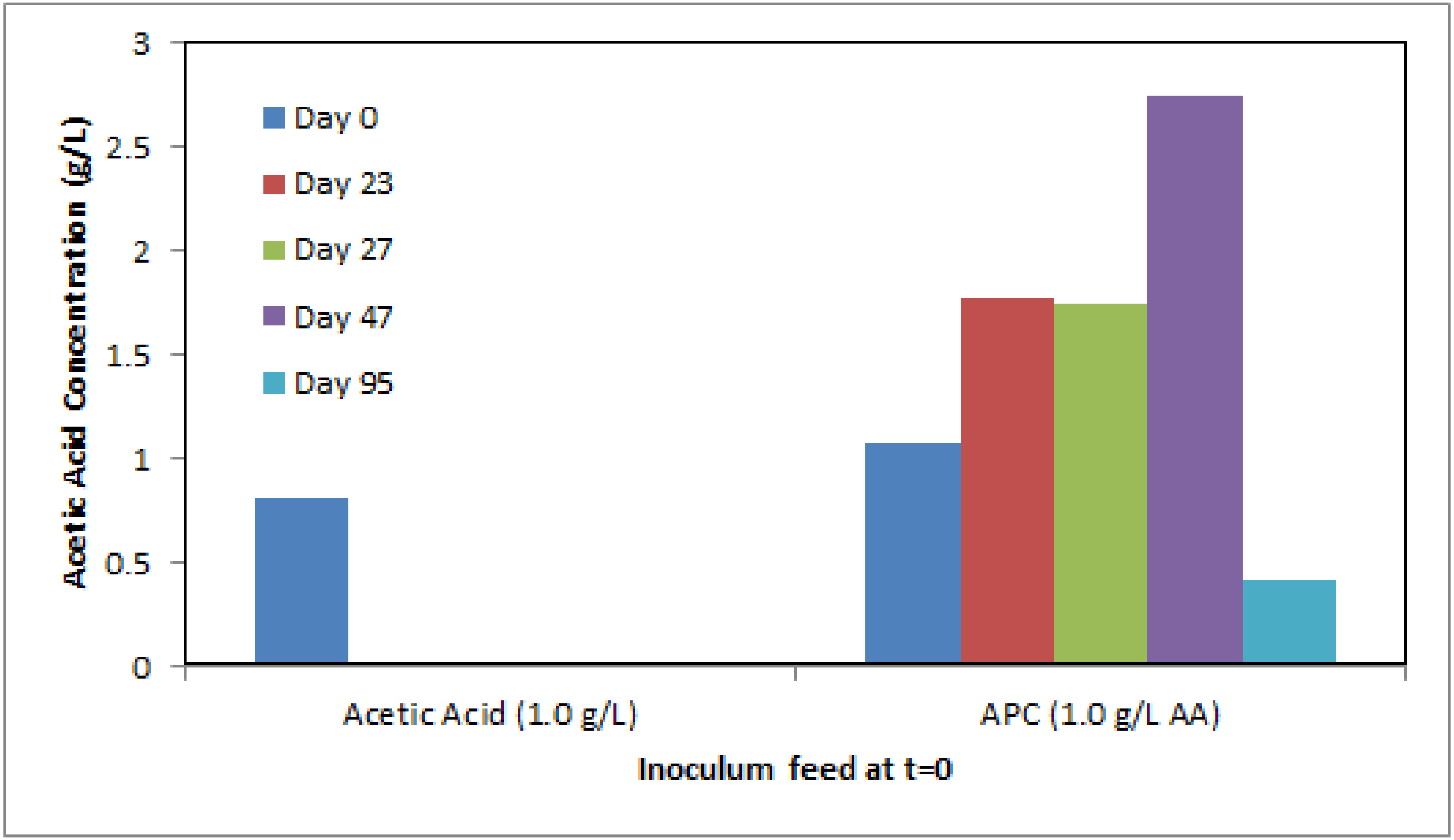
* Fang, H. H. P., Chan, O. C. (1997). Toxicity of phenol towards anaerobic biogranules. *Water Research*, *31*(9), 2229-2242.

Adaptation of AD Inoculum to APC- Batch 1

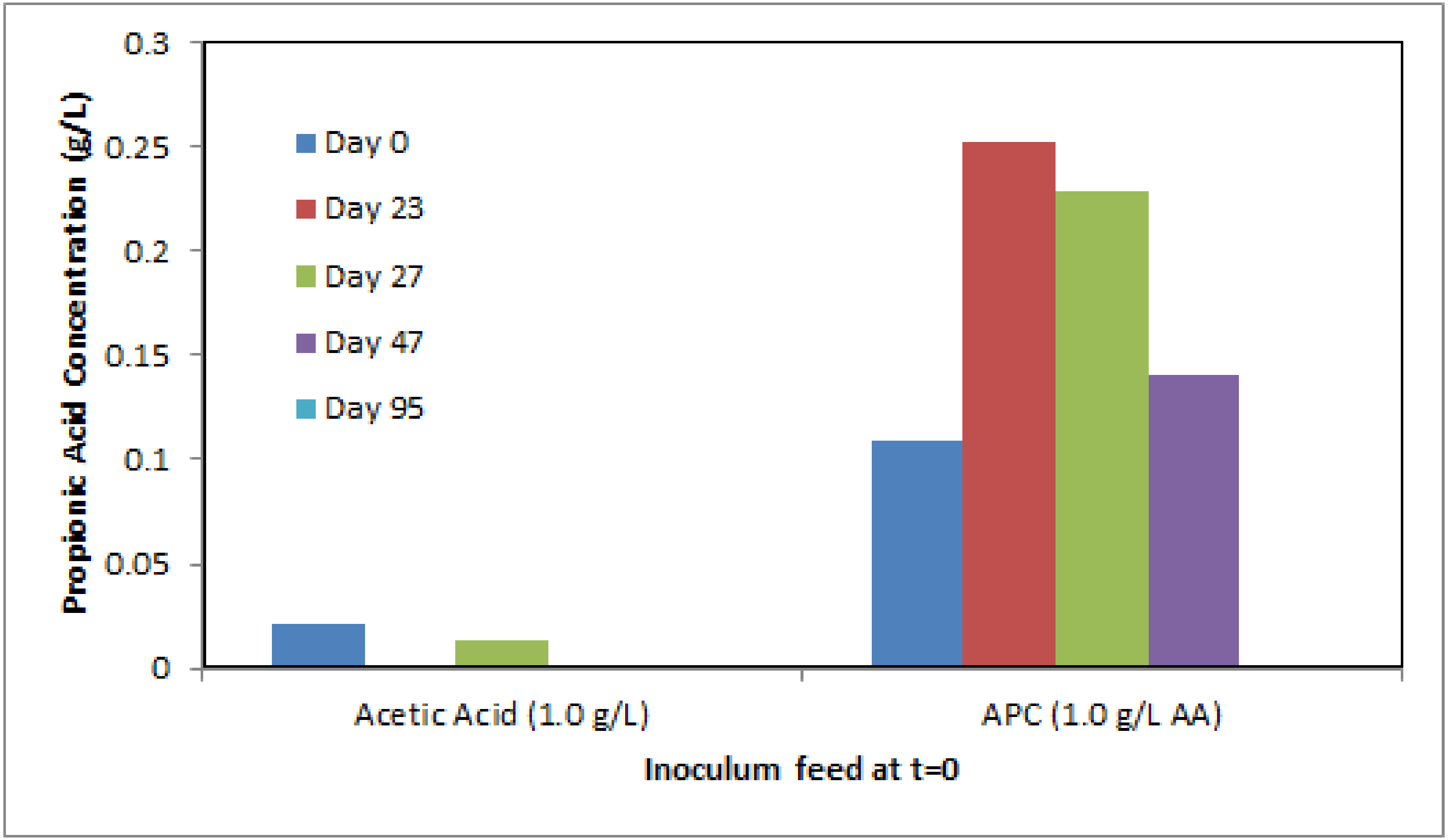


…plus, 30 % COD reduction was observed from Day 47 to Day 118!

Adaptation of AD Inoculum to APC- Batch 1

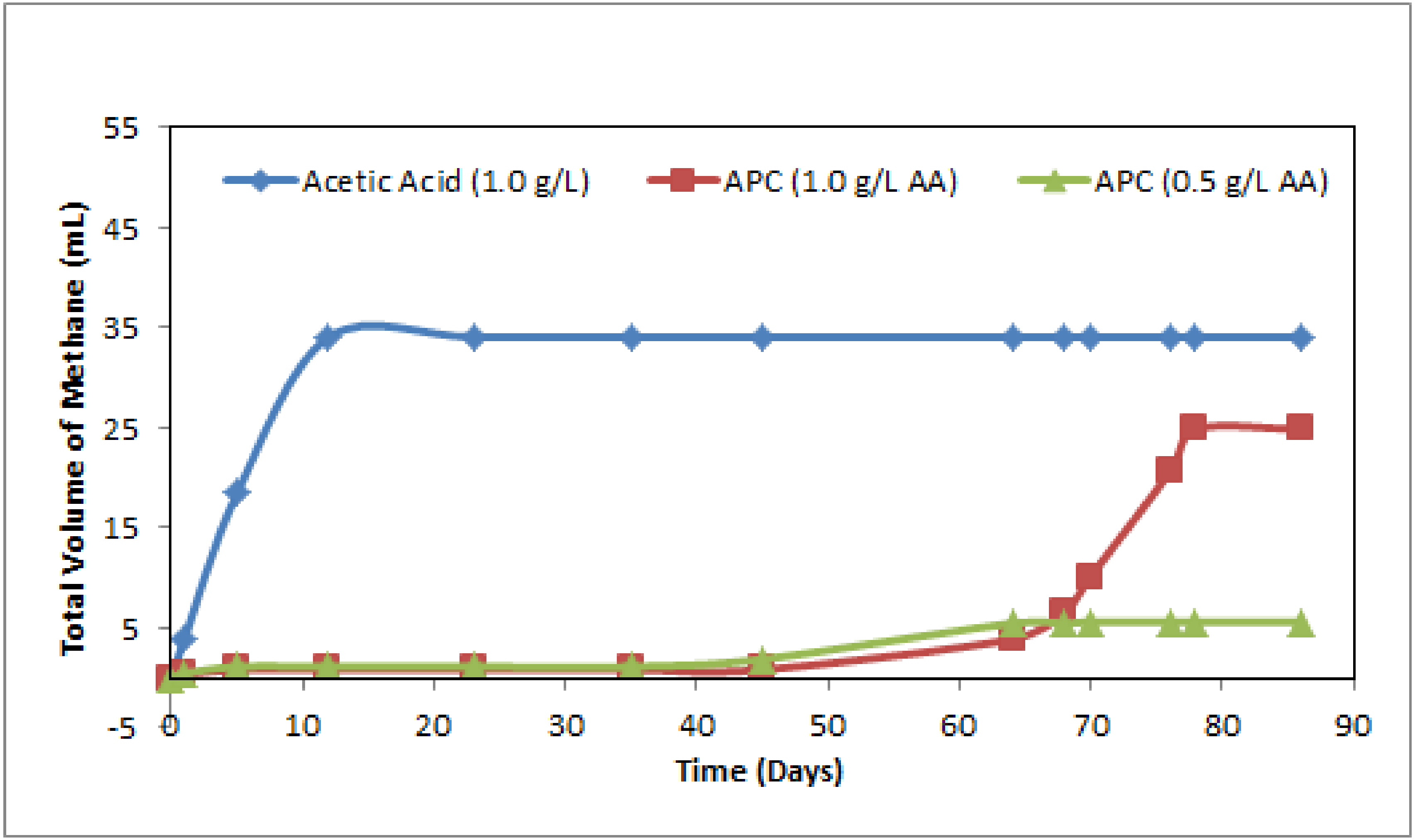


Adaptation of AD Inoculum to APC- Batch 1



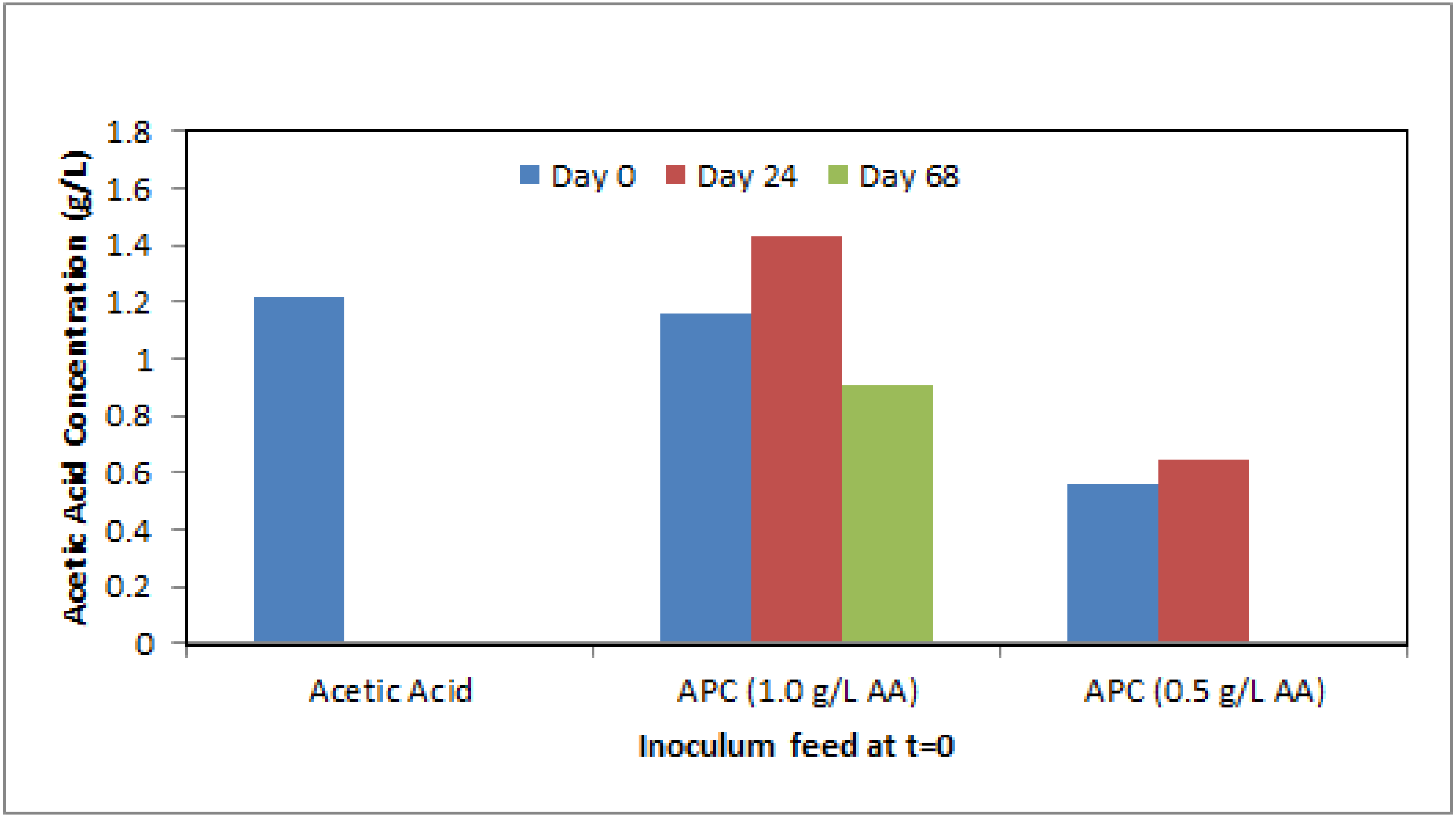
on Day 95, the amount of propionic acids from all is below detectable limit

Adaptation of AD Inoculum to APC- Batch 2



..plus, 31 % COD reduction was observed for APC (1.0 g/L AA)!

Adaptation of AD Inoculum to APC- Batch 2



on Day 68, the amount of acetic acids from APC (0.5 g/L) is below detectable limit

Next Step

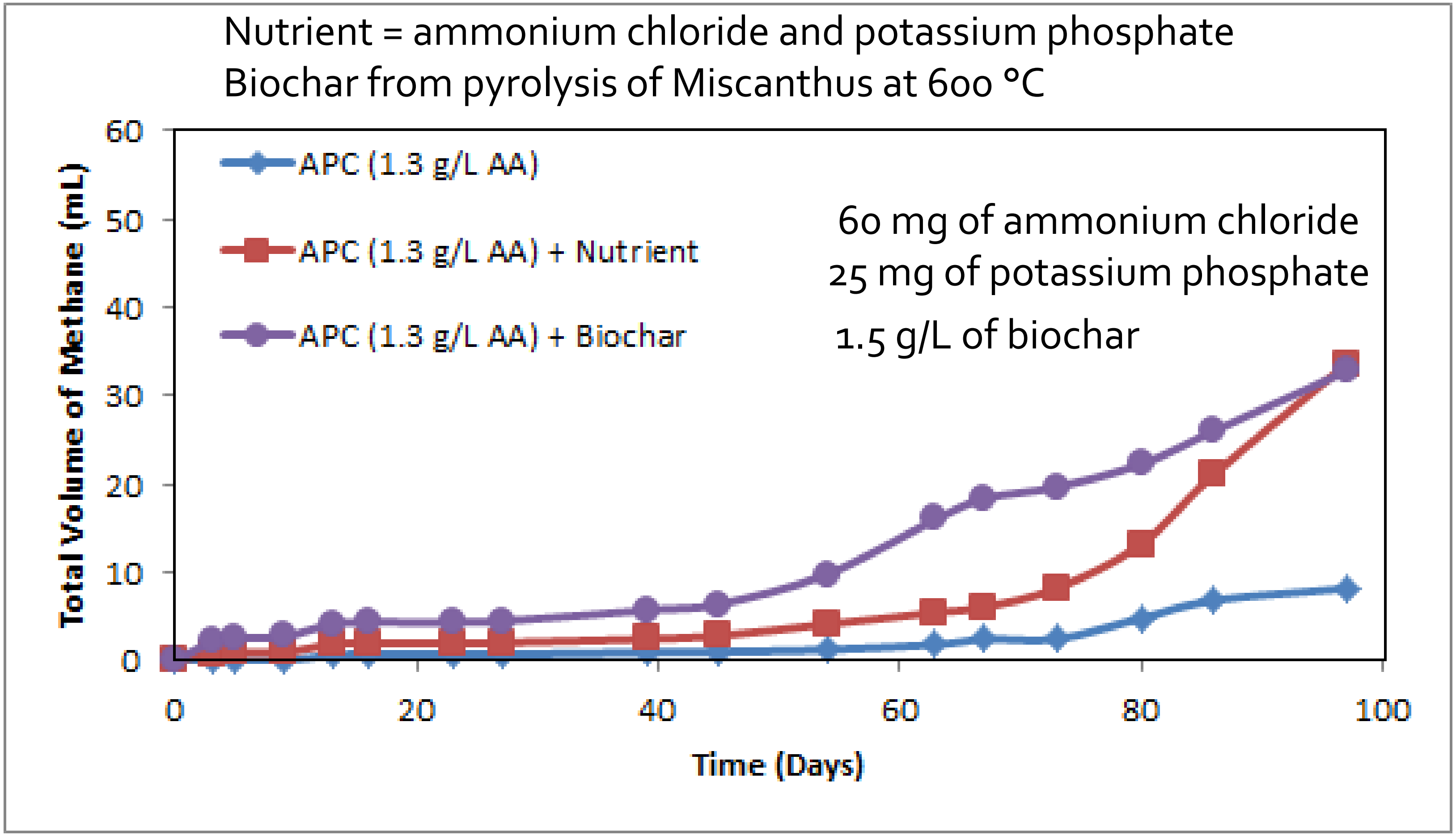
An inhibition was observed in AD of APC

To correct inhibition:

⟹ Add nutrient

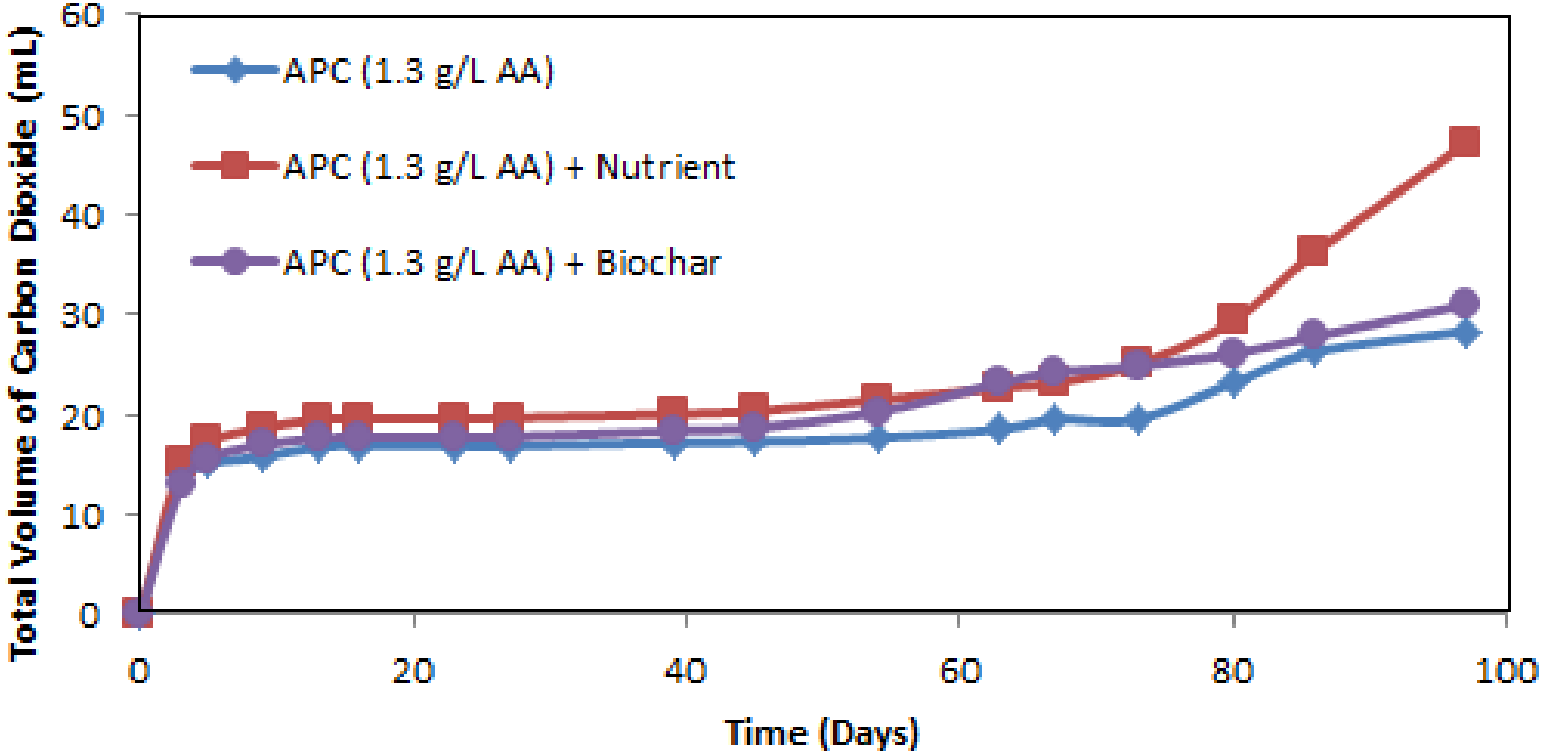
⟹ Add biochar natural inhibitor absorbent

Effects of Addition of Biochar and Nutrient on Biogas Production



Effects of Addition of Biochar and Nutrient on Biogas Production

Nutrient = ammonium chloride and potassium phosphate
Biochar from pyrolysis of Miscanthus at 600 °C



Conclusions

APC (from pyrolysis of Birchbark at 500 °C) can be successfully anaerobically digested

After 40 days, AD of APC started methane production

Phenolics in APC exceeded threshold inhibitory levels

Both biochar (from pyrolysis of Miscanthus at 600 °C) and nutrient addition helped to recover AD of APC from inhibition