A new anaerobic digestion effluent utilization system integrating electrocoagulation and algal accumulation

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Background – Electrocoagulation (EC)

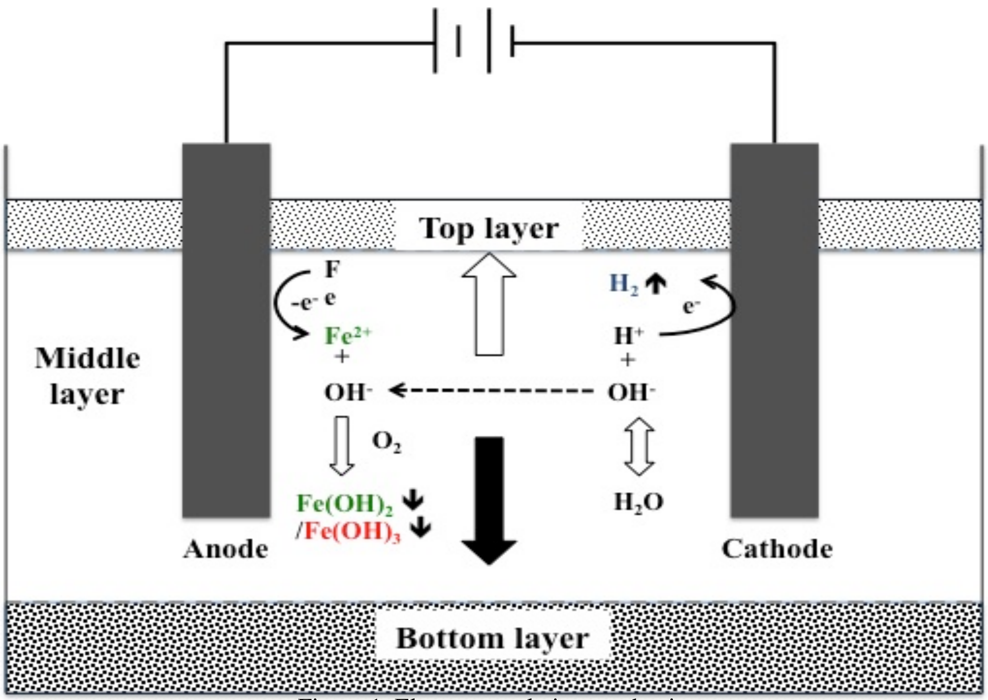


Figure 1. Electrocoagulation mechanism

- Electrocoagulation (EC) is basically an electrophoretic-oriented coagulation technology;
- Widely utilized in treating wastewater from pulp and paper, mining and metal, food and oil industries.

Background - Anaerobic Digestion (AD)

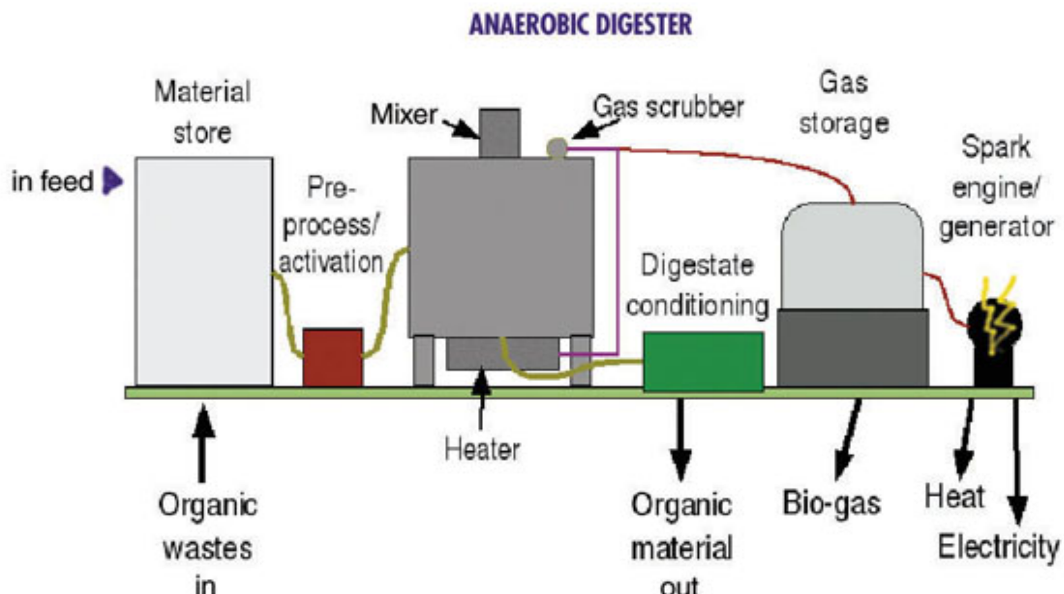


Figure2. Schematic of Anaerobic Digestion
(http://www.re-sourcerecycling.com/anaerobic-digestion)

- Anaerobic Digestion (AD) is a practical and traditional approach of nutrients recycling and further utilization from various organic wastes;
- Biogas (~60% CH_4, ~40% CO_2, 0.0001-1% H_2S, etc) for energy generation, while nutrients-abundant effluent not fully utilized and properly processed.

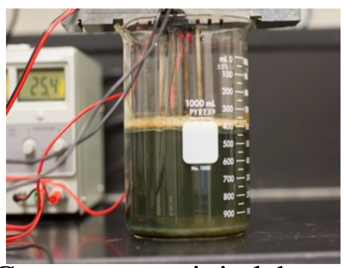
Research Procedure

AD effluent

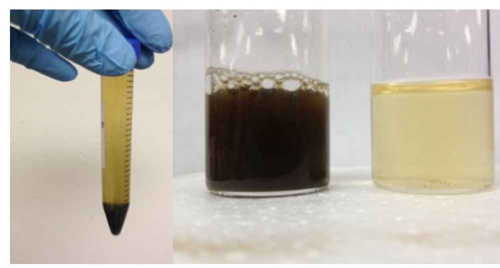
EC treatment

Clean water
Nutritious sediments

Anaerobic digester



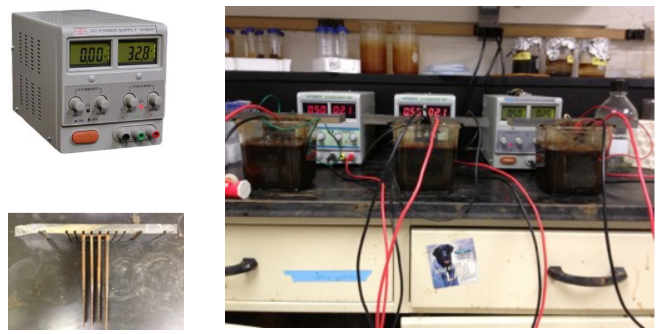
EC treatment unit in lab-scale



Separation of liquid and solid after EC treatment

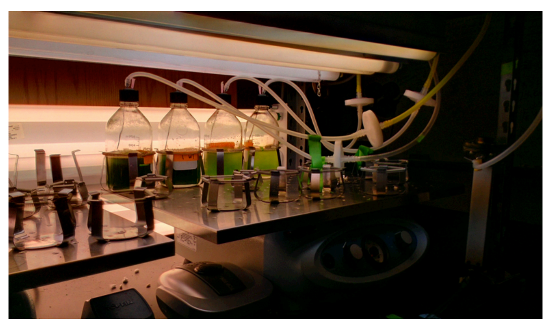
Materials and methods

Half million gallon CSTR anaerobic digester in ADREC, located in south campus of Michigan State University



Power supply and electrodes for EC
2 pairs of electrodes in parallel connection

3L EC column reactor



Algae culture instruments

AD effluent and EC treatment design

Table 1. Basic profile of AD effluent

	Manure AD effluent
pH	7.5-8.0
AD feed	66% Dairy manure ;33% food waste
CH4 %	55%-60%
TS	~ 0.5 %
TN	~300mg/L
TP	~ 140mg/L
COD	~2100mg/L

*Original AD effluent diluted 10 times before testing

Table 2. EC treatment design

	Leve l	Label
Current density (mA cm-2)	32.3	1A
	48.4	1.5A
	64.5	2A
Time (h)	0.5	0.5h
	1	1h

Results: Nutrients removal by EC – COD & Total nitrogen (TN)

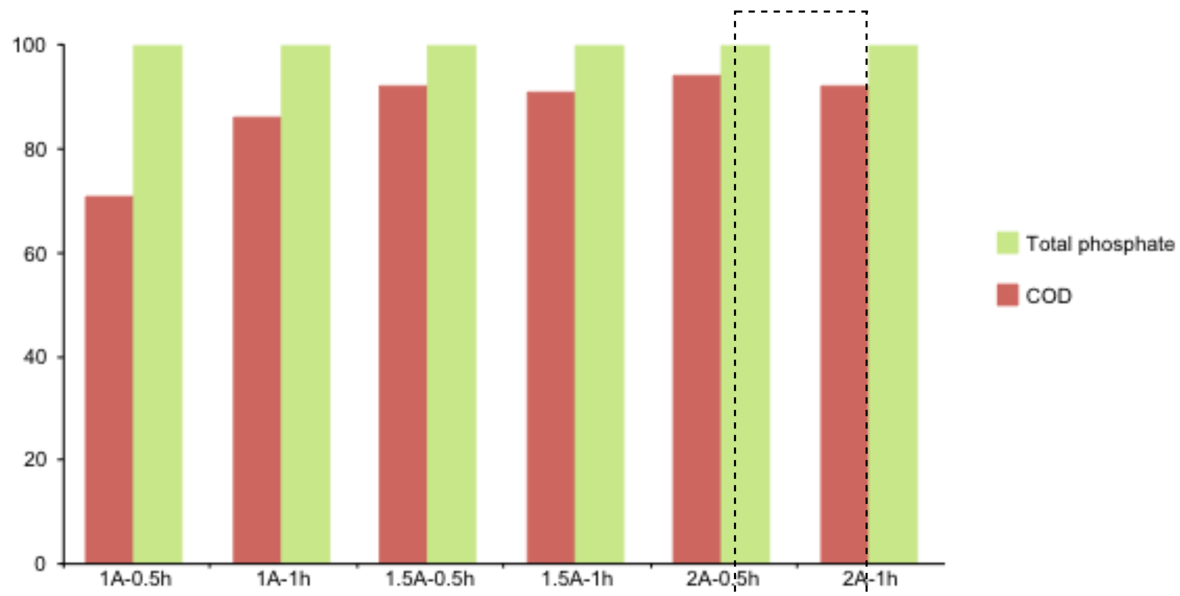


Figure 3. Nutrients removal efficiency comparison

Poor TN removal;
~200 mg L-1 remaining.

Nitrogen removal – integration of algae culture

- 60 – 80% of residue nitrogen is in form of NH4-N;
- NH4-N could be readily uptake and consumed by algae;
- Effluent solution's transparency was largely improved;

AD effluent

EC treatment

Clean water
Nutritious
sediments

Algae culture

Nitrogen removal – pre-selection of algae strains

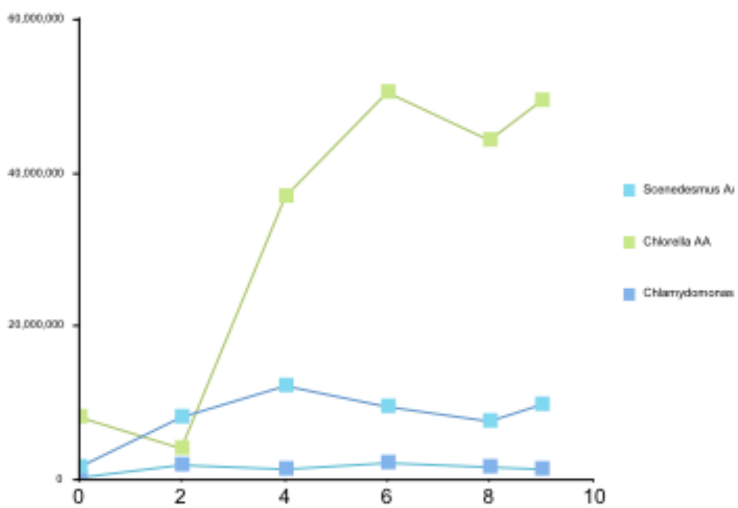


Figure 4. Growth of algae strains (cell number)

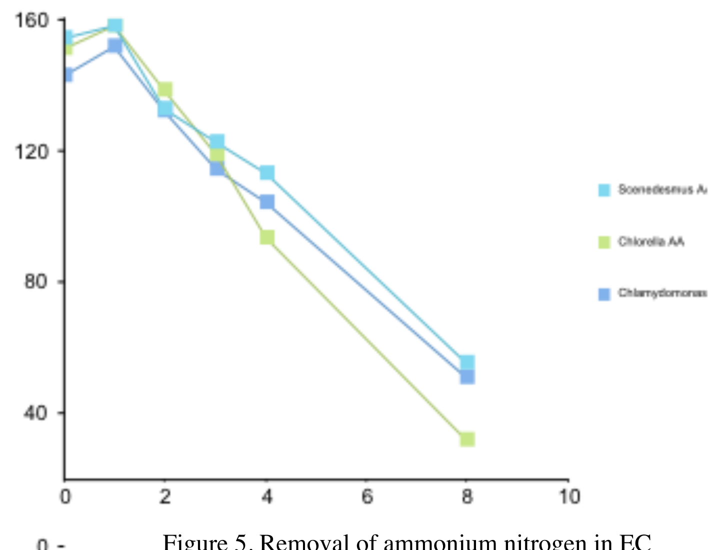


Figure 5. Removal of ammonium nitrogen in EC solution

*Each treatment was average of two replicates;
**'AA' indicates that pH of EC effluent was adjusted by acetic acid;

Chlorella vulgaris is better in growth and nitrogen removal.

Scale-up: evaluation of column EC reactor

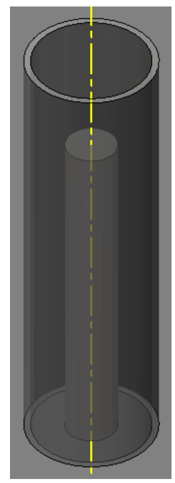
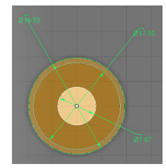
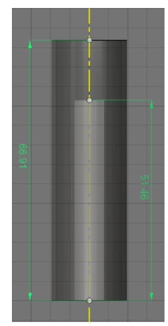
Column EC reactor design – key parameters

Table 3. Comparison of EC parameters of column and cubic reactor

	Column	Cubic
Current density (mA cm-2)	**13.2**	64.5
Surface area (cm2)	**379.5**	62.0
S/V (cm-1)	**0.124**	0.124
Volume (L)	**3**	0.5

Table 4. Comparison of operational parameters of column and cubic reactor

	Column	Cubic
Volume (L)	**3**	0.5
Time (min)	**90**	60
Initial TS %	**~ 0.9**	~0.9
Energy consumption (Kwh L-1)	**0.053**	0.12



Performance of column EC reactor on diluted AD effluent

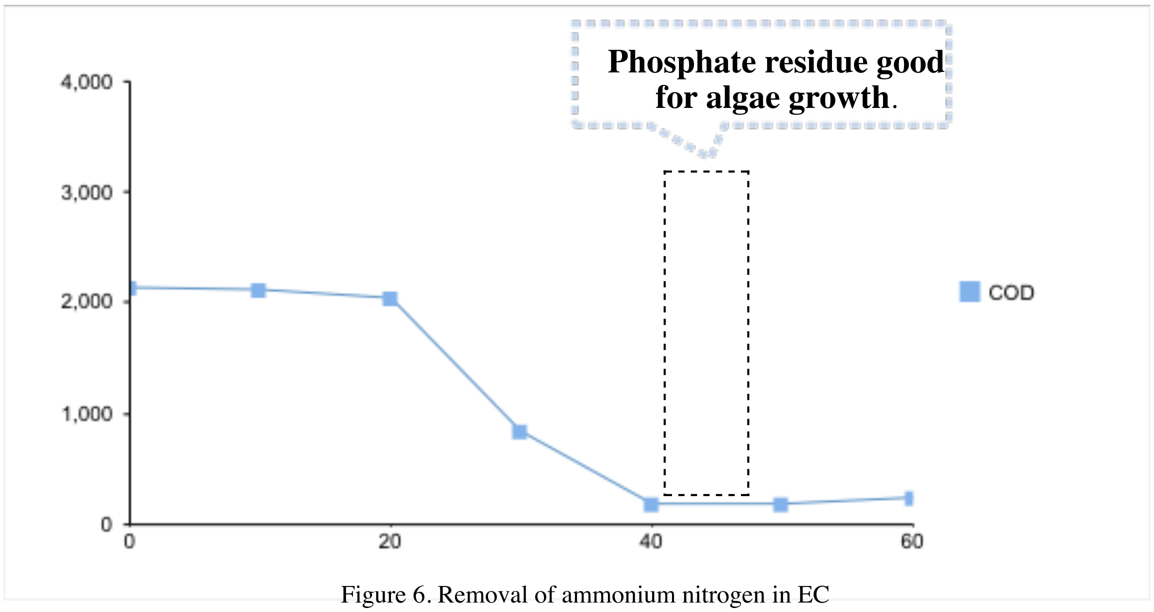


Figure 6. Removal of ammonium nitrogen in EC solution

Table 5. Column EC reactor setup to collect effluent for algae culture

Profile	Level
Initial total solid % (w/w)	0.5
Current (A)	5
Current density (mA/cm2)	13.2
Retention time (min)	40

Algae culture with EC effluent

- Growth of algae

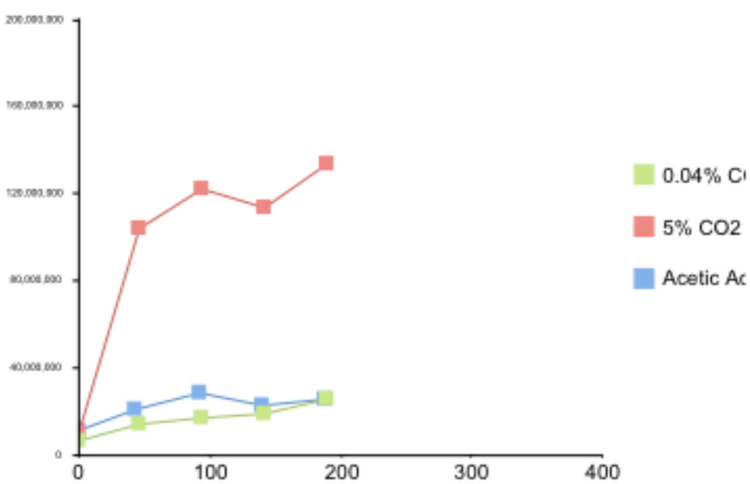


Figure 7. Growth of Chlorella vulgaris in cell concentration

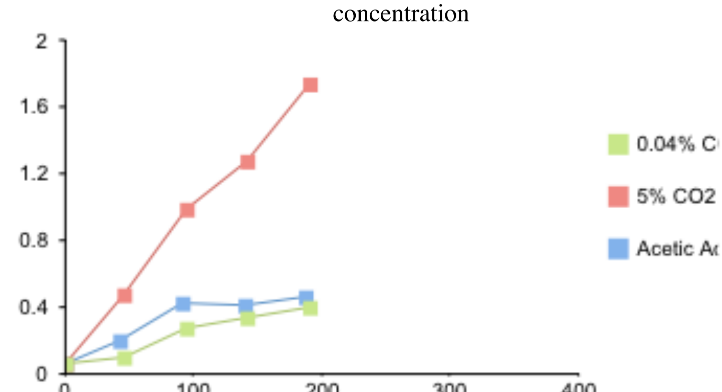
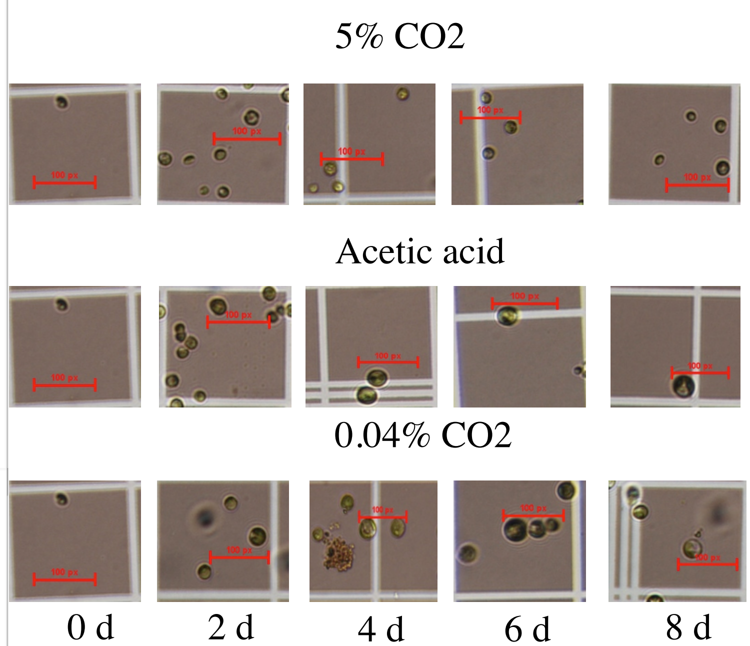


Figure 8. Growth of Chlorella vulgaris in dry



Algae culture with EC effluent

- Nitrogen removal and phosphorous consumption

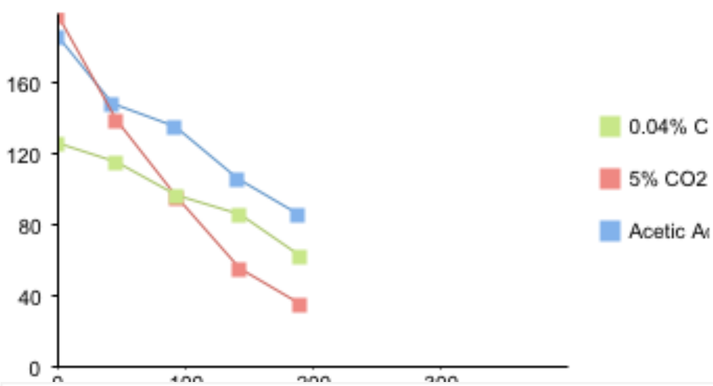


Figure 9. Removal of total nitrogen in EC solution

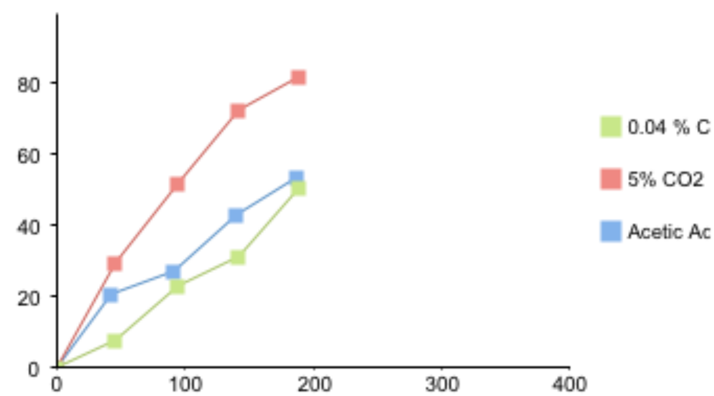


Figure 10. Removal efficiency of total nitrogen in EC solution

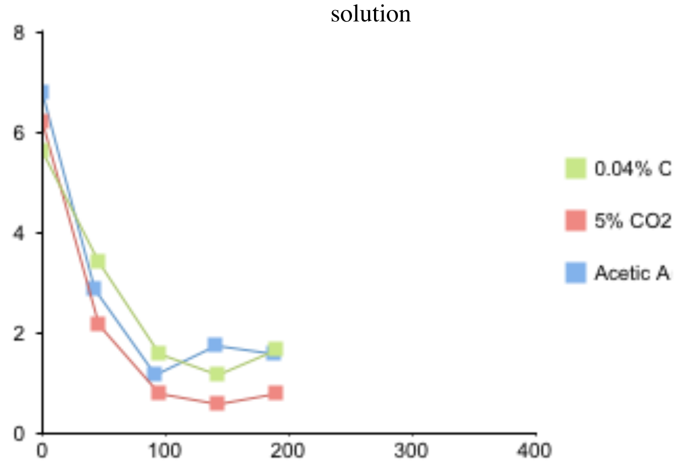


Figure 11. Total phosphate consumption

5% CO2 or extra carbon source is necessary in algal biomass accumulation and nitrogen removal.

*All points are average of two replicates

Algae culture with EC effluent

- Algal biomass composition analysis

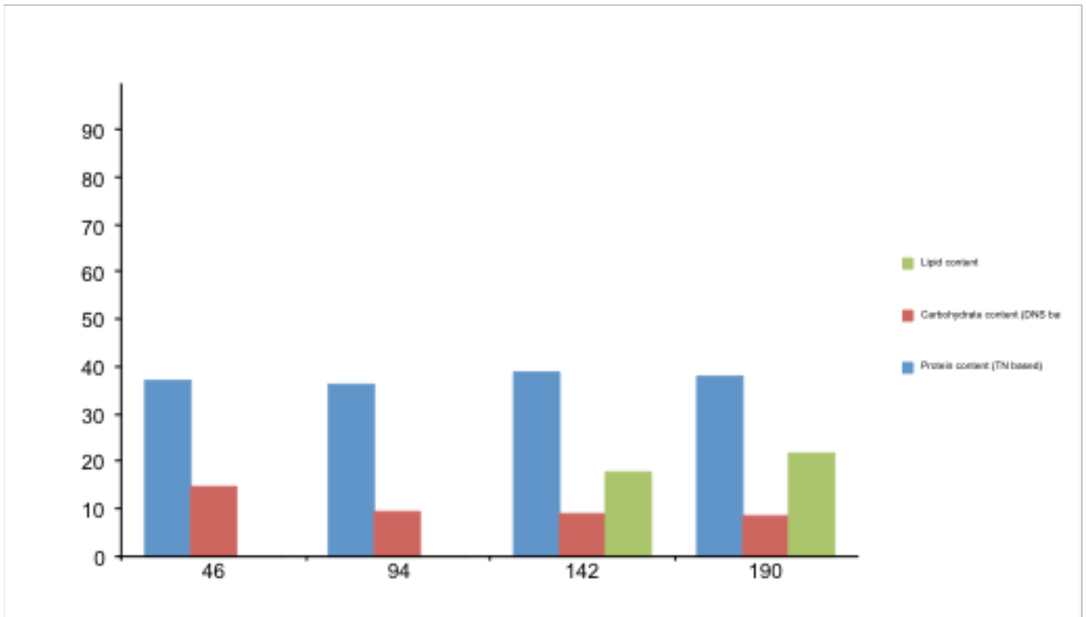


Figure 12. Biomass composition analysis of 5% CO_2 group

- 5% CO_2 group was processed for composition analysis for its relative abundant biomass;
- Lipid contents for 46 and 94 hours' samples are missing due to insufficient amount of biomass;
- Protein contents were estimated by total nitrogen, with nitrogen to protein conversion factor assumed as 6.25;
- Carbohydrate contents were calculated based on reducing sugar, estimated by 3,5-dinitrosalicylic acid (DNS) method;
- Lipids were extracted based on method described by Ruan, et al. 2013.
- Protein content was less than reported, which might be due to insufficient hydrolysis by diluted acid.

Conclusions

- Electrocoagulation (EC) is efficient in nutrients removal except total nitrogen (TN);
- Chlorella vulgaris shows better capability in biomass accumulation and further nitrogen removal from EC effluent;
- Scale-up column EC reactor is more energy efficient than small scale cubic EC reactor;
- Extra carbon source is necessary in biomass accumulation and efficient nitrogen removal;
- Relative high level of algal biomass could be accumulated without obvious inhibition;

Acknowledgements

DQY® Agriculture Technology Co. Ltd;

Questions ?

Department of Biosystems and Agricultural Engineering

Thanks for your attention !