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Effect of ferroferric oxide on batch anaerobic treatment of high strengthen synthetic wastewater

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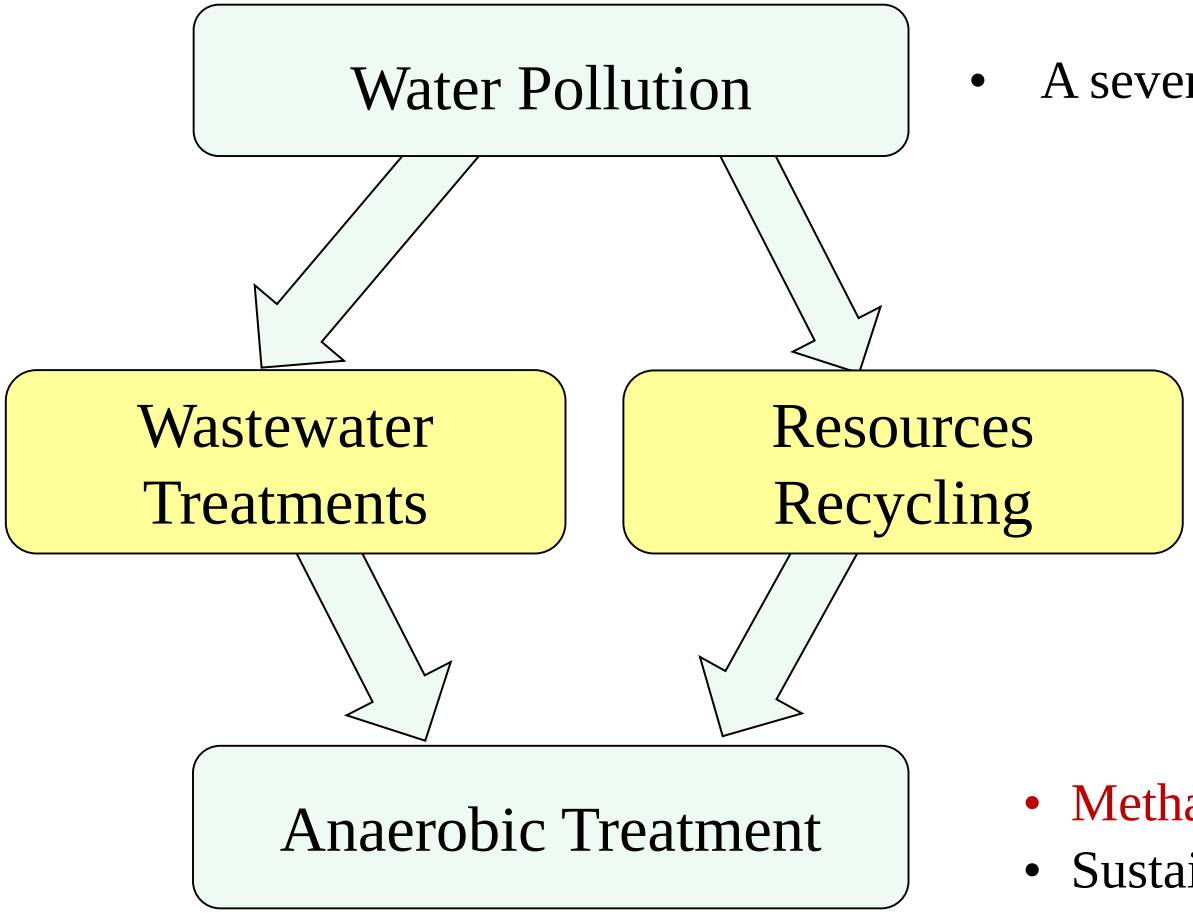
1 Background

1.1 Anaerobic treatment

- Anaerobic treatment is a sustainable technology



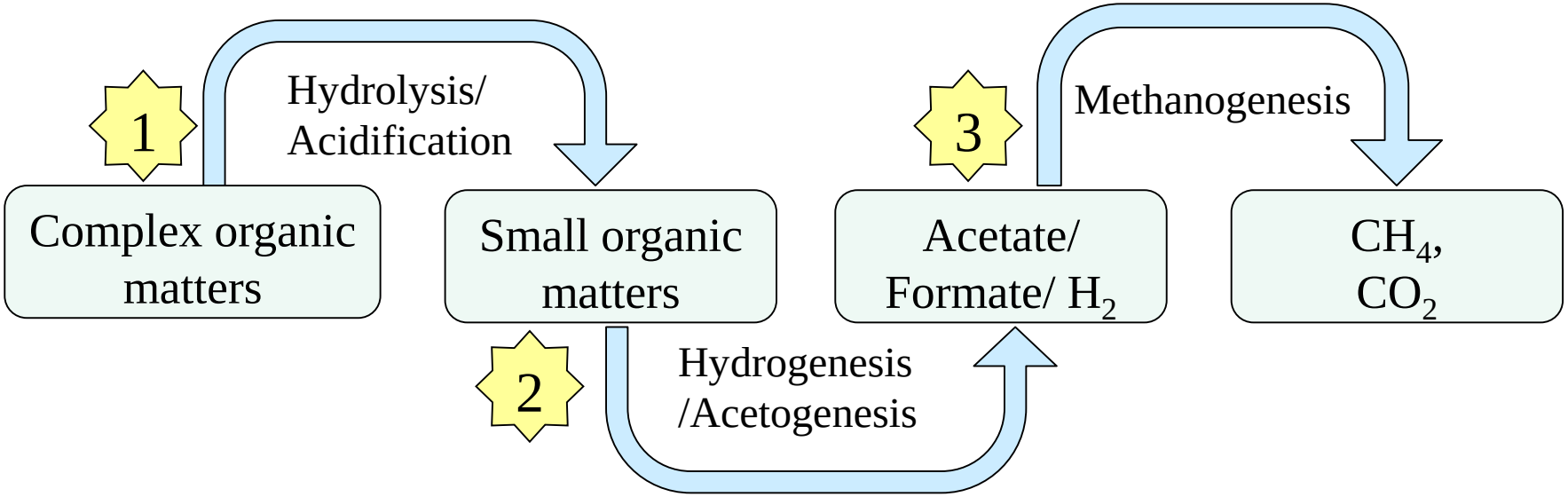
- A severe environmental issue

- Water Reuse
- Energy Recovery

- Methane Production
- Sustainable Technology

1.1 Anaerobic treatment

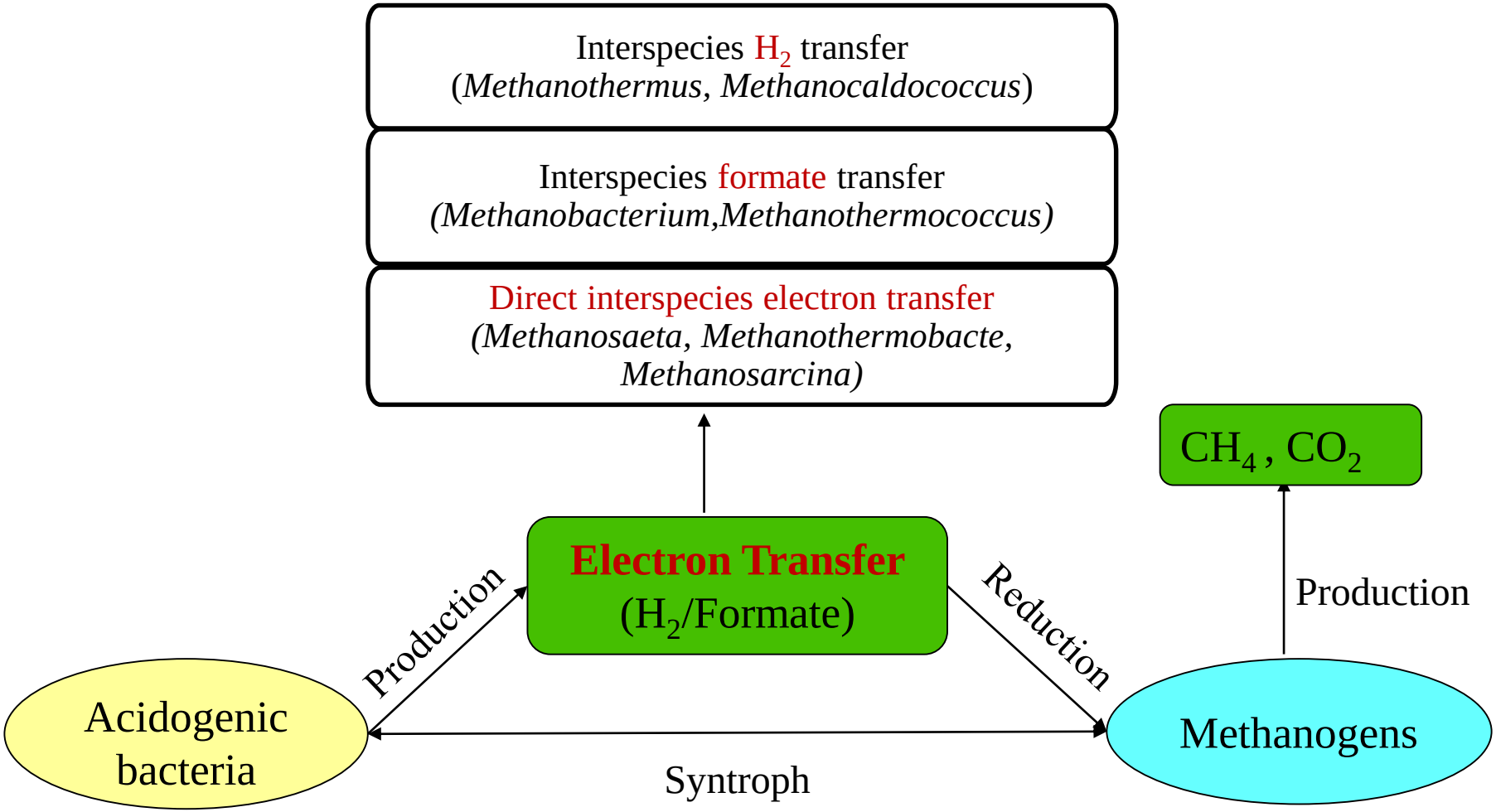
- Three-step mechanisms



- Syntrophic Communities: The complete conversion from organic matters to methane requires a microbial consortium composed of various types of species.

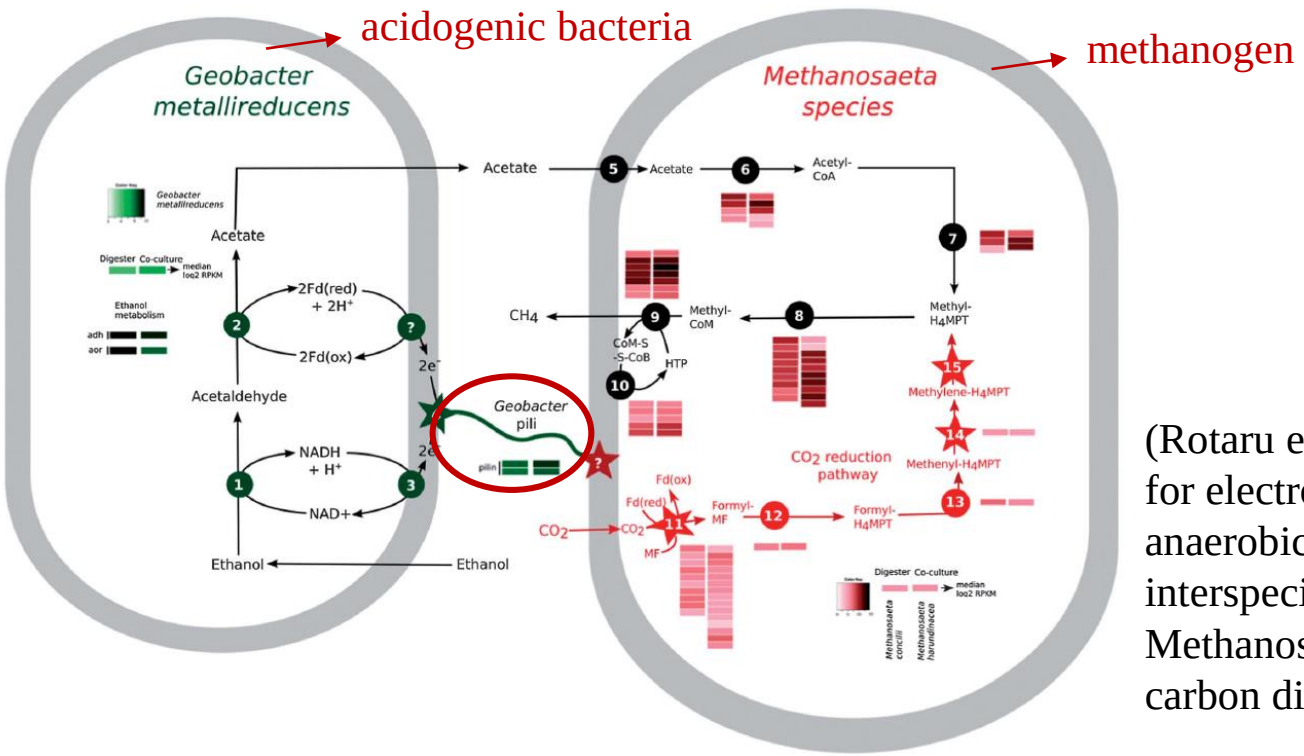
1.2 Interspecies electron transfer，IET

- Interspecies electron transfer (IET)



1.3 Direct interspecies electron transfer, DIET

- DIET is a new mechanism
  - ➢ DIET means acidogenic bacteria (*Geobacter*) can transfer electron to methanogens directly using its conductive pili or outer membrane cytochromes, rather than H_2/Formate.

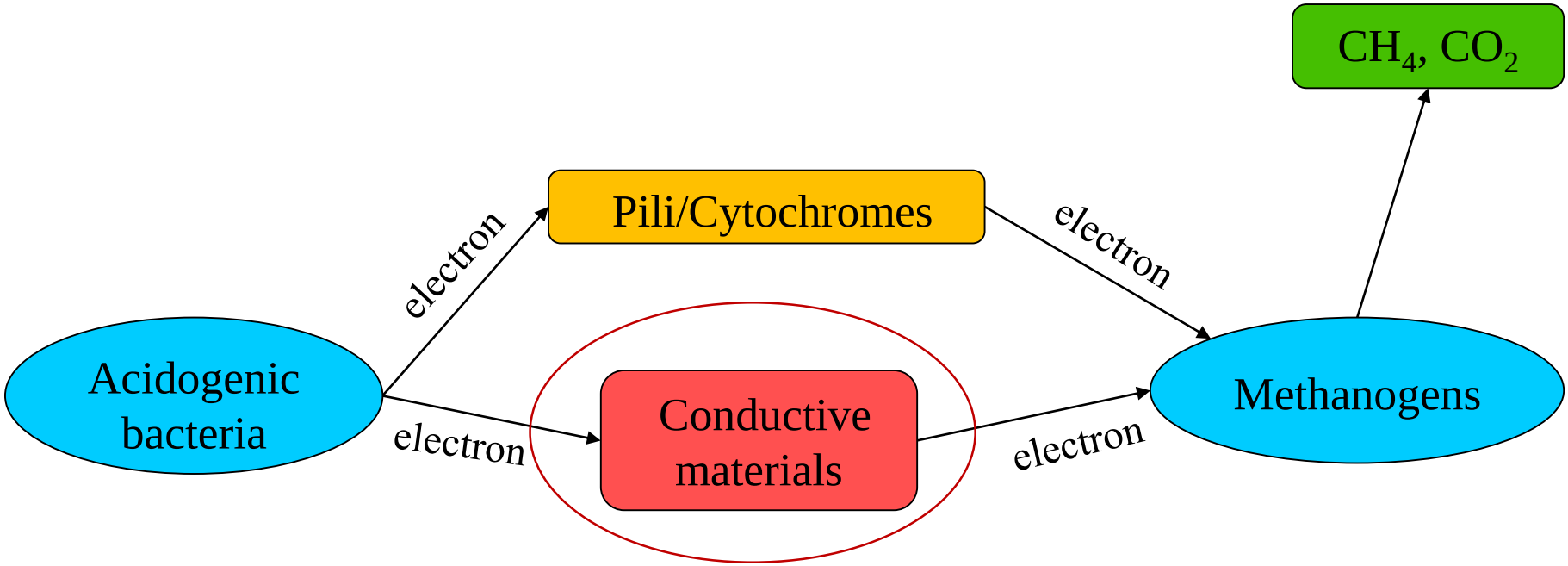


(Rotaru et al. 2013. A new model for electron flow during anaerobic digestion: direct interspecies electron transfer to Methanosaeta for the reduction of carbon dioxide to methane.)

1.3 Direct interspecies electron transfer, DIET

- Conductive materials

  - Dosing conductive materials could accelerate the electron transfer among syntrophic communities.



1.3 Direct interspecies electron transfer, DIET

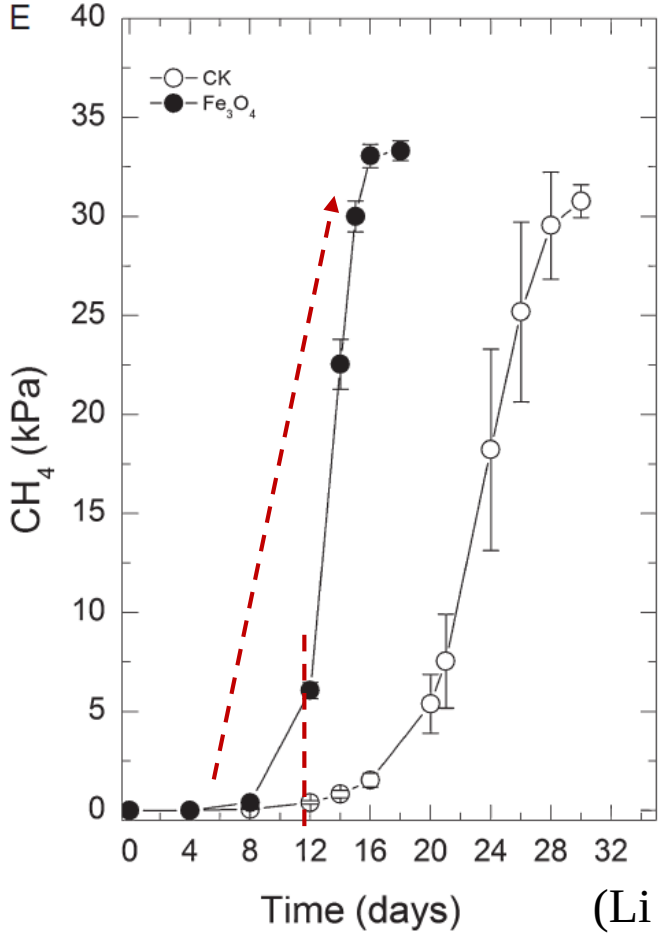
- Conductive materials

  - Conductive materials can facilitate the methanogenesis.

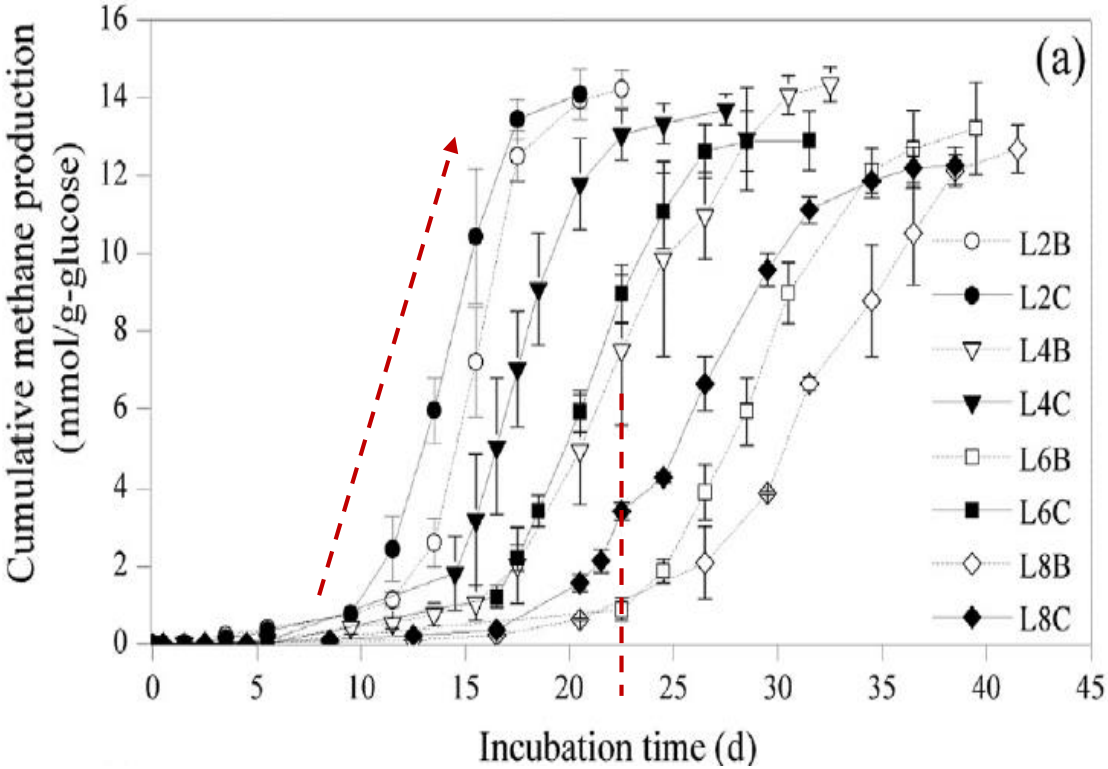
Conductive materials	Carbon source	Effect	Reference
Carbon materials（GAC/ carbon cloth/ biochar）	Glucose/ Ethanol	Facilitate CH_4 production rate/Shorten lag phase /Facilitate the consumption of VFA	Rotaru et al.,2014; Liu et al.,2012; Chen et a.,2014; Luo et al.,2015
Magnetite (Fe_3O_4)/ Hematite (Fe_2O_3)	Acetic acid/ Propionic acid/Butyric acid/ Beef extract		Kato et al.,2012; Carolina et al.,2014; Yamada et al.,2015; Li et al.,2015; Zhu et al.,2015

1.3 Direct interspecies electron transfer, DIET

- Conductive materials
  - ➢ Conductive materials facilitated the production rate and shortened the lag phase during CH_4 production.



(Li et al. 2015)



(Luo et al. 2015)

1.4 Research Purposes

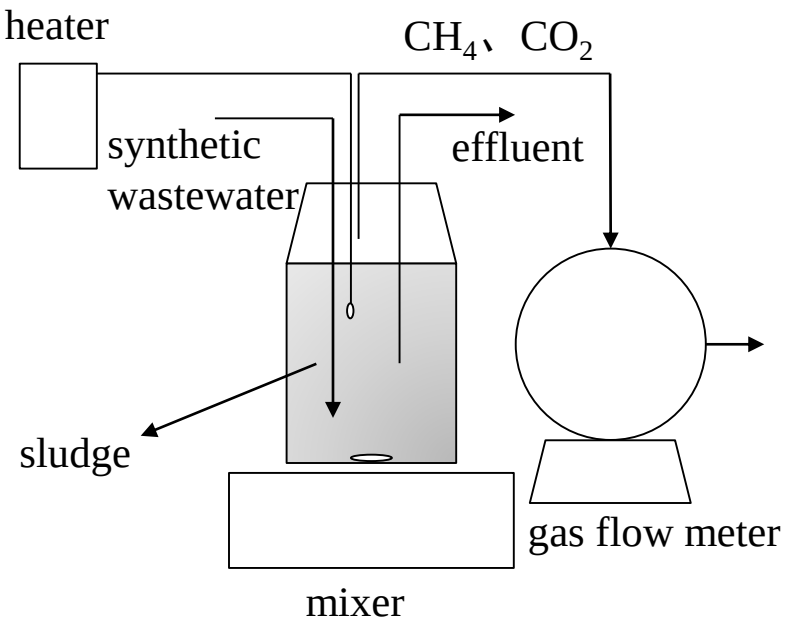
The aims of this study were to

- Examine the effect of conductive material Fe_3O_4 on the performance of anaerobic treatment of high strengthen synthetic wastewater.
- Compare the effect of Fe_3O_4 on anaerobic sludge acclimated with different carbon substrates.

2 Materials and Methods

2 Materials and Methods

- System operation
  - 2 ASBR: Starch based reactor/ Tryptone based reactor
  - COD concentration: 3 g COD/L (starch or tryptone)
  - Starch and tryptone were used to represent carbohydrate and protein substrate, respectively.

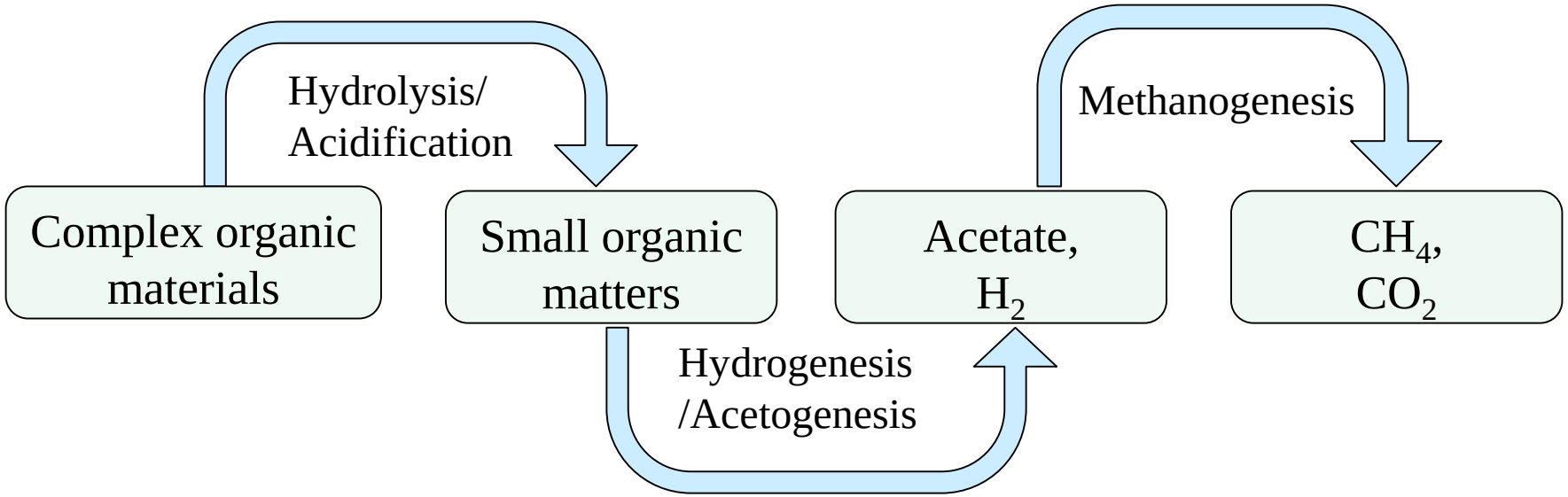


Operating conditions

Parameter	ASBR
Volume	2 L
HRT	48 h
SRT	33 d
Temperature	35℃
Operation mode	23 h anaerobic（5min filling）+1 h settling（5min decanting）

2 Materials and Methods

- Batch effect by the dosage of Fe_3O_4



- Experimental conditions

➢ Conductive material
- Effect of carbon by Fe_3O_4 dosage:
  10 g/L Fe_3O_4
- Effect of Fe_3O_4 dosage concentrations:
  2.5 g/L, 5 g/L, 10 g/L, 15 g/L, 20 g/L.

➢ Groups: Control group/ Fe_3O_4 group

➢ Inoculated Sludge: taken from ASBRs

Operating condition

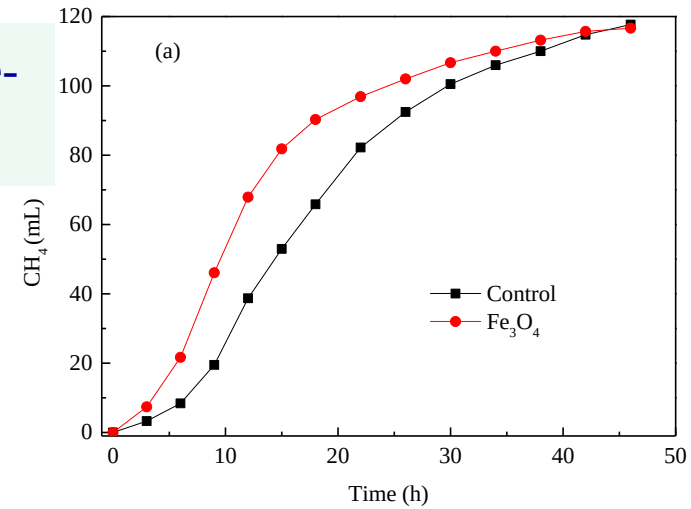
Parameter	Value
Volume	500 mL
Mixer speed	170 rpm
Temperature	35℃

3 Results and Discussions

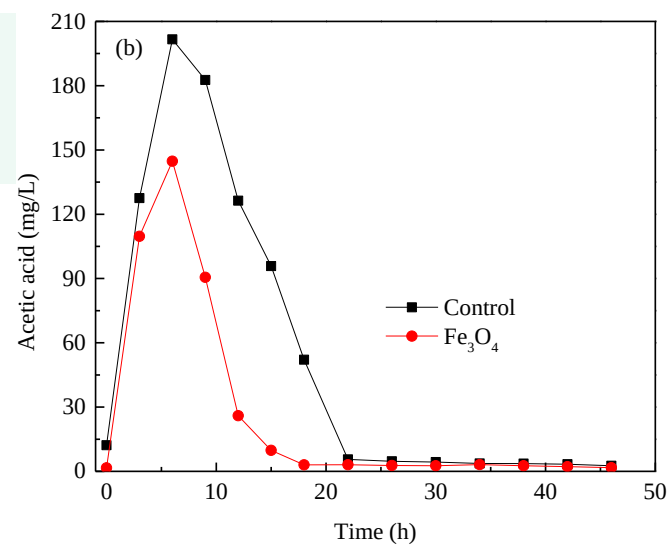
3.1 Batch experiments

- Short term effect by the dosage of Fe_3O_4

Tryptone-CH_4



Tryptone-Acetic acid



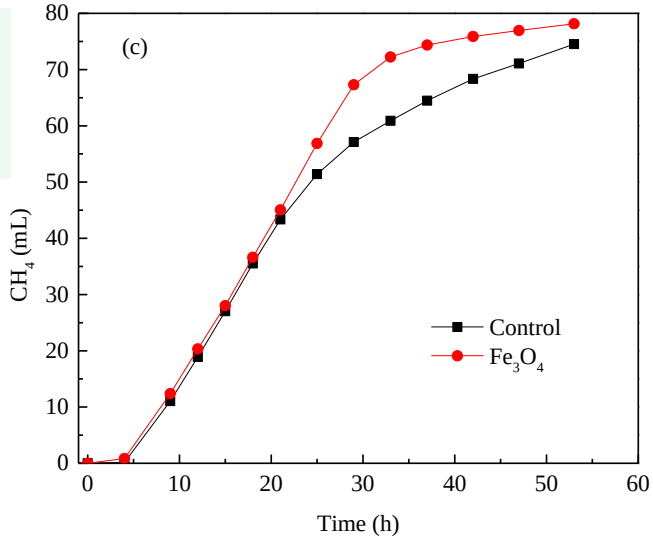
- The R_{max} was increased by 35.3% and the lag time was shortened by 48% after dosing Fe_3O_4.
- Acetic acid consumption rate was also improved.

Reactor	Ultimate CH_4 yield (mL)	Lag phase λ (h)	Maximum production rate (mL/h)	Correlation coefficient R^2
Control	117.3	5.0	5.1	0.999
Fe_3O_4	112.5	2.6	6.9	0.995

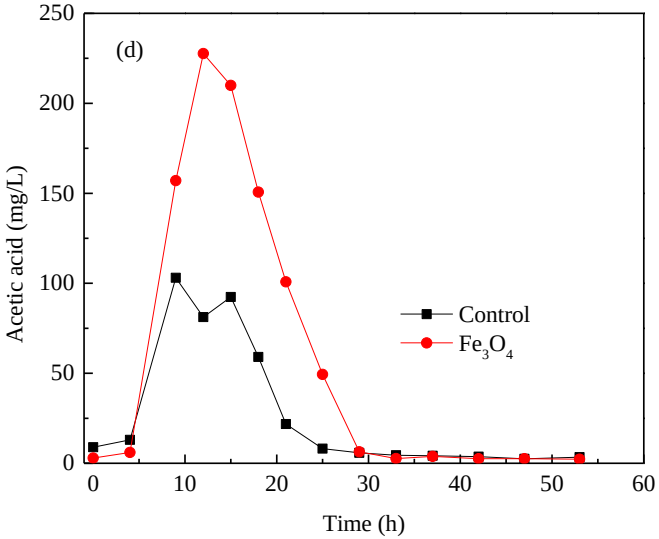
3.1 Batch experiments

- Short term effect by the dosage of Fe_3O_4

Starch-CH_4



Starch-Acetic acid



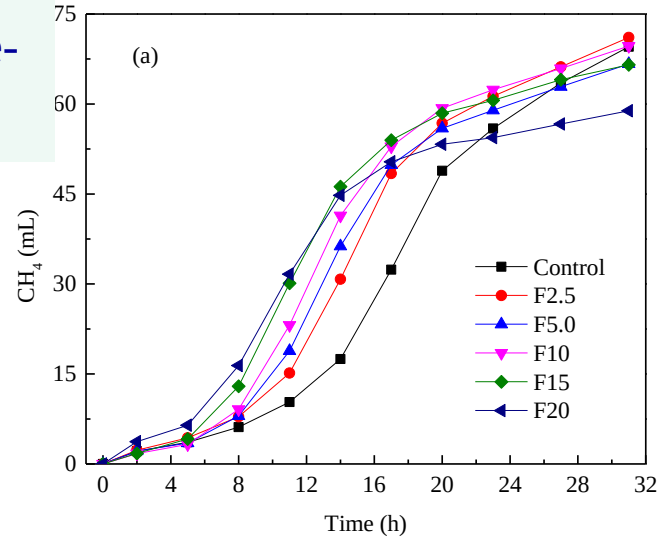
- The addition of Fe_3O_4 had little effect on the CH_4 production rate or the lag phase.
- The produced acetic acid concentration was increased.

Reactor	Ultimate CH_4 yield (mL)	Lag phase λ (h)	Maximum production rate (mL/h)	Correlation coefficient R^2
Control	73.5	5.4	2.8	0.999
Fe_3O_4	80	6.4	3.3	0.999

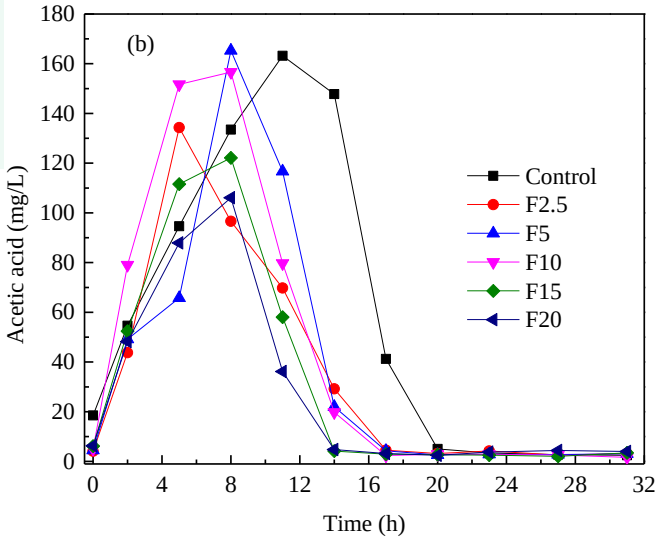
3.1 Batch experiments

- Short term effect by the dosage of different Fe_3O_4 concentrations

Tryptone-CH_4



Tryptone-Acetic acid



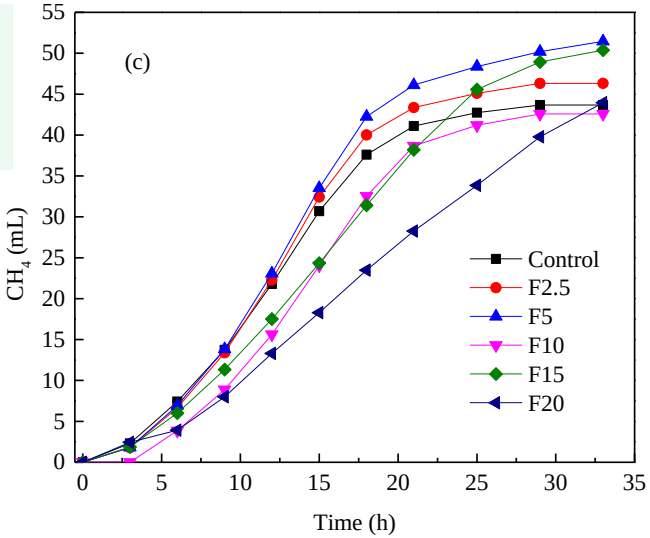
- Generally, the R_{max} was increased and the lag phase became shorter with the Fe_3O_4 concentration.
- Acetic acid consumption rate was faster.

Reactor	Ultimate CH_4 yield (mL)	Lag phase λ (h)	Maximum production rate (mL/h)	Correlation coefficient R^2
Control	77.35	9.19	4.31	0.9931
F2.5	72.67	7.51	4.98	0.9931
F5	66.56	6.96	5.19	0.9967
F10	68/96	6.56	5.51	0.9981
F15	65.38	5.51	5.54	0.9980
F20	58.06	4.31	4.85	0.9963

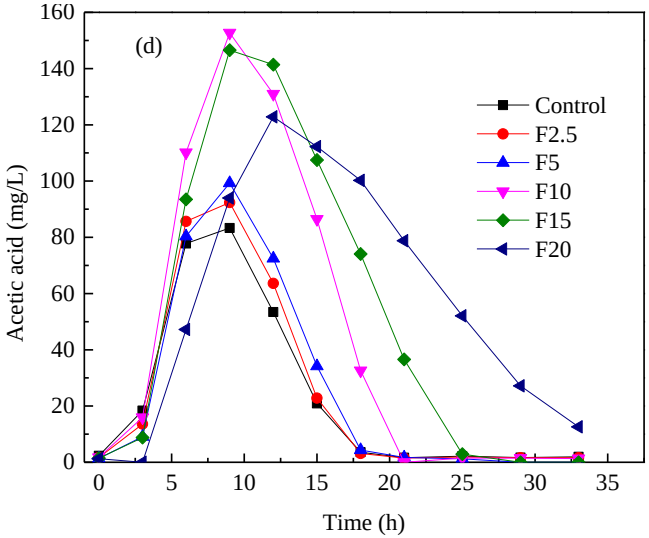
3.1 Batch experiments

- Short term effect by the dosage of different Fe_3O_4 concentrations

Starch-CH_4



Starch-Acetic acid



- Different Fe_3O_4 concentrations all led to longer lag phase.
- Only the R_{max} of F2.5 and F5 increased.
- No significant improvement was found.

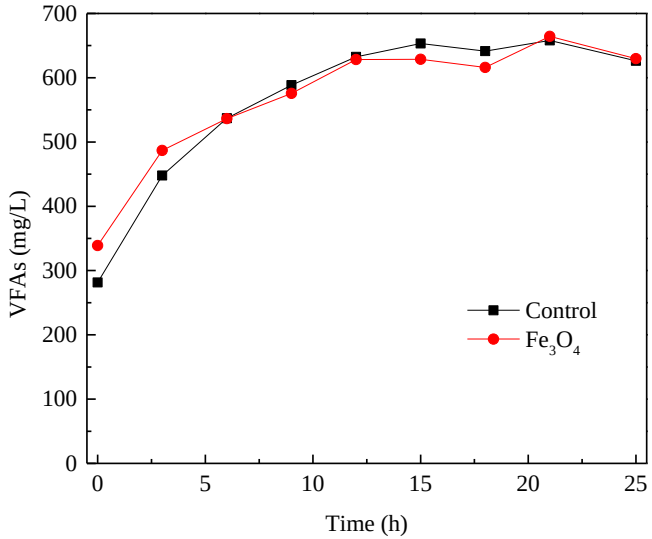
Reactor	Ultimate CH_4 yield (mL)	Lag phase λ (h)	Maximum production rate (mL/h)	Correlation coefficient R^2
Control	45.37	4.28	3.04	0.9931
F2.5	47.82	4.93	3.40	0.9931
F5	52.57	4.92	3.48	0.9967
F10	44.71	6.37	2.98	0.9981
F15	56.71	4.8	2.46	0.9980
F20	54.39	5.0	1.79	0.9963

3.1 Batch experiments

- Short term effect of Fe_3O_4 (10g/L) on hydrolysis and acidification phase of tryptone

BES was added to inhibit the activity of methanogens

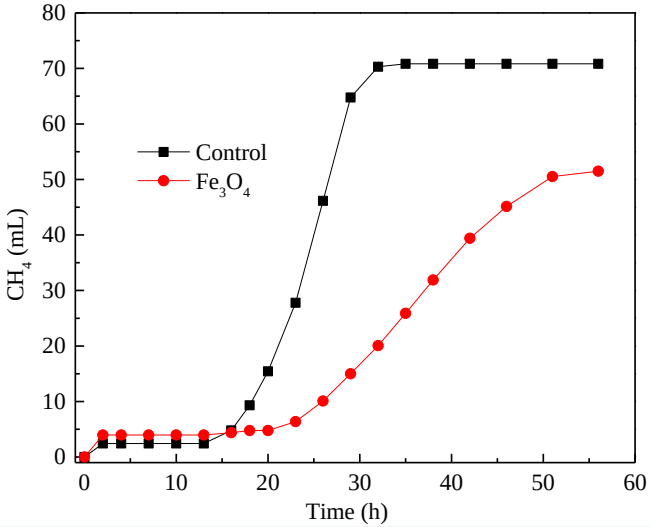
(BES: 2-bromoethanesulfonic acid sodium salt)



- The control group and the Fe_3O_4 group had similar trend of VFAs production, indicating that short term dosage of Fe_3O_4 might not facilitate the hydrolysis and acidification of tryptone.
- Similar results were obtained by the metabolic end product of hydrolysis and acidification, acetic acid.

3.1 Batch experiments

- Short term effect of Fe_3O_4 on methanation

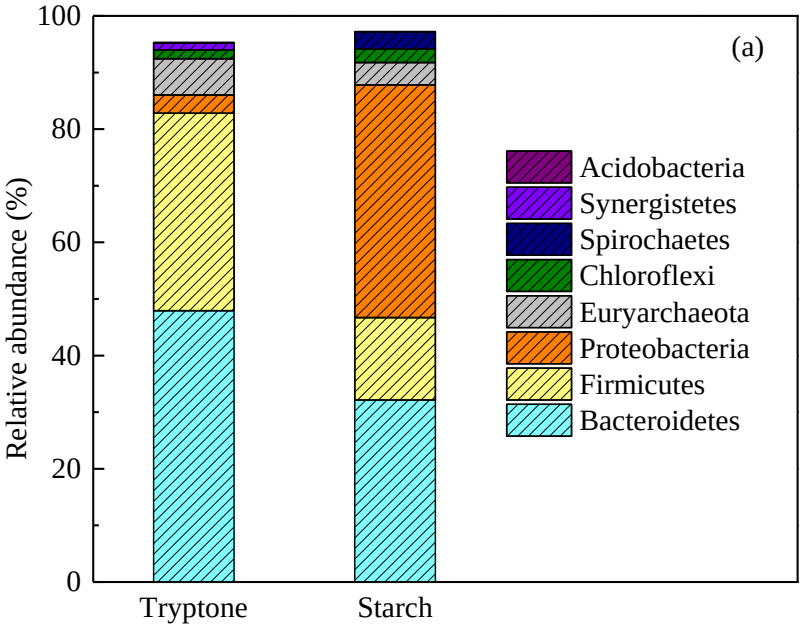


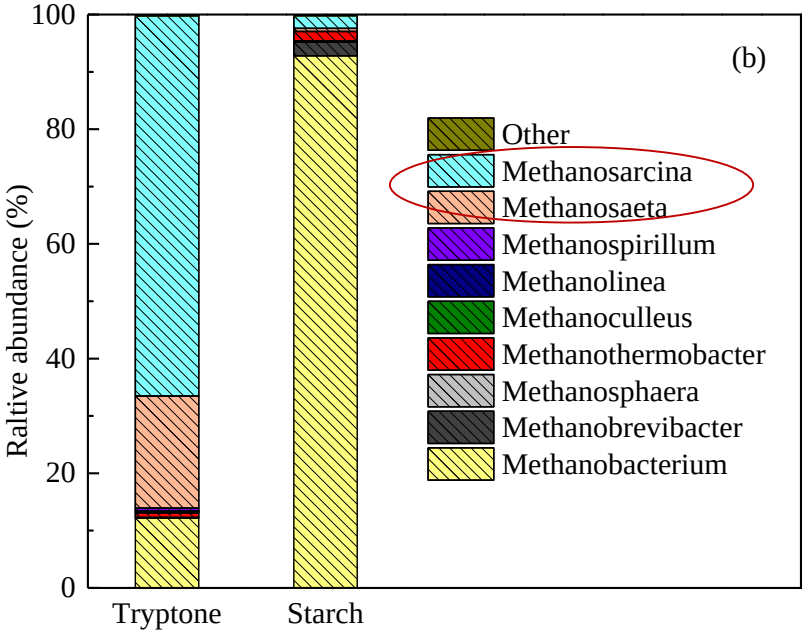
Reactor	Ultimate CH_4 yield (mL)	Lag phase λ (h)	Maximum production rate (mL/h)	Correlation coefficient R^2
Control	72.6	17.91	6.42	0.9915
Fe_3O_4	67.87	19.64	1.72	0.9828

- Only acetate was added as carbon substrate, instead of tryptone.
- Without hydrolysis and acidification, adding Fe_3O_4 seemed to hinder the activities of methanogen.
- The R_{max} was decreased by 73.1% and the lag time was delayed by 9.7%.

3.2 Microbial community

Short-term effect– Microbial community

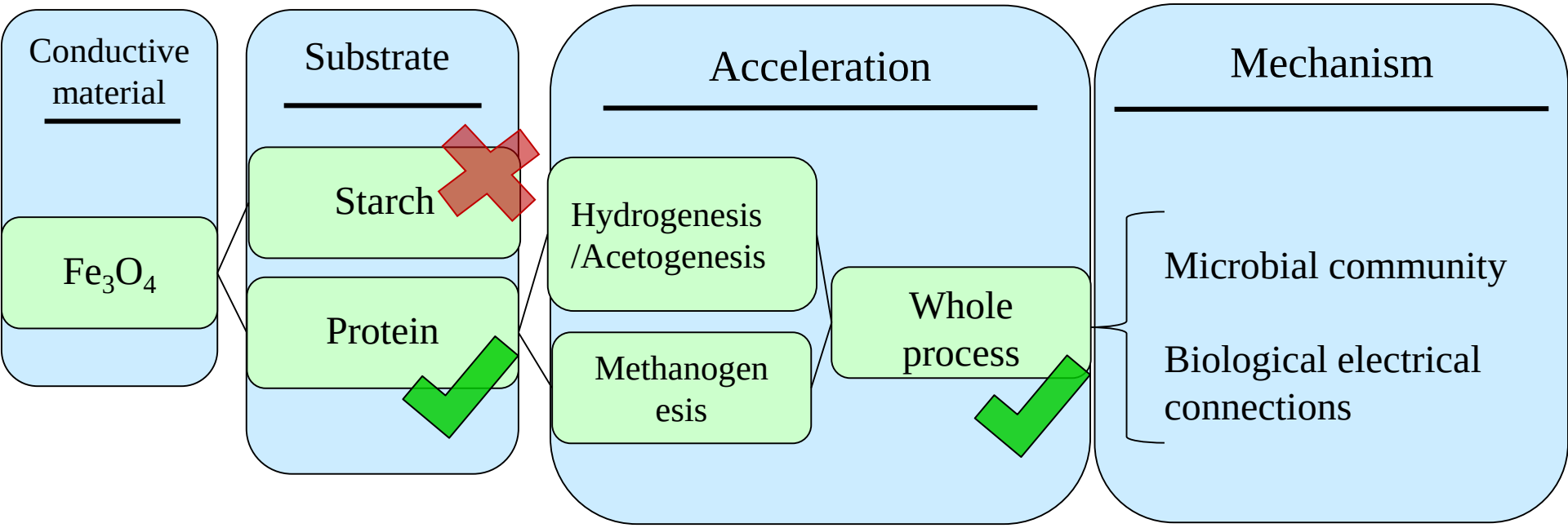




- *Methanosarcina* (66.28%) was the dominant methanogen in the sludge acclimated with tryptone and *Methanosarcina* was proved to accept electrons via DIET.
- *Methanobacterium* (92.80%) was predominant in the sludge acclimated with starch. And its ability of DIET is still controversial.

4 Conclusions

4 Conclusions



- Fe_3O_4 accelerated methane production for microorganisms acclimated with protein-based substrate.
- Acceleration only occurred when the interspecies electron transfer between acidogenic bacteria and methanogen existed.
- Organic carbon affected the acclimated microbial communities, leading to different performance when dosing conductive materials.

Thank you!