NEW MICROALGAE BIOREFINERY CONCEPT

Laura Azócar, Hernán Díaz, Robinson Muñoz, Leonel González, David Jeison, Rodrigo Navia

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Introduction

Table 3
Different culture methods for various microalgae strains.

Strain	Nutrients	Culture condition	Specific growth rate (day^{-1})	Biomass productivity (g/L/day)	Biomass yield (g/L)	Lipid productivity (g/L/day)	Total lipid extracted (wt.% of biomass)	Comment	Reference
Botryococcus braunii	Secondary treated sewage	Air flowrate of 0.5 v/v/min	0.13	0.288	–	–	17.85	High potential of using secondary treated sewage from domestic wastewater to grow microalgae	Órpez et al., 2009
		Air flowrate of 1 v/v/min	0.14	0.346	–	–	17.85		
Botryococcus braunii	Secondary domestic wastewater	100% of wastewater medium was used without dilution	0.11	0.034	0.48	–	36.14	Microalgae biodiesel production coupled with waste water treatment appears as a good opportunity to commercialize the process	Sydney et al., 2011
Botryococcus braunii	Modified Chu 13	With supplement of 2% (v/v) CO_2	–	0.043	0.9	–	22	The organism exhibited wide range of pH adaptability	Dayananda et al., 2007
Chlamydomonas reinhardtii	Wastewater	Microalgae was cultured in biocoil	0.564	2	–	0.505	25.25	High lipid content and biomass productivity can be attained through biocoil due to greater light exposure and intensity inside the polyvinyl tubing.	Kong et al., 2010
Chlorella protothecoides	Inorganic basal medium	Heterotrophic culture with corn powder hydrolysate as carbon source	–	2.02	15.5	–	55.2	Higher lipid content was observed if microalgae cultured in heterotrophic condition	Xu et al., 2006
Chlorella protothecoides	Basal Medium	Heterotrophic growth with glucose (24 g/L) as carbon source and yeast (4 g/L) as fermentation media	–	7.3	51.2	–	50.3	High lipid was obtained through heterotrophic growth	Xiong et al., 2008
Chlorella protothecoides	Basal medium	Heterotrophic culture with Jerusalem artichoke (30 g/L) as carbon source	–	4.1	17	1.7	43	Jerusalem artichoke appears as a low cost carbon source for heterotrophic microalgae culture	Cheng et al., 2009
Chlorella sp.	Anaerobic digested dairy manure	25× diluted digested dairy manure	0.409	–	–	–	13.7	Anaerobic digested manure served as a low cost nutrients source to culture microalgae while at the same time, microalgae provide a valuable solution to refractory dairy waste.	Wang et al., 2010
Chlorella sp.	Walne medium with urea as nitrogen source	Urea concentration of 0.025 g/L and microalgae was cultured in batch culture mode for 6 days	0.86	–	0.464	0.051	66.1	Urea is relatively low cost compare to other inorganic nitrogen sources.	Hsieh and Wu, 2009
		Urea concentration of 0.20 g/L and microalgae was cultured in batch culture mode for 6 days	1.42	–	2.027	0.11	32.6		
Chlorella vulgaris	Modified Fitzgerald medium	Normal nutrients condition (20 days)	–	0.043	0.86	0.0128	29.5		
		20 days of normal nutrients condition followed by 17 days of nitrogen limited condition	–	–	–	–	44		

Lam and Lee, 2012

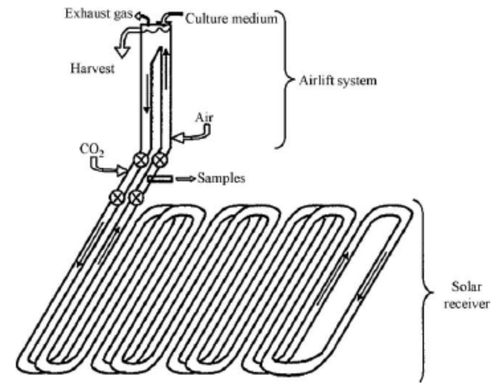


Fig. 2. Basic design of a horizontal tubular photobioreactor (adapted from Becker

Brennan and Owende, 2010

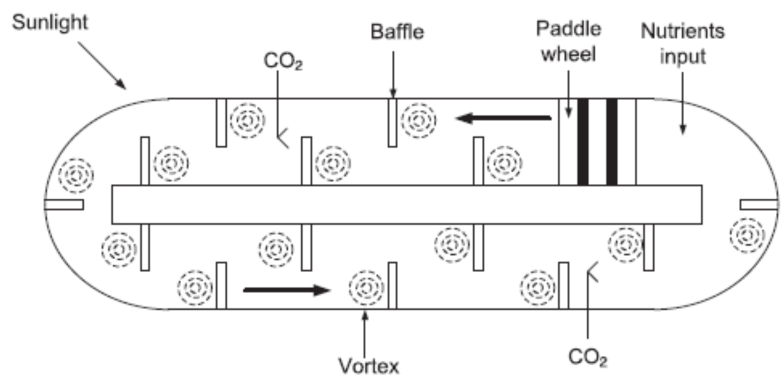


Fig. 2. Conceptual baffled system in raceway pond to culture microalgae. Modified from Chisti (2007).

Downstream

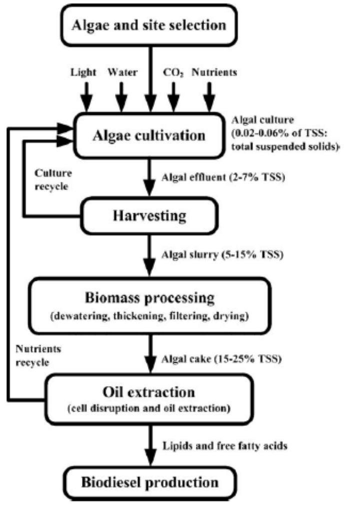


Fig. 1. Microalgae biodiesel value chain stages.

Mata et al. 2012

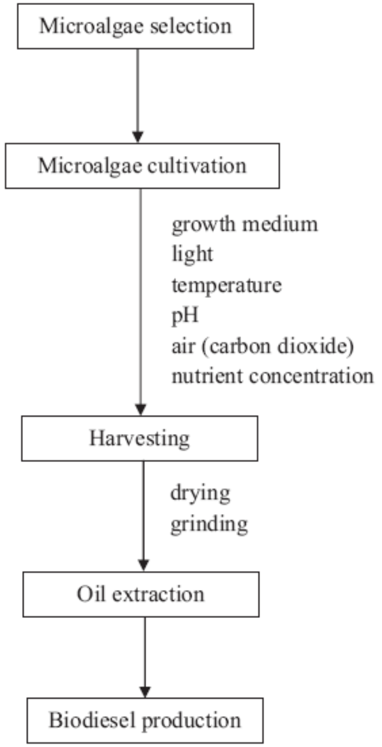


Fig. 6. Production of biodiesel from microalgae.

Ahmad et al. 2012

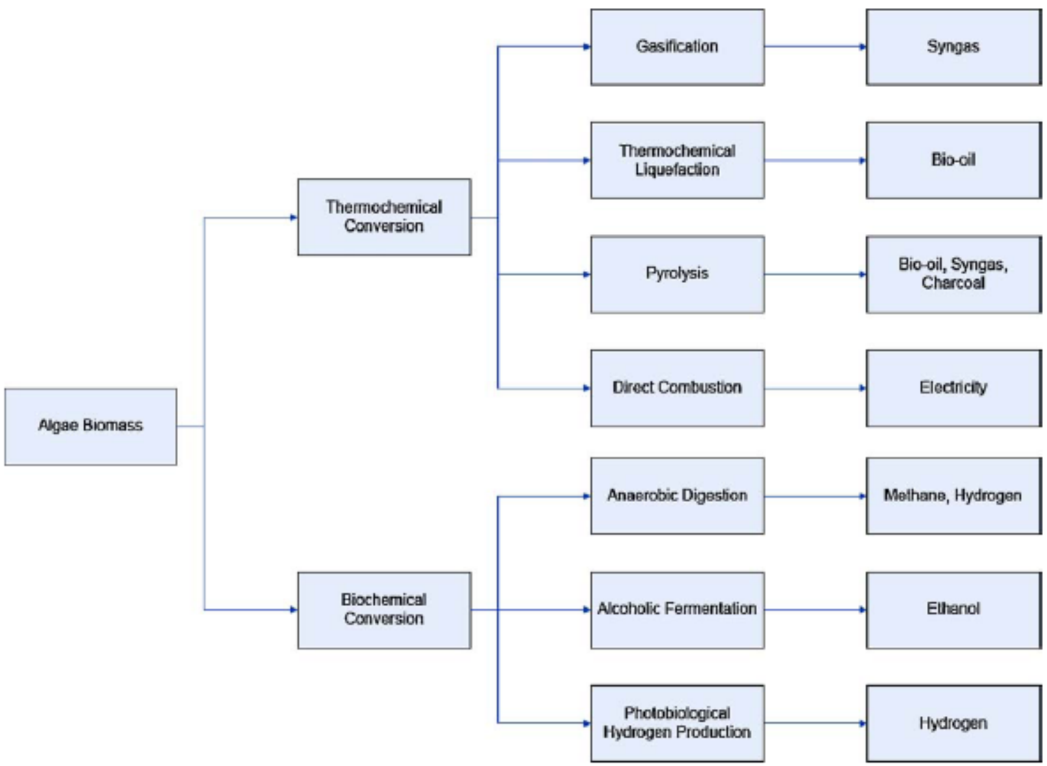
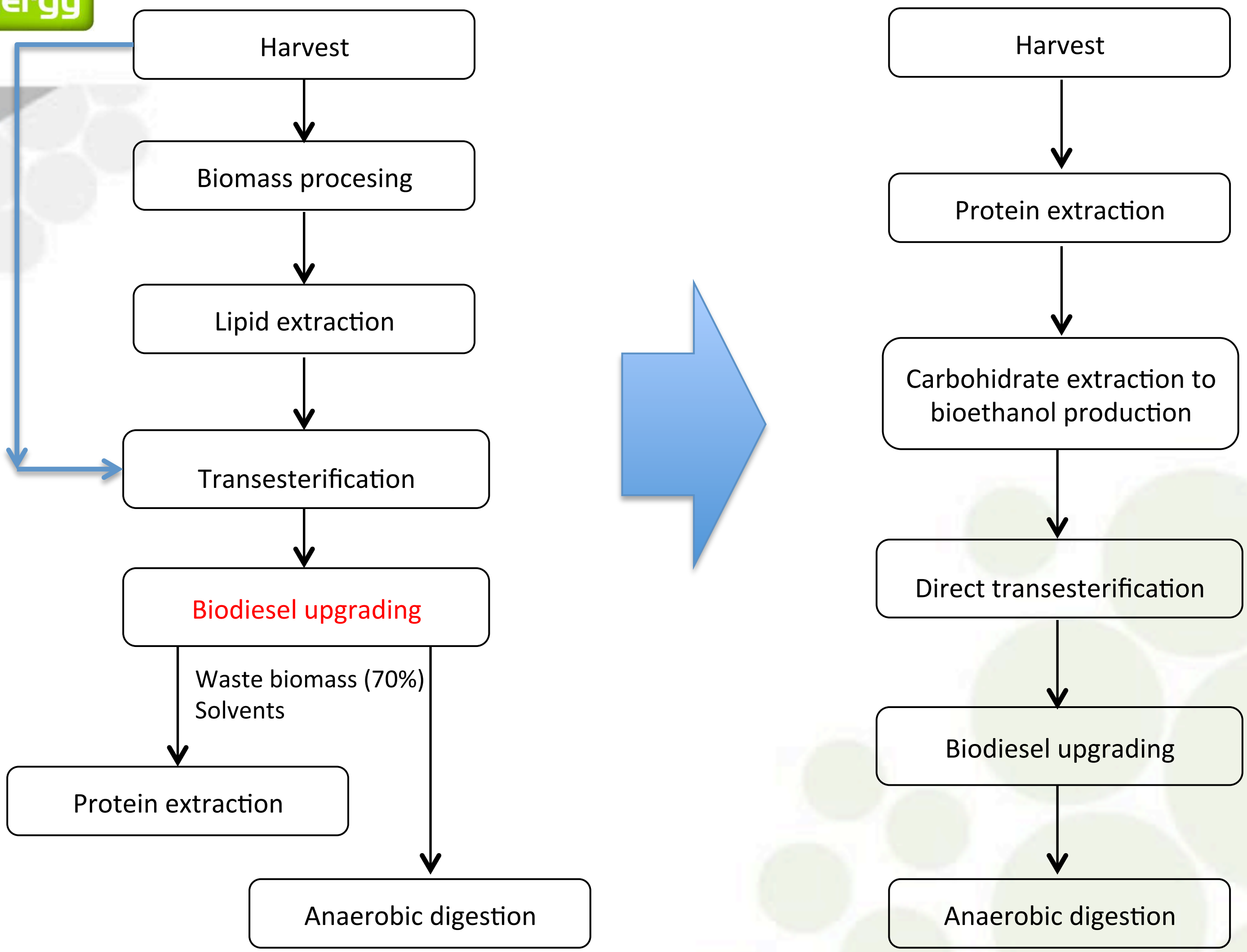


Fig. 3. Potential algal biomass conversion processes (adapted from Tsukahara and Sawayama [162]).

Brennan and Owende, 2010

Downstream



Harvest
Biomass procesing
Lipid extraction
Transesterification
Biodiesel upgrading
Waste biomass (70%)
Solvents
Protein extraction
Anaerobic digestion
Harvest
Protein extraction
Carbohidrate extraction to bioethanol production
Direct transesterification
Biodiesel upgrading
Anaerobic digestion

PROTEIN EXTRACTION

Chemical proteins solubilization & Enzymatic hydrolysis

CHEMICAL PROTEIN SOLUBILIZATION

Sequential optimization

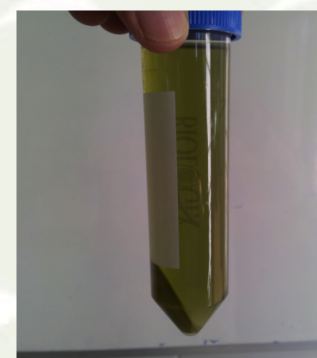
<u>Variables</u>

pH= 9-10-11- 12-13

Temperature (°C)= 30-50-70

time (min)= 10- 20- 30

Stir (rpm)= 100- 200- 300



Results

✓50°C
✓20min
✓200 rpm

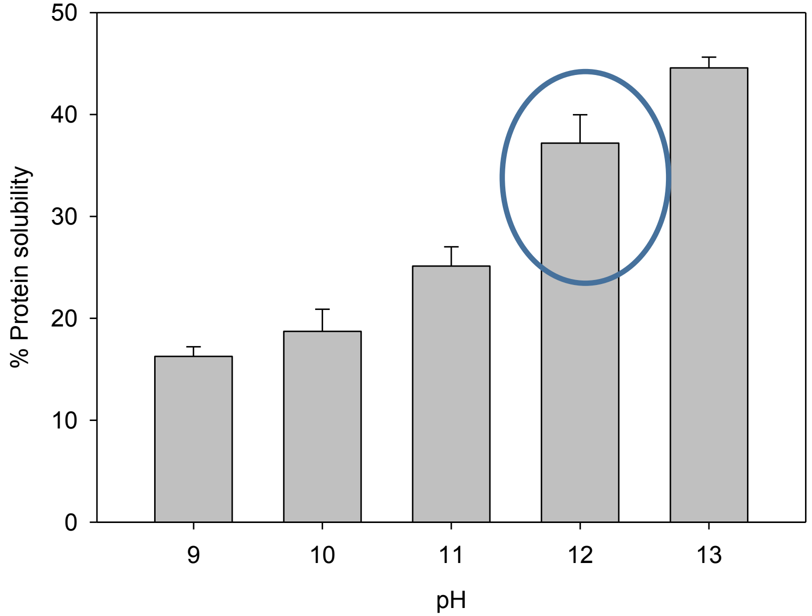


Figure 1. % Protein solubility from microalgae biomass to different pH conditions

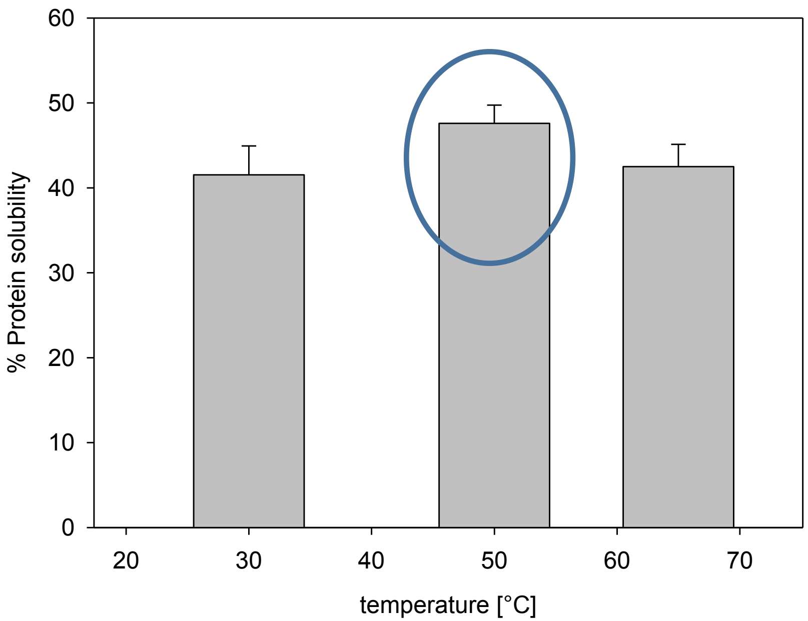
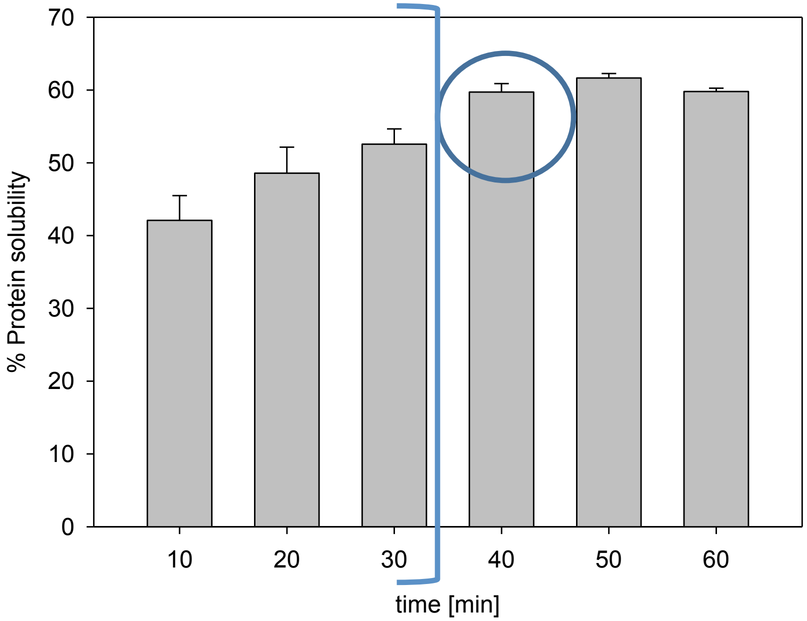


Figure 2. % Protein solubility from microalgae biomass to different reaction temperature

✓pH 12
✓20min
✓200 rpm



✓pH 12
✓50°C
✓40 min

Figure 3. % Protein solubility from microalgae biomass to different reaction time

✓pH 12
✓50°C
✓200 rpm

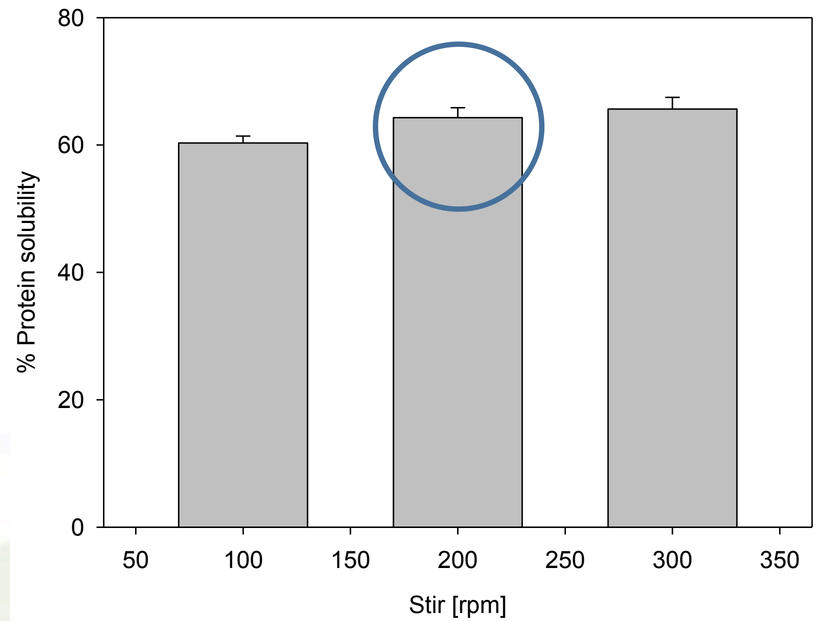


Figure 4. % Protein solubility from microalgae biomass to different stir conditions

Optimal conditions:
pH 12
50°C
40 min
200rpm

Yield: 64%

ENZYMATIC HYDROLYSIS

1) Enzymatic hydrolysis of microalgae biomass through successive steps addition of: Viscozyme, Alcalasa and Flavourzyme

2) Enzymatic hydrolysis of solubilized protein by chemical treatment by using Alcalasa.

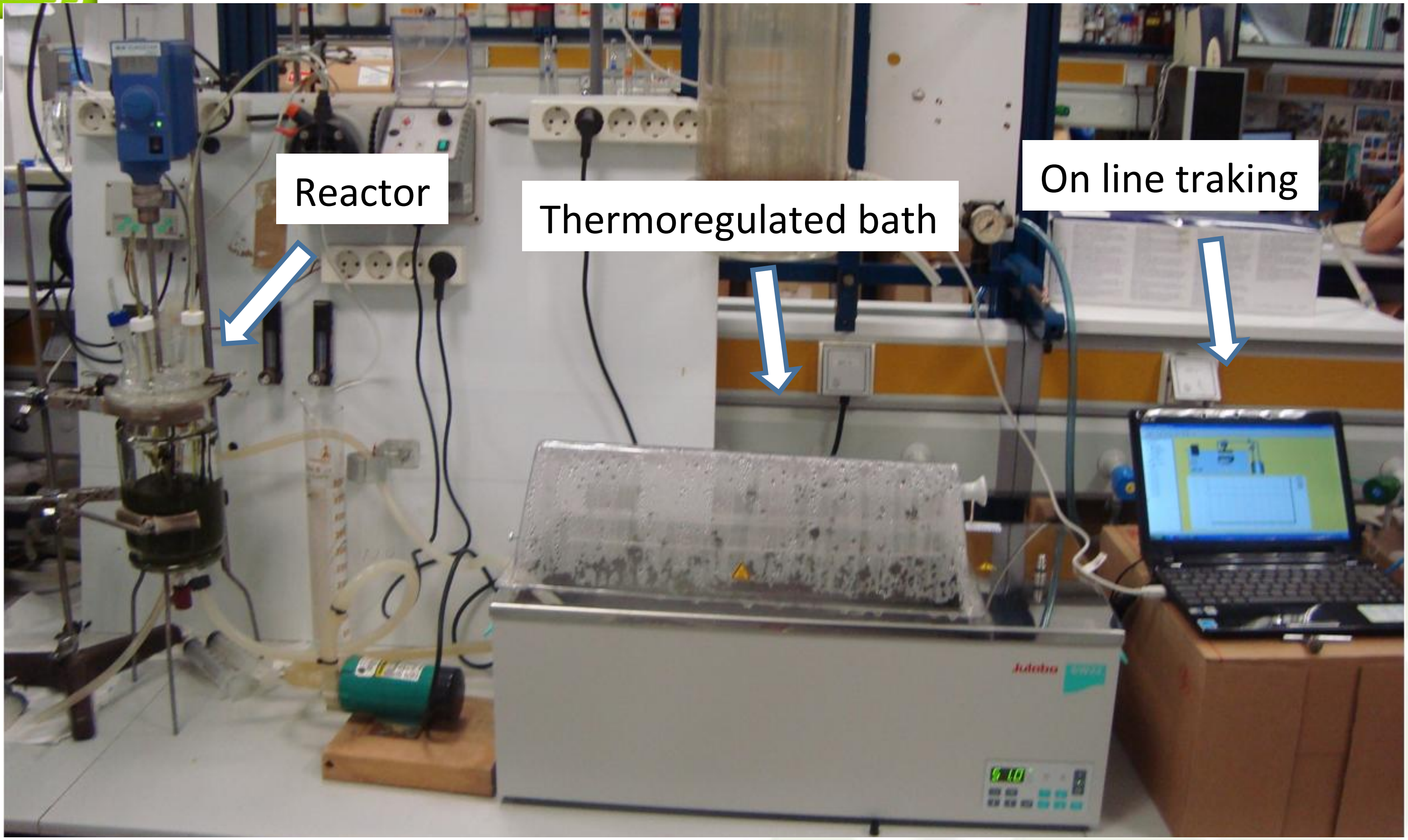
3) Enzymatic hydrolysis of solubilized protein by chemical treatment by using Flavourzyme.

Raw material

1) Pretreated *Microalgae*

150g/L (similar to biomass post harvest)

Set up



Enzymatic hydrolysis of microalgae biomass

Hydrolysis degree: 84%

Disadvantage
Carbohydrates loss
(65%)

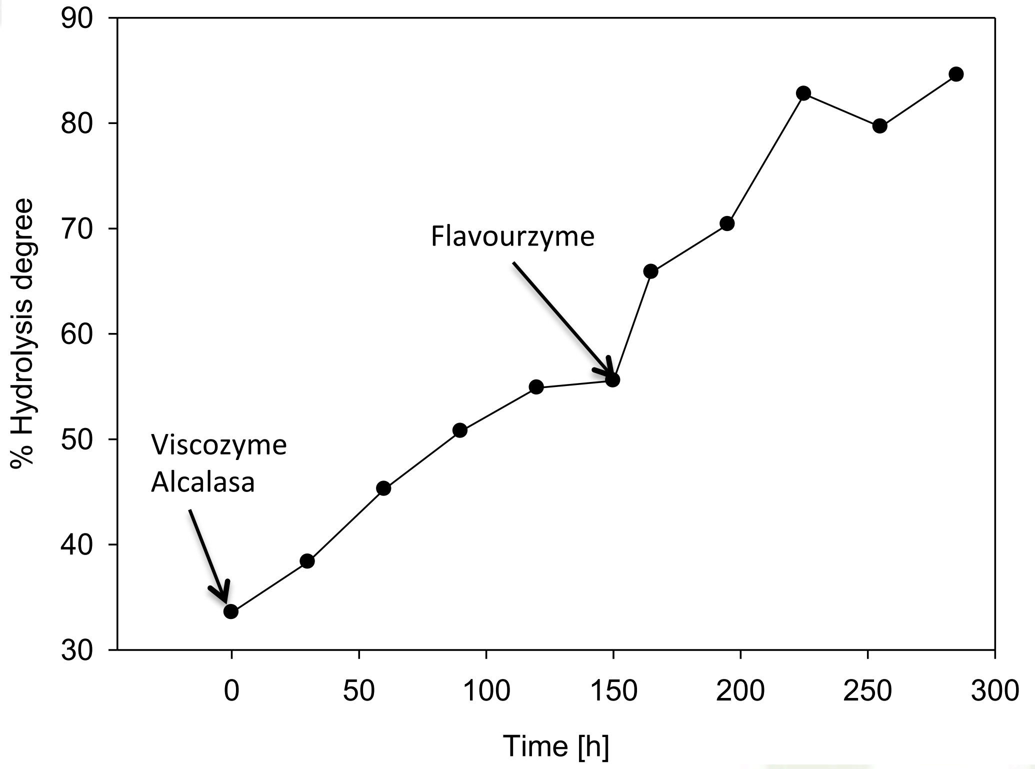


Figure 5. Hydrolysis degree after enzymatic hydrolysis of microalgae biomass

Enzymatic hydrolysis of previously solubilized protein by chemical process

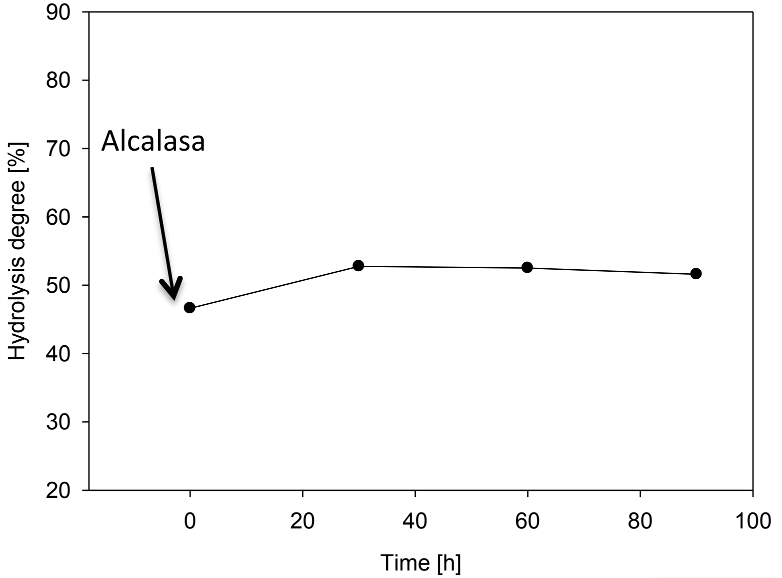


Figure 6. Hydrolysis degree after enzymatic hydrolysis of solubilized protein by chemical process

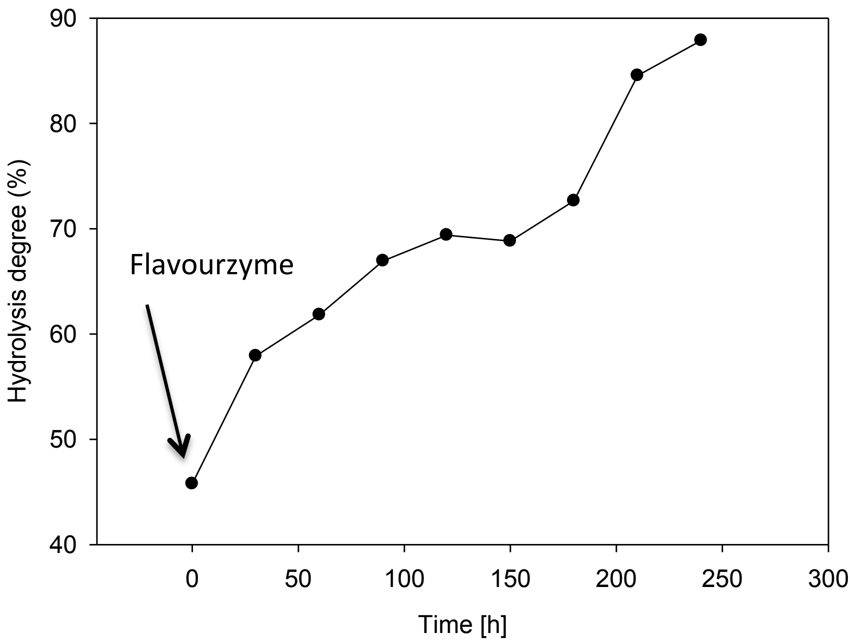


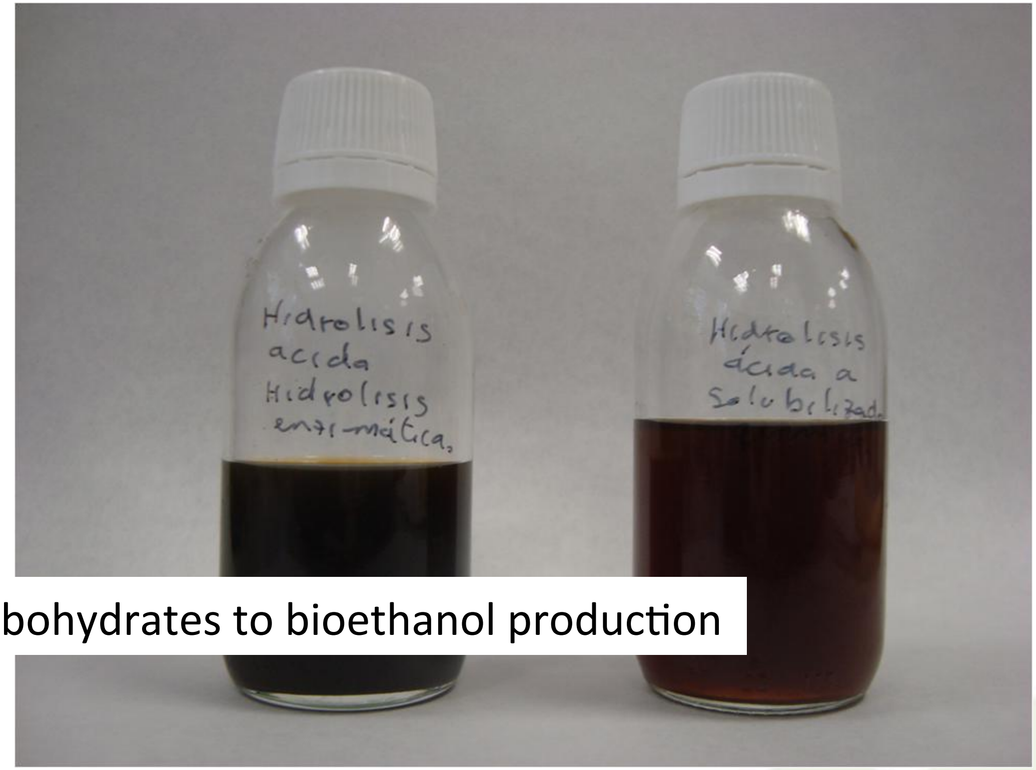
Figure 7. Hydrolysis degree after enzymatic hydrolysis of solubilized protein by chemical process

Total yield: 88%

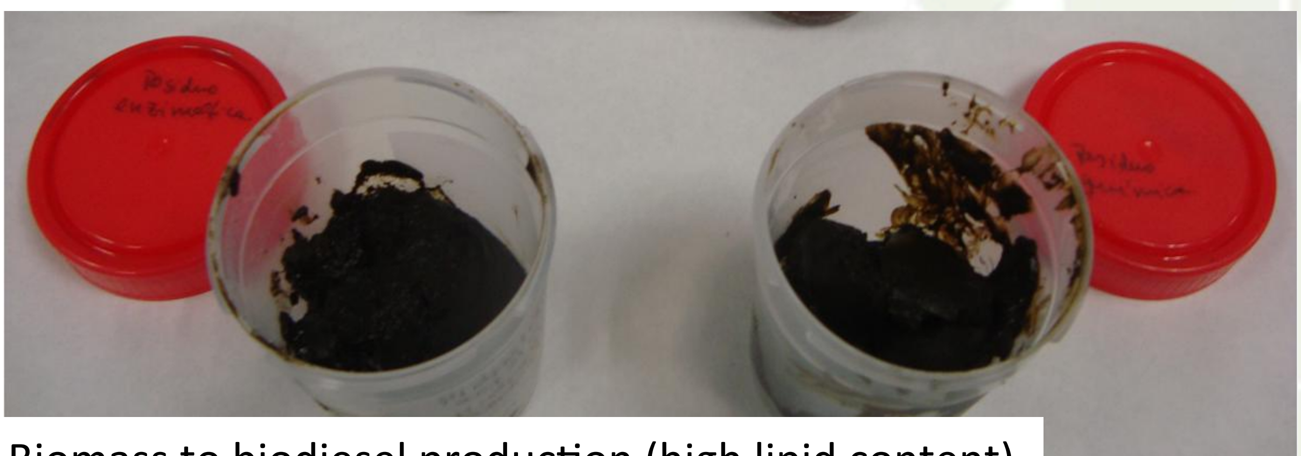
Low carbohydrates loss

Carbohydrates extraction to bioethanol production???

CARBOHYDRATES EXTRACTION TO BIOETHANOL PRODUCTION



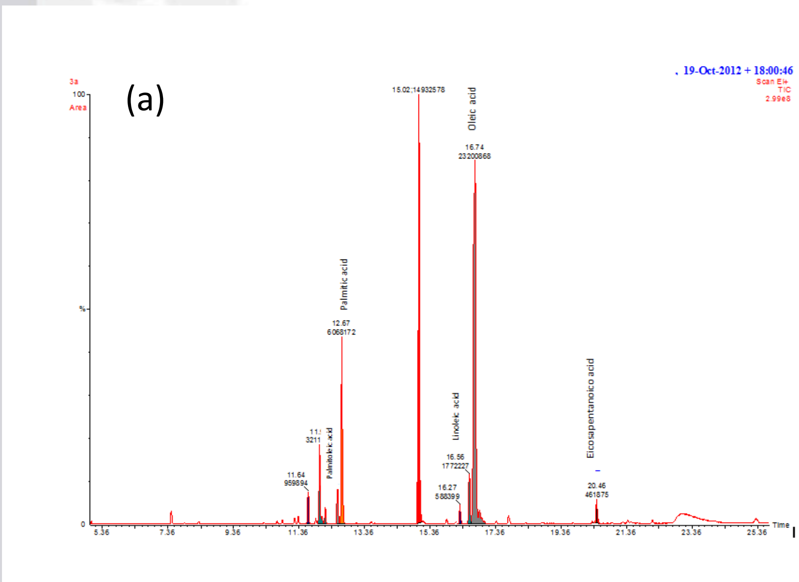
Carbohydrates to bioethanol production

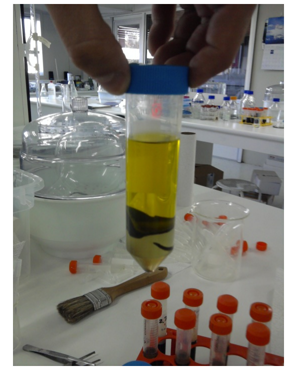


Biomass to biodiesel production (high lipid content)

BIODIESEL PRODUCTION

Lipids extraction and transesterification





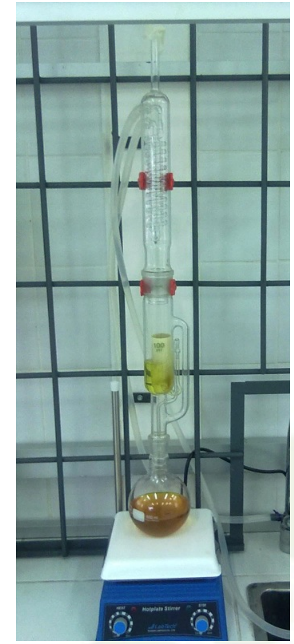
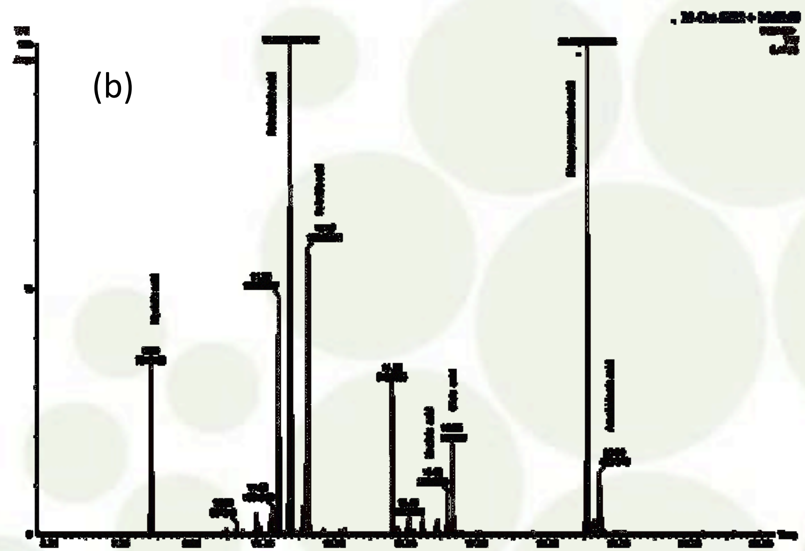


Figure 8. Chromatogram fatty acid profile (a) microalgae 1 and (b) microalgae 2



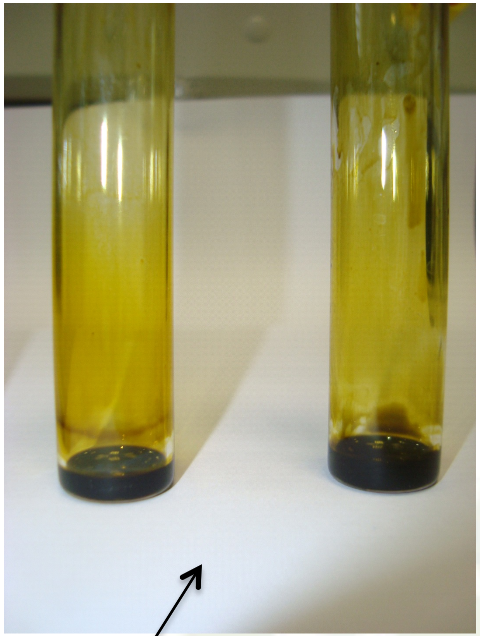
Desert Bioenergy

BIODIESEL PRODUCTION

Direct transesterification

Conditions investigated RSM

- ✓Methanol to oil molar ratio
- ✓Catalyst
- ✓Time
- ✓Temperature



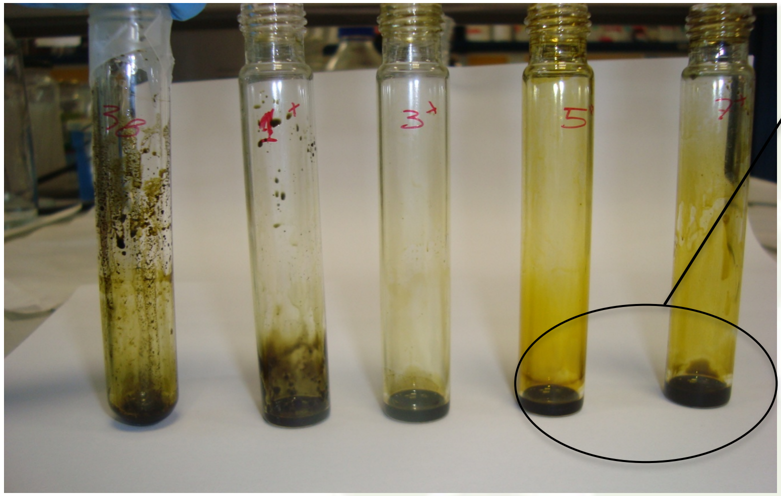


Figure 9. Biodiesel produced by direct transesterification

BIOGAS PRODUCTION

Biochemical methane potential by using microalgae biomass after lipids extraction

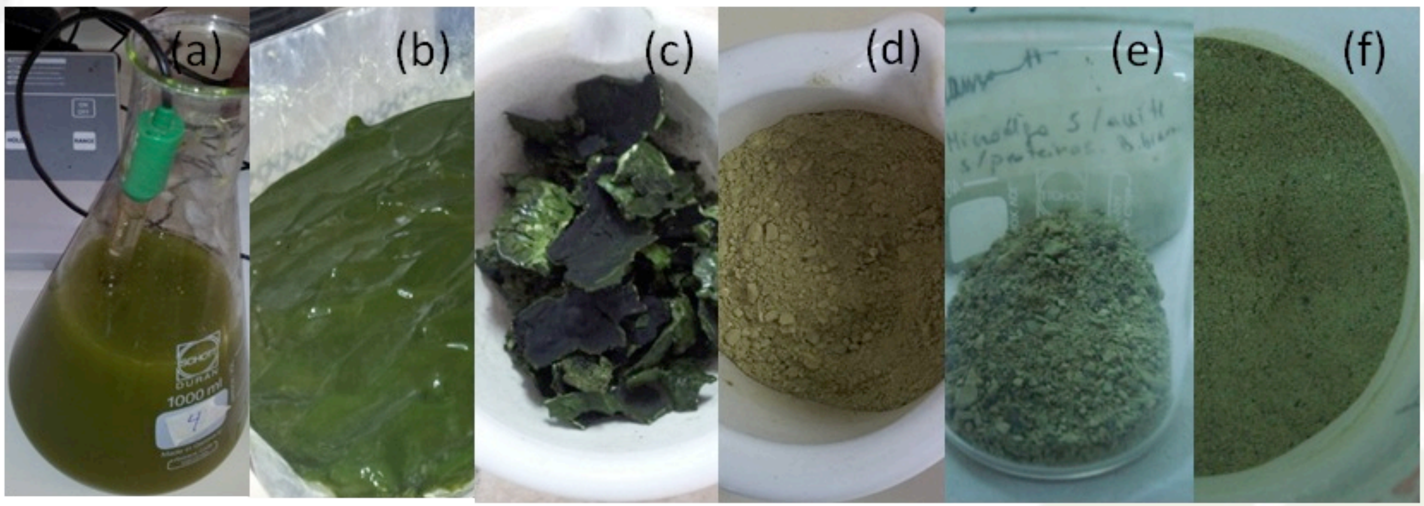


Figure 10. Biomass during microalgae biorefinery process (a)Protein extraction, (b) Drying, (c) Dry biomass, (d) Biomass milled to the lipids extraction, (e) Biomass after lipids extraction, (f) Biomass milled to biogas production

BIOGAS PRODUCTION

Biochemical methane potential by using microalgae biomass after transesterification reaction

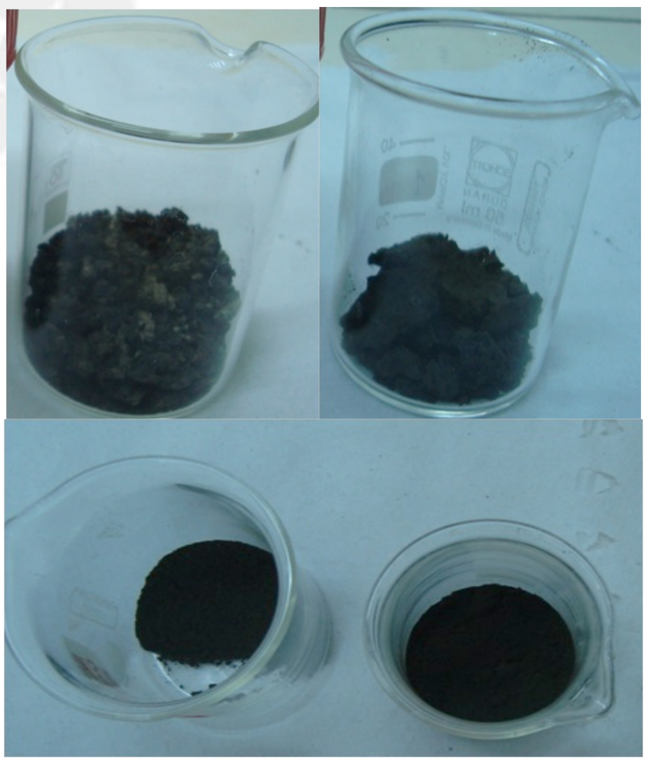


Figure 10. Biomass after transesterification reaction

Assays

117 serum bottles
50 mL reaction
Nutrients
Bicarbonate
35°C

BIOGAS PRODUCTION

Table 1. Microalgae characterization

Parámetro	***Microalgae 1***	***Spent microalgae 1***	***Spent microalgae 2***	***Spent microalgae 2***
Humidity content [%]	79,58	7,66	3,99	3,13
Lipids [%]*	19,20	5,23	9,61	7,4
Protein [%]*	33,00	22,80	39,42	41
Fiber [%]*	3,33	7,94	4,34	3,54
Ash [%]*	31,00	40,13	10,34	13,75
Carbohidrates [%]	13,47	16,24	32,3	31,18
C/N [gC/gN]	5.85	6.97	-	-

*dry basis

BIOGAS PRODUCTION

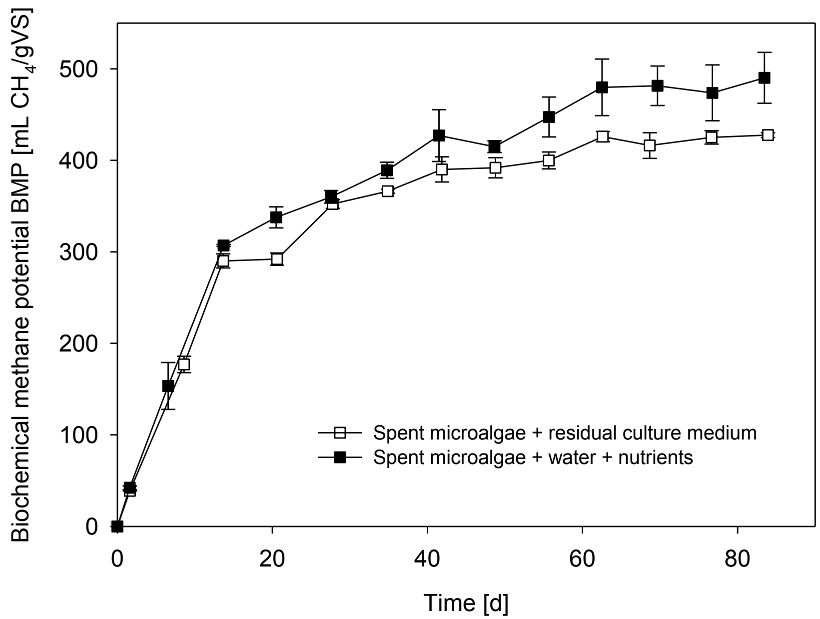


Figure 11. BMP using spent microalgae after protein and lipids extraction

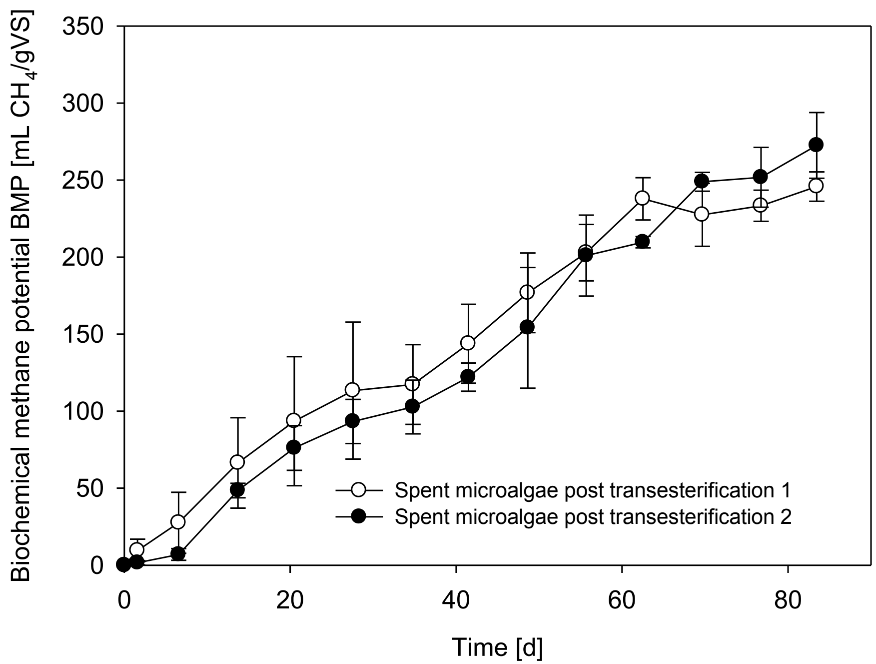


Figure 12. BMP using spent microalgae after direct transesterification

BIOGAS PRODUCTION

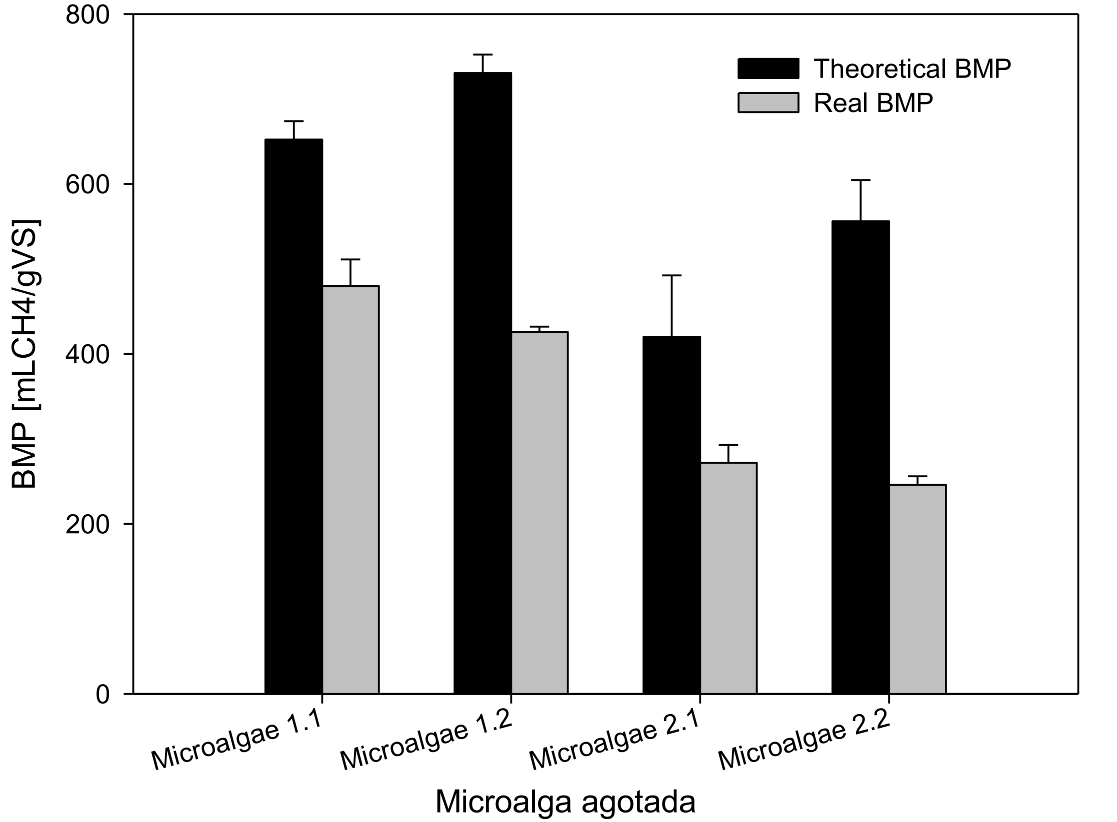
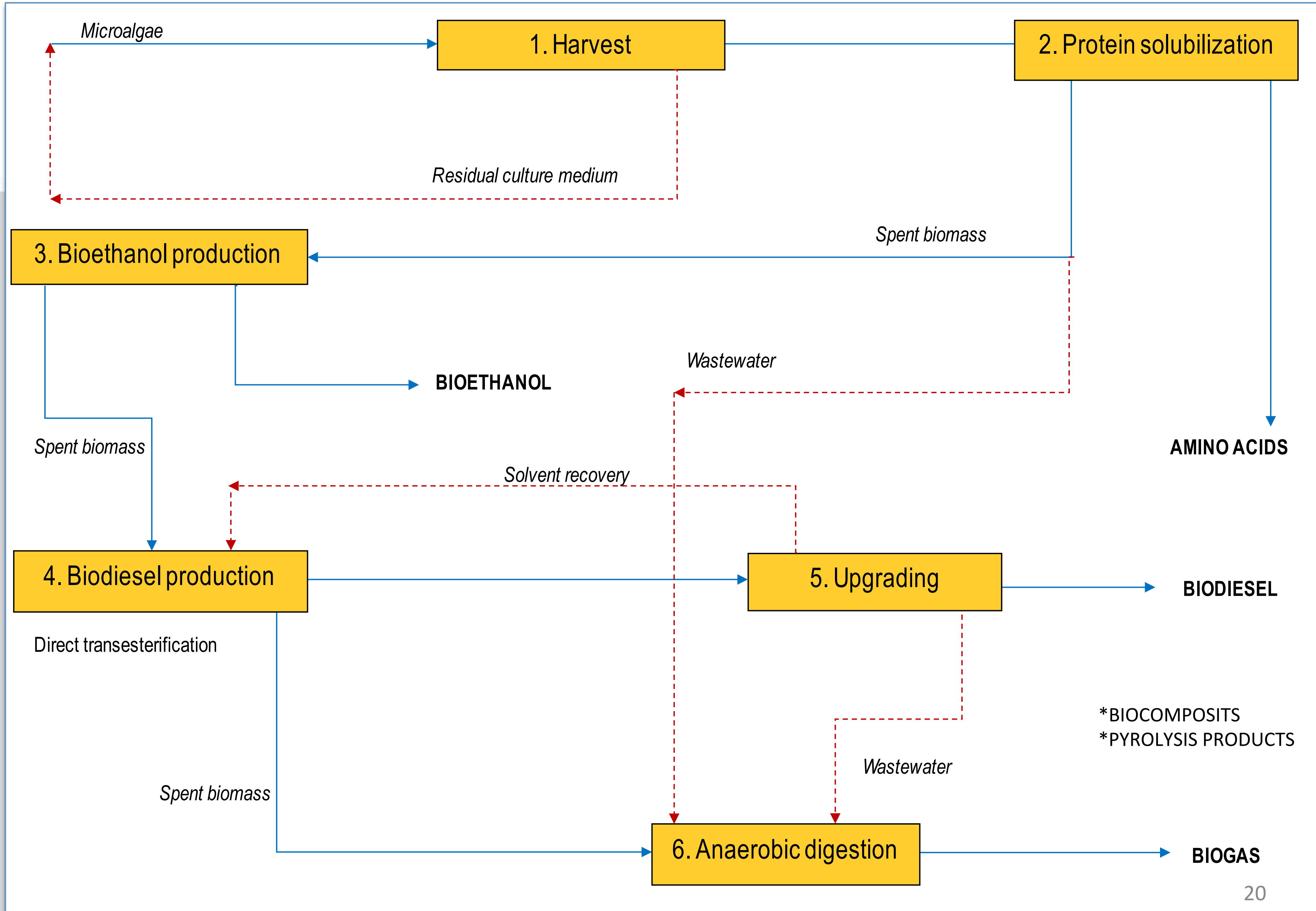


Figure 13. Theoretical and real BMP usiing spent microalgae

NEW MICROALGAE BIORREFINERY CONCEPT



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Laura Azócar, Hernán Díaz, Robinson Muñoz, Leonel González, David Jeison, Rodrigo Navia

www.desertbioenergy.cl
www. bioren.cl
lazocar@desertbioenergy.cl