Bio-energy III, ECI
May 22-27, 2011, Lanzarote, Spain

Butanol extractive fermentation to simultaneously produce "properties improved" biodiesel & butanol in a water and energy-saving operation way

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2011-05-26

Scopes of the presentation

1) Objectives

2) Methods

3) Updated results

4) Conclusions

Bio-energy III, Lanzarote, Spain - Objectives

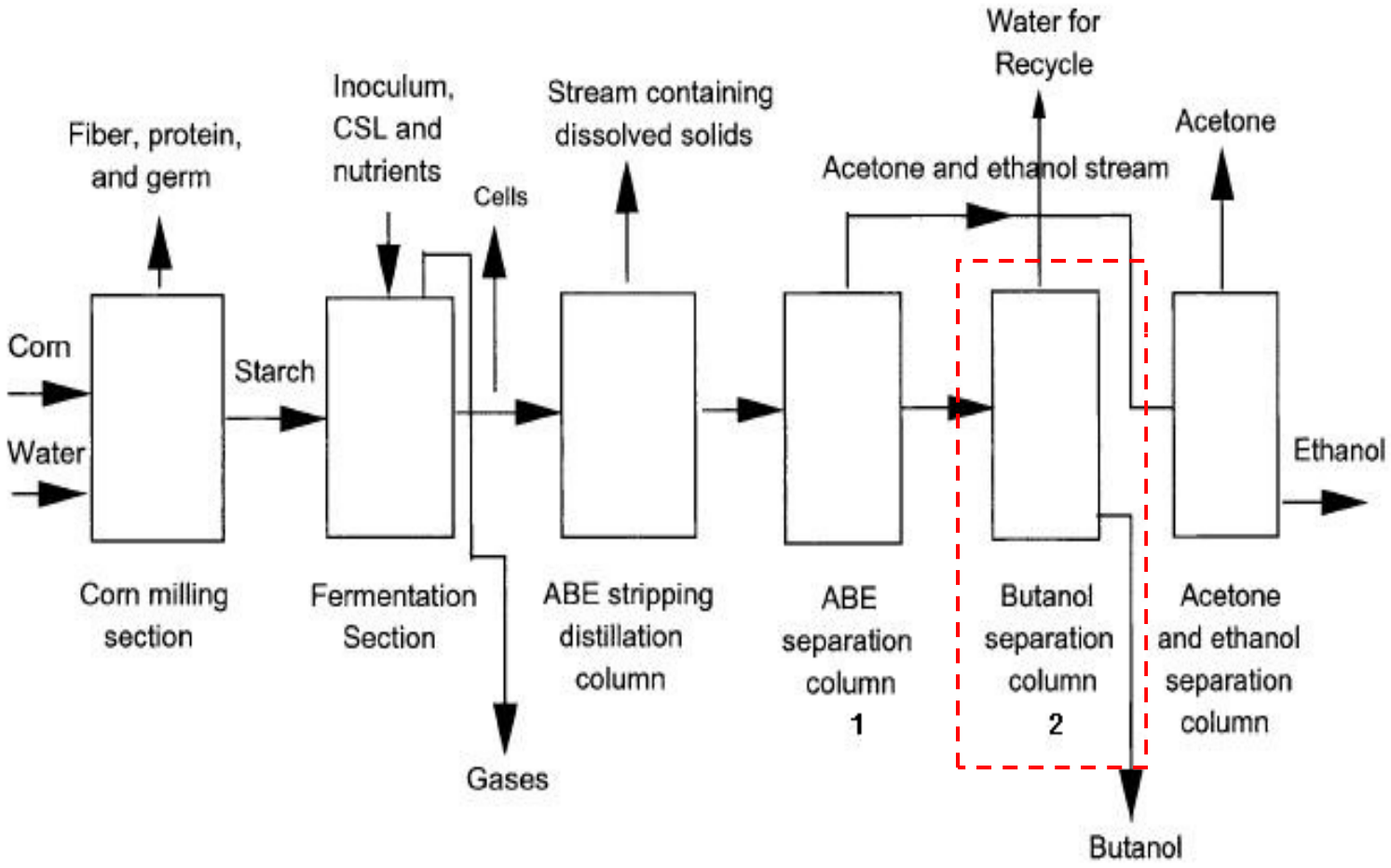
Important organic chemicals & intermediate

Bio-Butanol

High performance fuel & liquid fuel additive

Bio-energy III, Lanzarote, Spain - Objectives

Traditional ABE fermentation & purification process



BtOH 13g/l, ACE 6.5g/l, EtOH 2g/l

Bio-energy III, Lanzarote, Spain - Objectives

General comparison of Fossil Diesels & Bio-diesels

Example of the major index	Related Performance	Palm oil methyl ester (One of bio-diesels)	Fossil diesels (#2 diesel US)
Cetane Number (CN)	Ignition delay, combustion, black smoke	49	56
Combustion Heat (MJ/Kg)	Combustion properties Output power	39.8	45.7
Boiling point (°C)	Ignition at low temp.	+10 °C	-7 °C
S content (wt, %)	Air pollution, environment	0.01	0.07
Total gas exhausts amount (g/Kwh)	Air pollution, environment, global green-house effect	0.421	0.486
Available sources	Sustainable/renewable features	Renewable biomass	Fossil sources

Disadvantages

Advantages

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Increased CN value of the bio-diesel extracted butanol

中国石油化工股份有限公司金陵分公司质量检验中心

检 测 报 告

委托单位：江南大学　　报告编号：WT2008－01－07－26＃
样品名称：地沟生物柴油　　样品编号：WT2008－01－07－26＃
样品数量：4 个　　客户编号：－－－－51.4
送样日期：2008－01－07　　检测日期：2008－01－08

检 测 结 果

检 测 项 目	检 测 结 果	检 测 方 法
十六烷值，（实测）	51.4（A）	GB/T 386
十六烷值，（实测）	51.4（B）	GB/T 386
十六烷值，（实测）	49.0（C）	GB/T 386
十六烷值，（实测）	54.4（D）	GB/T 386

Cetane Number (CN)

Original BD

BD extracted with 12 g/l BtOH

BD extracted with 12 g/l BtOH but treated with 1.6% Na_2SO_4 dehydration

BD: Bio-diesel

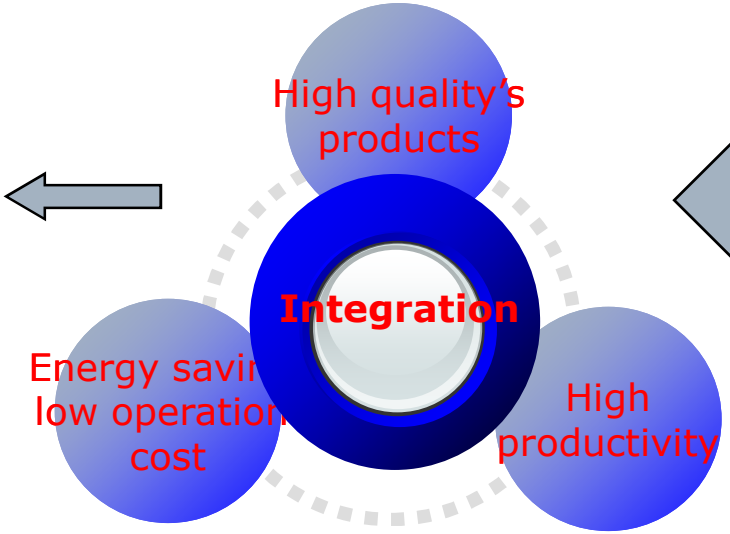
Bio-energy III, Lanzarote, Spain - Objectives

#1 High raw materials cost

#2 Low fermentation productivity by end products inhibition

#3 Low products concentration, huge energy requirement for purification

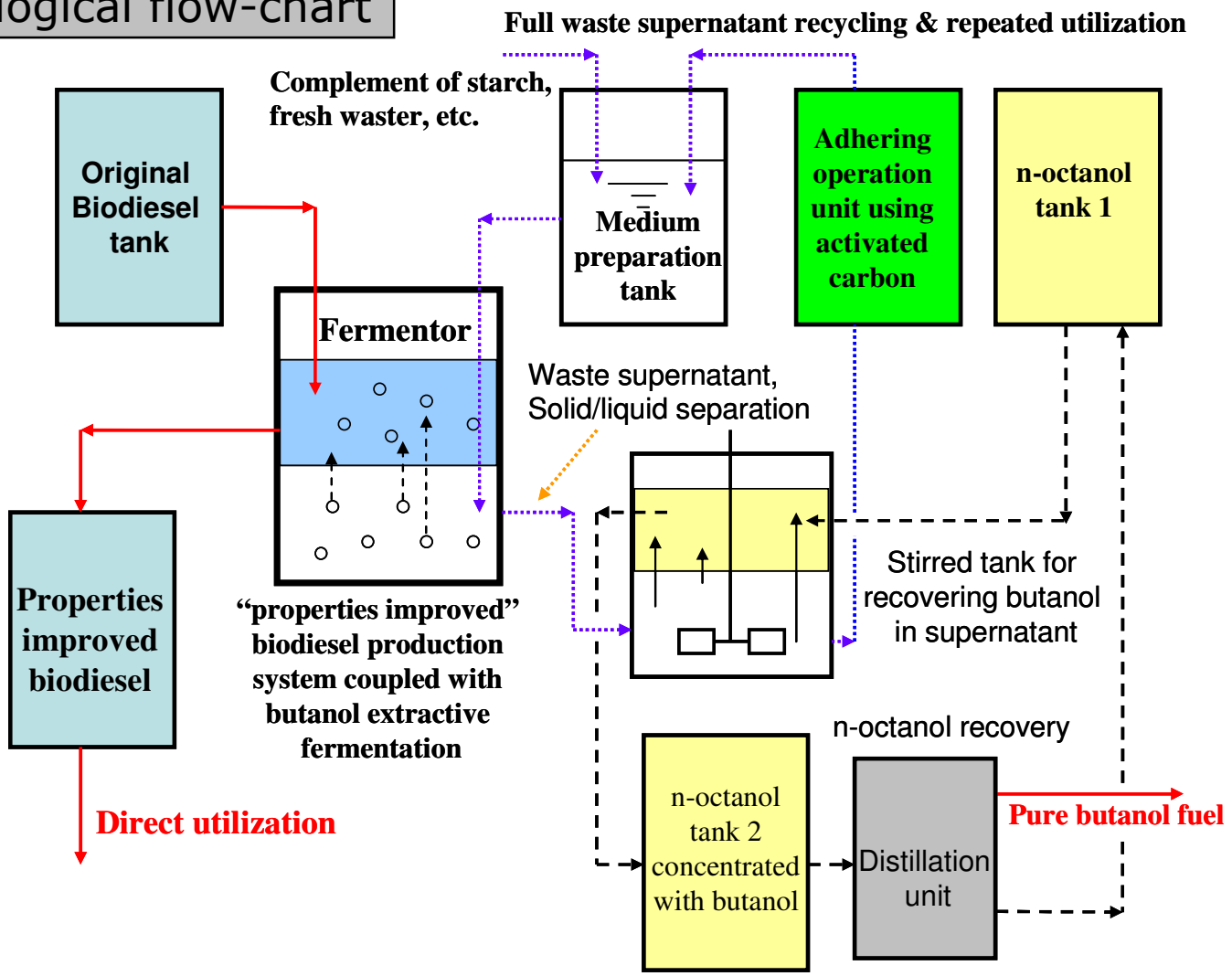
1) Developing an integrated AB fermentation to enhance productivity;
2) Direct utilizing butanol extracted bio-diesel as "properties improved" biodiesel, eliminating products recovery process;
3) Fully utilizing residual waste water to save fresh water & minimize water pollution;
4) Recovering BtOH in the waste to increase "aimed" yield.



Creating novel Biofuels system, products diversity

Bio-energy III, Lanzarote, Spain - Methods

Technological flow-chart



Bio-energy III, Lanzarote, Spain - Methods

Fermentation conditions

Strain: *Clostridium acetobutylicum* ATCC824

Fermentation medium: corn flour & cassava powders (15%~30%)

Fermentation volume: 2.0~2.5 L

Fermentation extractants: bio-diesels/olyel alcohol, volume ratio 1:1

Fermentation condition: 37°C, strictly anaerobic, static

Initial urea amount: 1% (w/w) of the total sugar

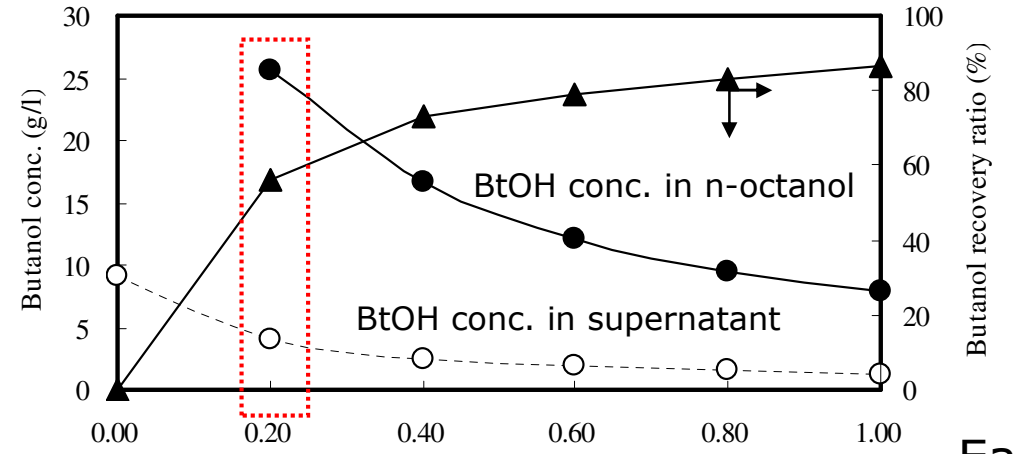
Yeast extracts addition amount: 2.5 g/L-broth

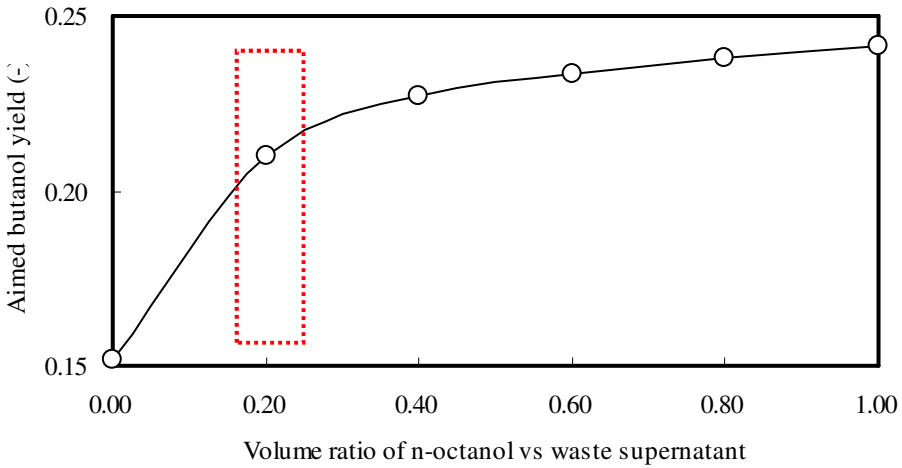
Bio-energy III, Lanzarote, Spain - Methods

Fermentor and instruments

Bio-energy III, Lanzarote, Spain - Results

Using n-octanol to extract BtOH in residual wastes before pretreatment





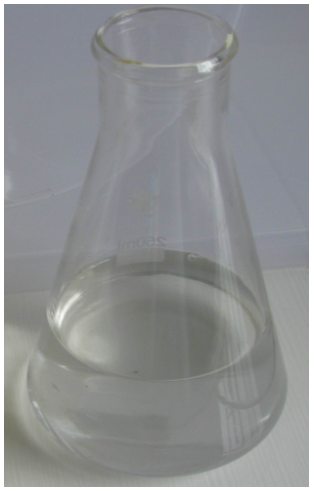
Ease distillation load
& save purification energy

Aimed BuOH yield =

$$\frac{BtOH^{Bio-diesel} + BtOH^{n-octanol}}{Starch\ \ consumed}$$

Bio-energy III, Lanzarote, Spain - Results

Color changes of waste supernatant after adding activated carbon

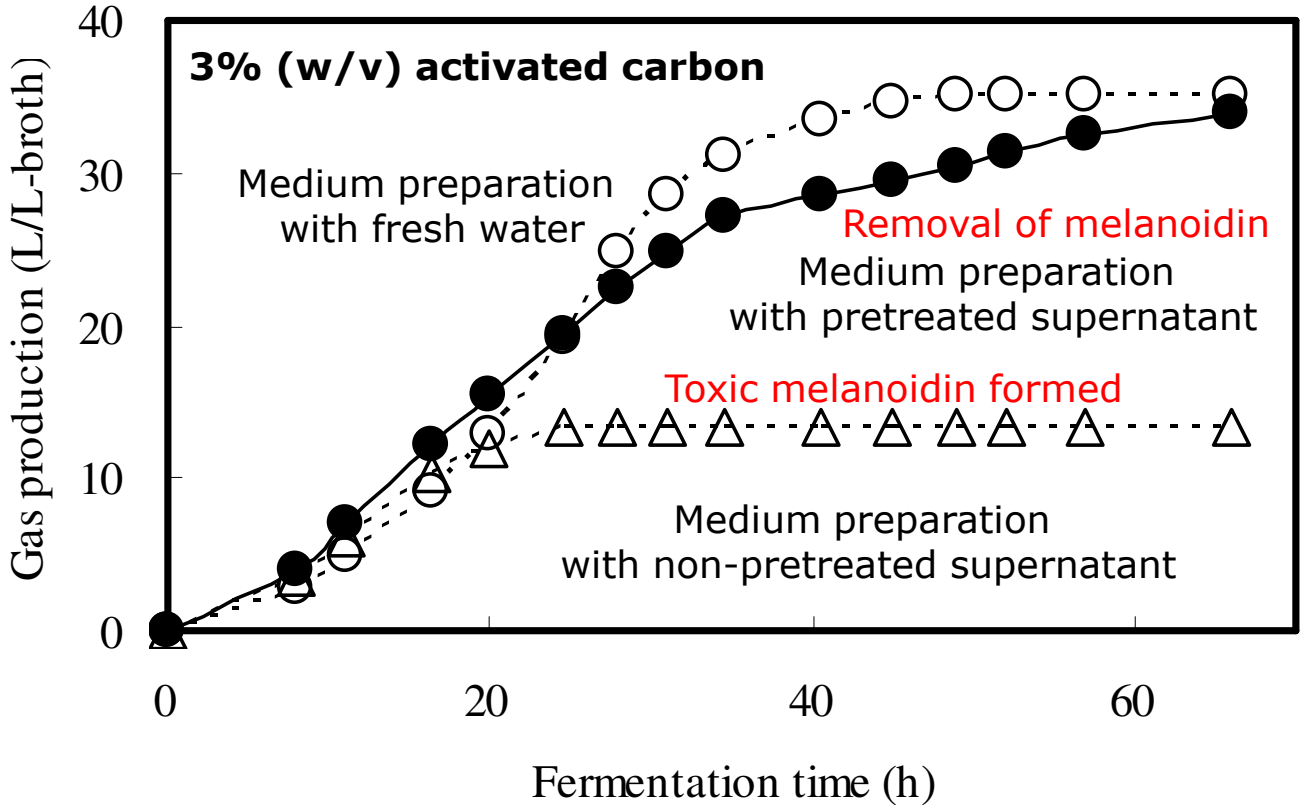


Without activated C treatment

With activated C treatment

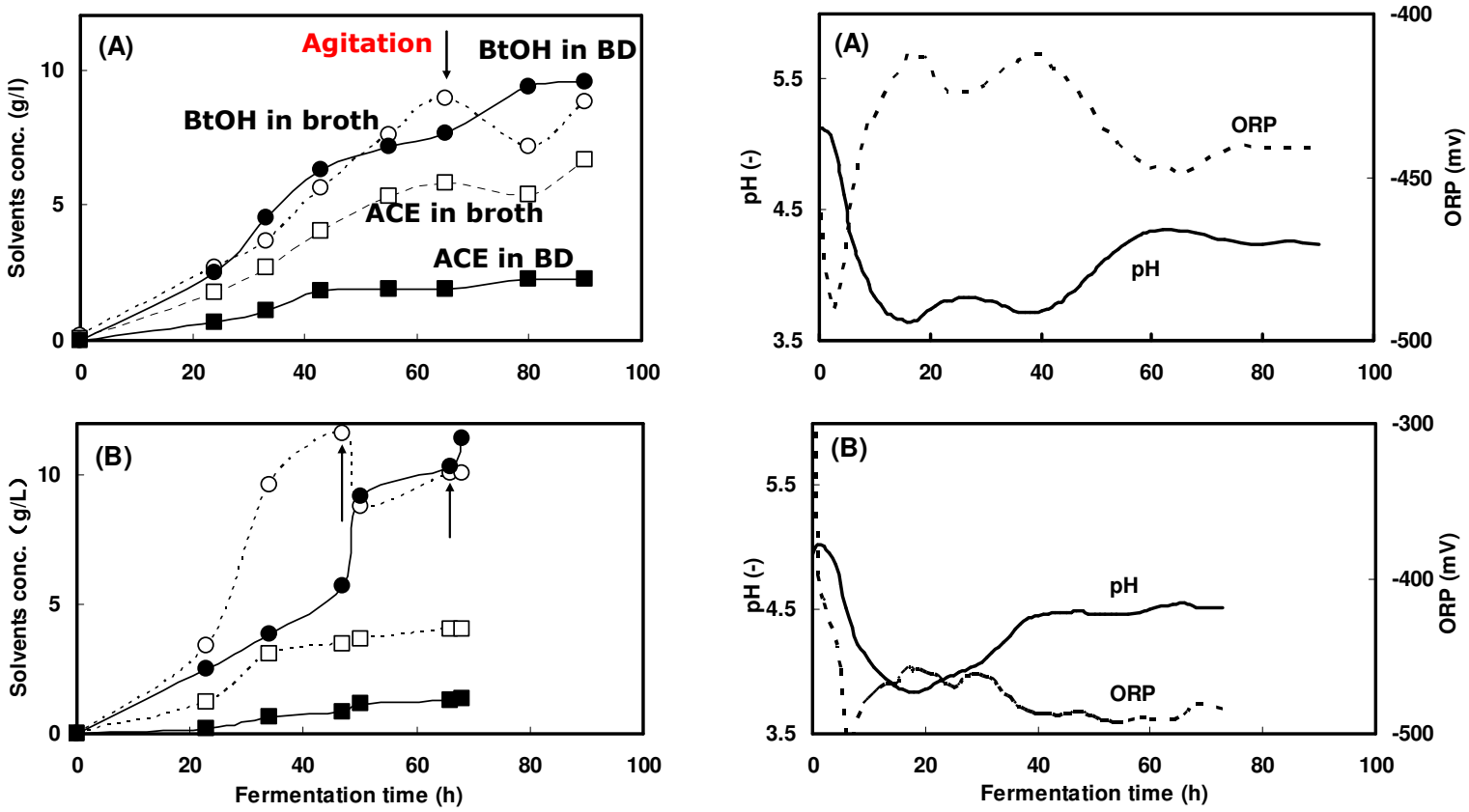
Bio-energy III, Lanzarote, Spain - Results

Pretreatment (residual BtOH extraction + activated C adhere) & full (100%) utilization of supernatant - gas production



Bio-energy III, Lanzarote, Spain - Results

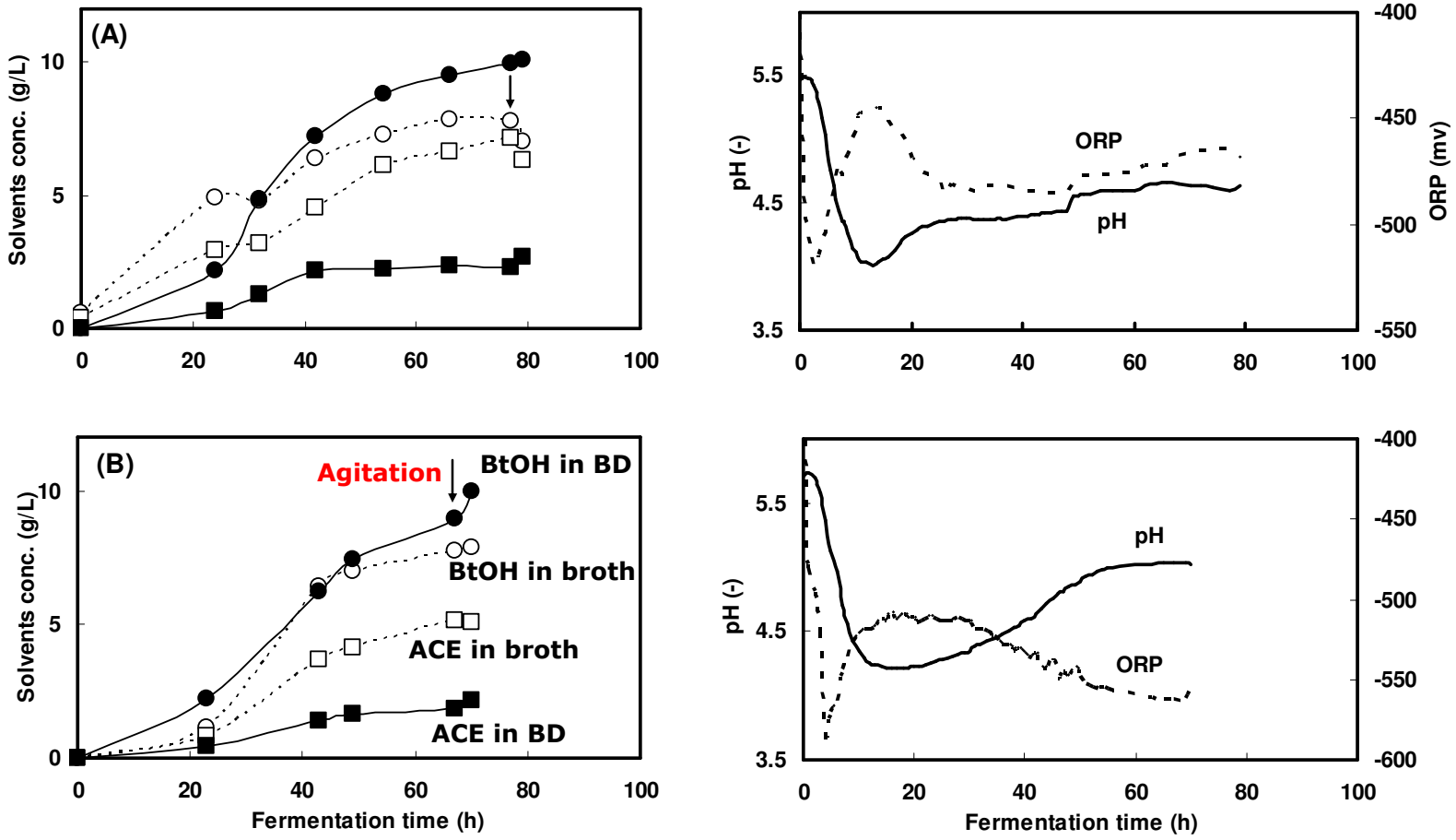
AB fermentation when using fresh water for medium preparation



A: without neutral red addition; B: with 0.1% (w/v) neutral red addition

Bio-energy III, Lanzarote, Spain - Results

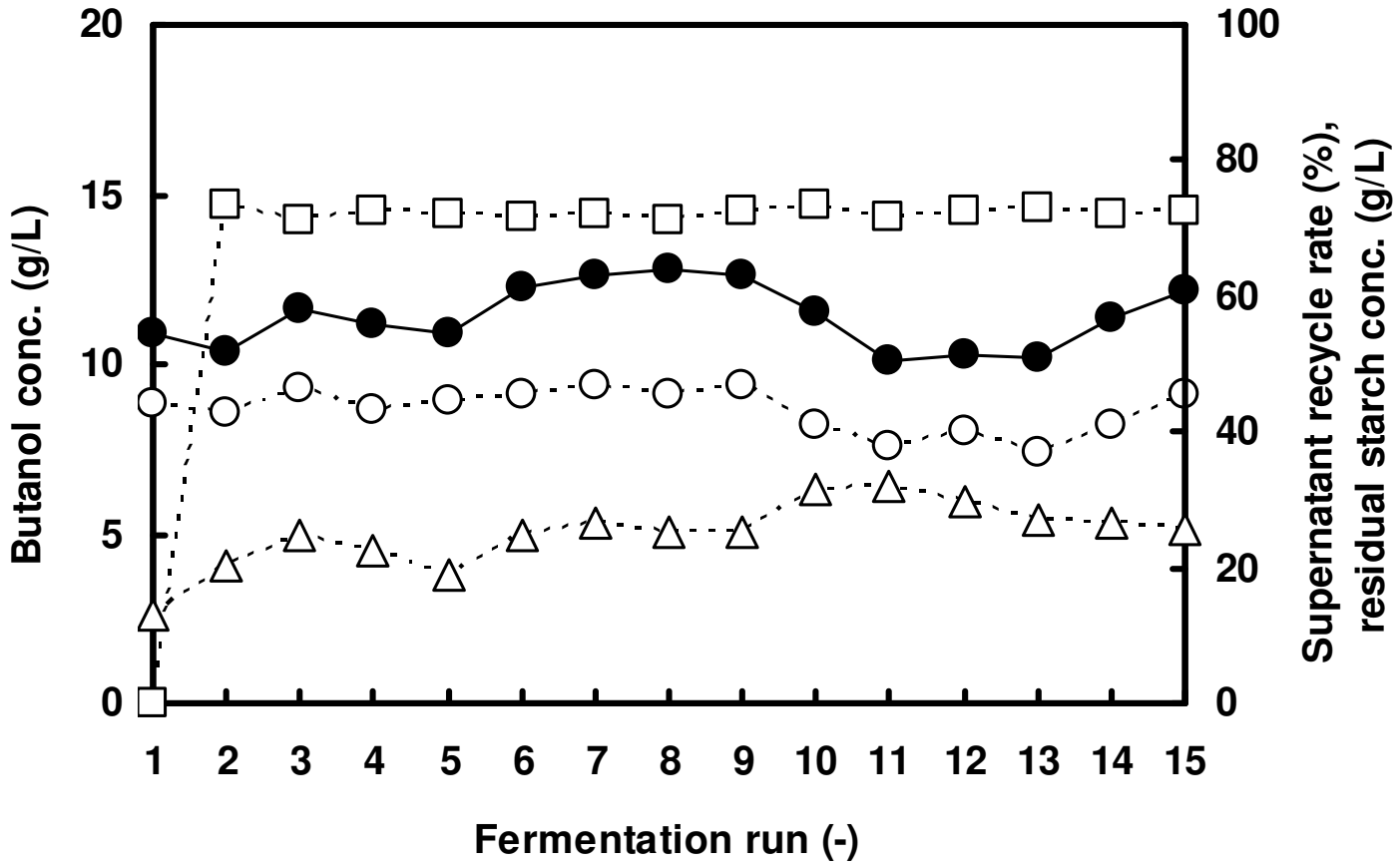
AB fermentation using 100% pretreated waste supernatant for medium preparation



A: without neutral red addition; B: with 0.1% (w/v) neutral red addition

Bio-energy III, Lanzarote, Spain - Results

Repeated utilization of pretreated waste supernatant



△: residual starch conc.; ○: BtOH in aqueous broth; ●: BtOH in bio-diesel; □: waste recycle ratio

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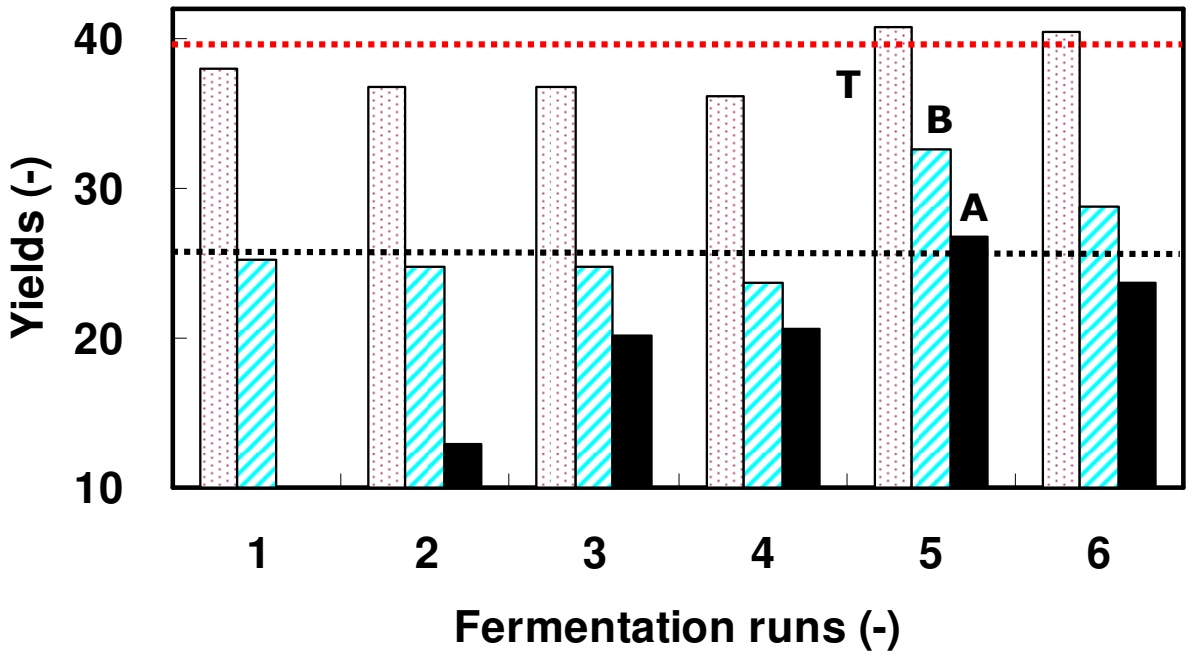
Yields of total solvents, total butanol and “aimed” butanol in different fermentation runs

Yields of total solvents (T), total butanol (B), and aimed butanol (A)



1) Traditional AB fer.;
2) Extractive AB fer. using fresh water without recovering residual butanol and using supernatant for the next run;
3) Extractive AB fer. with fresh water, recovering residual butanol and using waste supernatant;
4) Extractive AB fer. using 100% pre-treated waste supernatant;
5) Extractive AB fer. using fresh water for medium preparation with addition of 0.1% neutral red;
6) Extractive AB fer. using 100% pre-treated waste supernatant with addition of 0.1% neutral red.

Bio-energy III, Lanzarote, Spain - Results

The performance and comparison of the integrated AB extractive fermentation process

run #	"Properties improved" biodiesel amount (L/L-broth)	BtOH concentration (g/L), in				Starch consumed (g/L)	Aimed BtOH Yields (-)**	Total aimed BtOH amount (g/L-broth)	BtOH/(BtOH+ACE) (in n-octanol, %)	Total BtOH productivity (g/h/L-broth)
		biodiesel	broth	n-octanol	supernatant*					
1	0.00	0.00	11.63	0.00	0.00	46.12	0.00	0.00	0.00	0.18
2	0.97	9.57	8.80	27.20	3.36	74.15	19.86	14.72	80.98	0.21
3	0.96	10.09	7.00	23.50	2.30	72.00	19.98	14.39	88.68	0.22
4	0.97	11.44	10.07	31.10	3.86	66.38	26.09	17.32	92.97	0.27
5	0.97	9.95	7.88	27.30	2.42	61.87	24.42	15.11	91.21	0.25

Run #1: Traditional AB fermentation;

Run #2: AB extractive fermentation using fresh water;

Run #3: AB extractive fermentation using 100% waste supernatant;

Run #4: AB extractive fermentation using fresh water and with 0.1% (w/v) neutral red addition;

Run #5: AB extractive fermentation using 100% supernatant and with 0.1% (w/v) neutral red addition.

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Exploring the possibility of using cassava as fermenting source for bio-butanol production

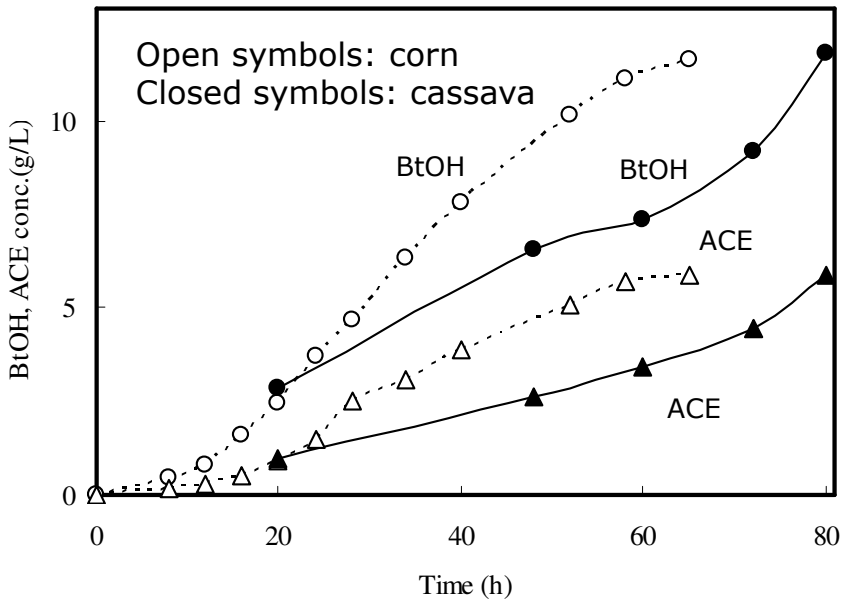
Corn based sources
- **competition with foods for arable land**

Cassava
- **high productivity in in-arable lands even mountain areas**
- **non-competition with foods for arable land**
- **high starch content, but low protein content, cheap**

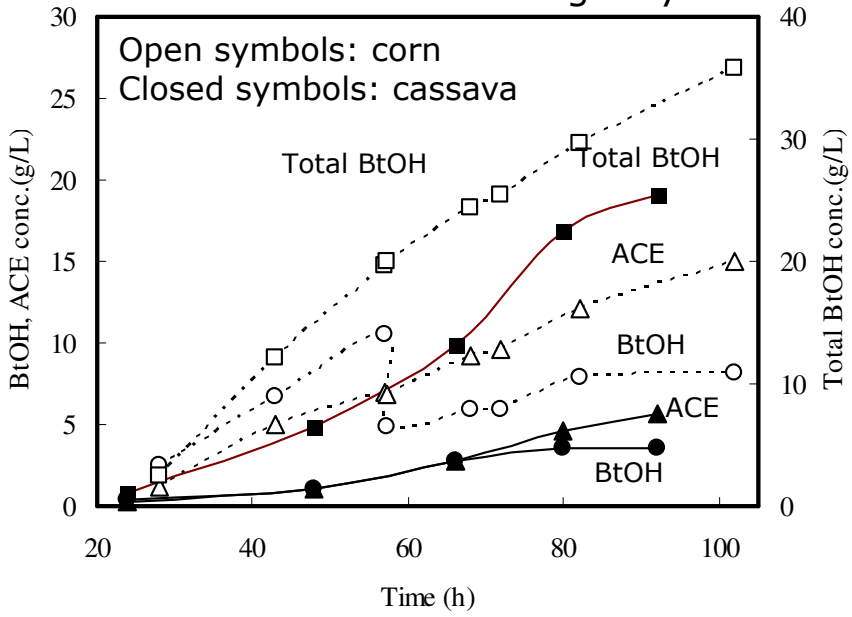
Bio-energy III, Lanzarote, Spain - Results

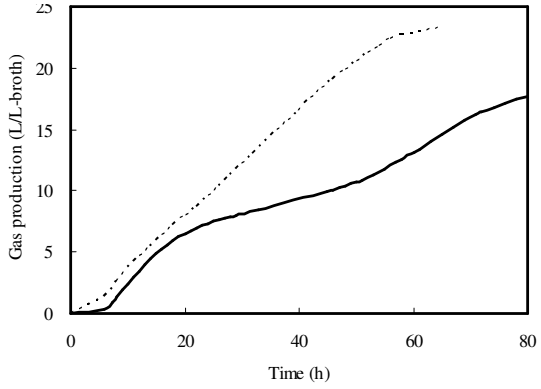
Very low solvents production rates

Traditional AB fermentation

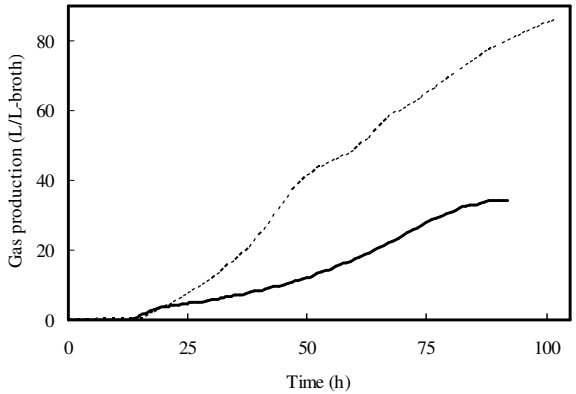


Extractive AB fermentation using oleyl alcohol





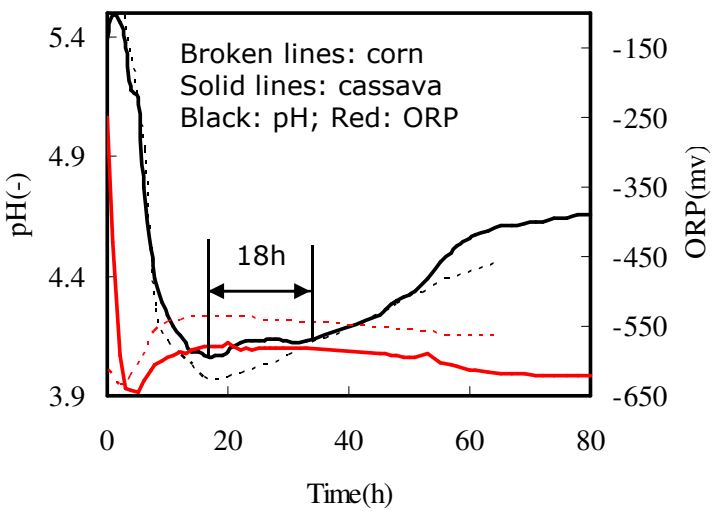
Solid lines: cassava



Bio-energy III, Lanzarote, Spain - Results

Long time delay in shifting from acidogenic to solventogenic phase

Traditional AB fermentation



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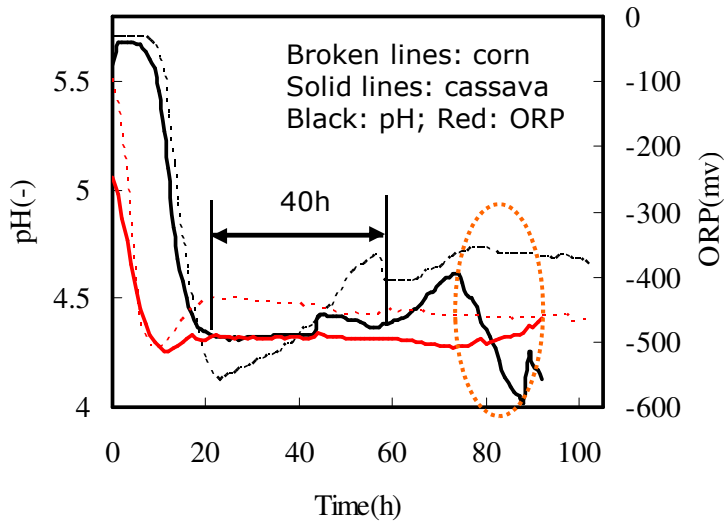
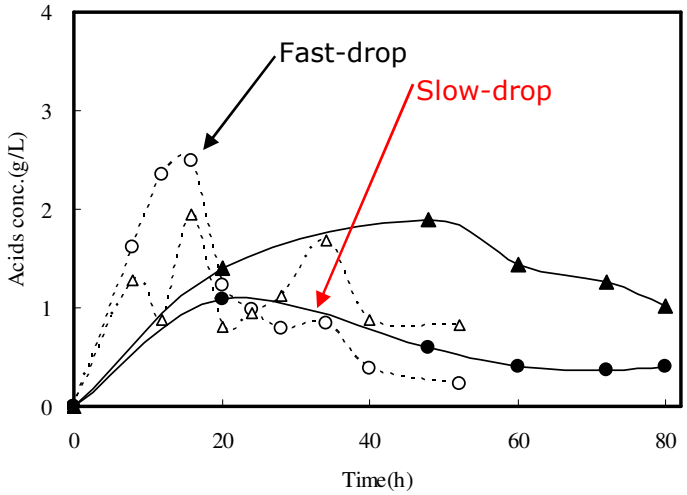
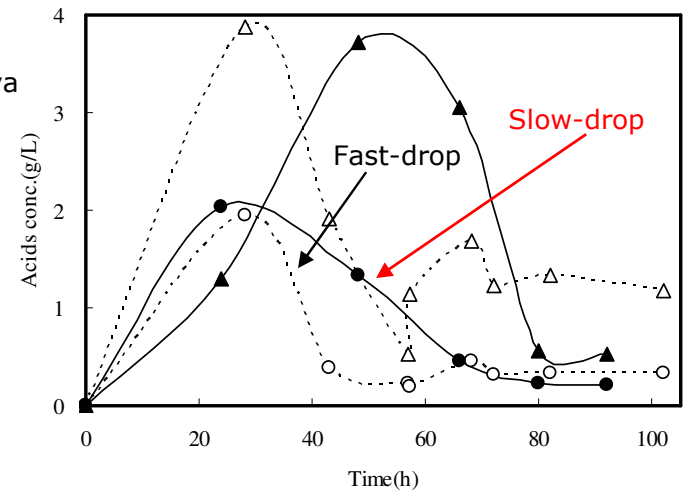




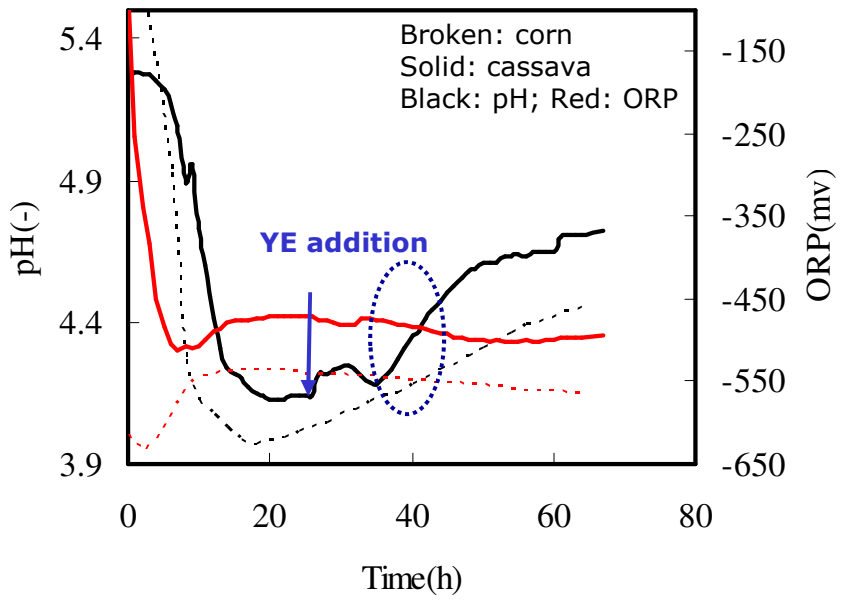
Broken lines: corn
Solid lines: cassava
Circle: butyrate
Triangle: Acetate



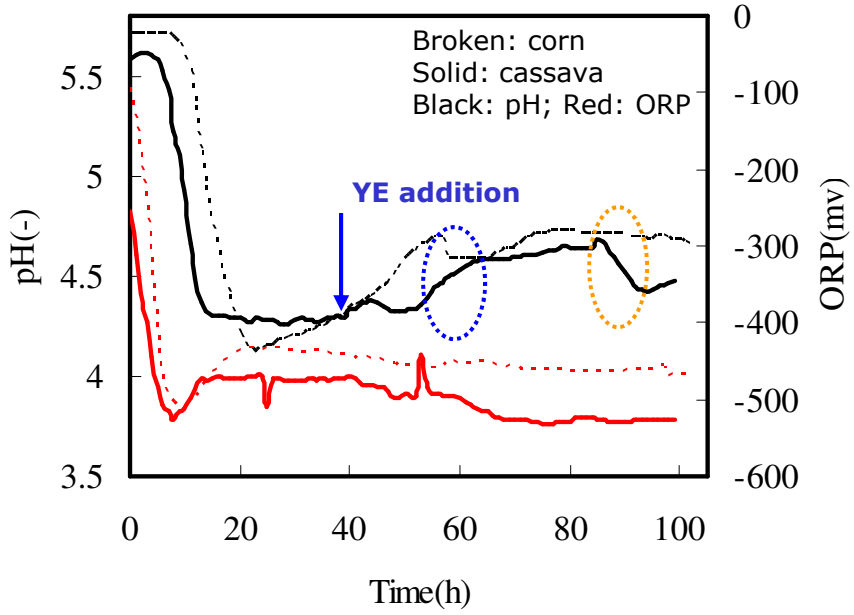
Bio-energy III, Lanzarote, Spain - Results

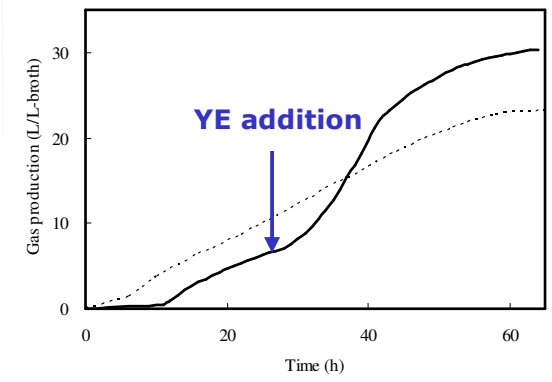
Yeast extract stimulates bio-butanol production from cassava

Traditional AB fermentation

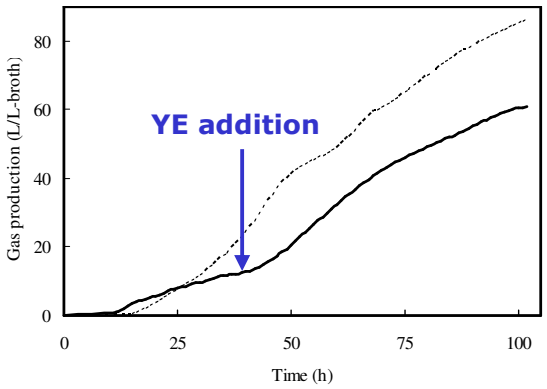


Extractive AB fermentation using oleyl alcohol





Broken lines: corn
Solid lines: cassava



Bio-energy III, Lanzarote, Spain - Results

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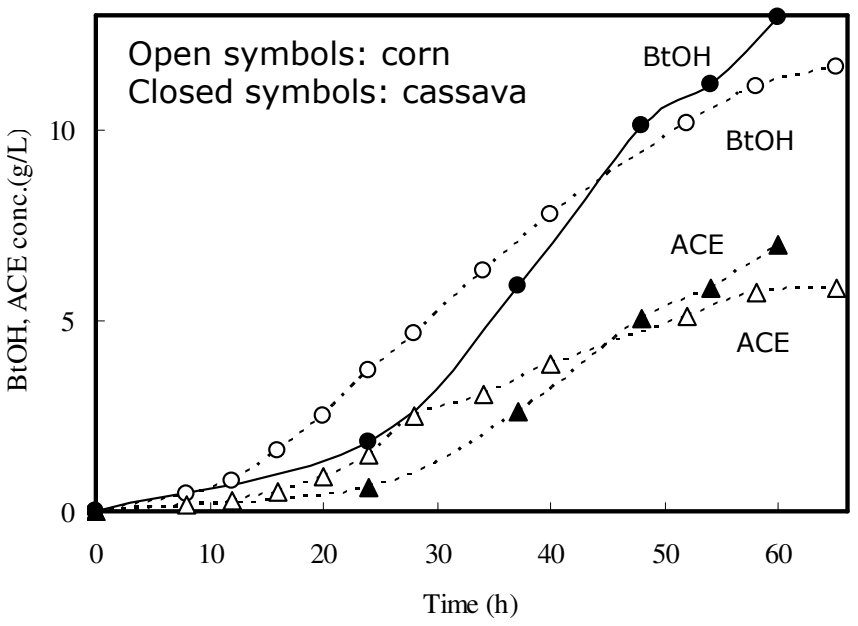
Traditional AB fermentation



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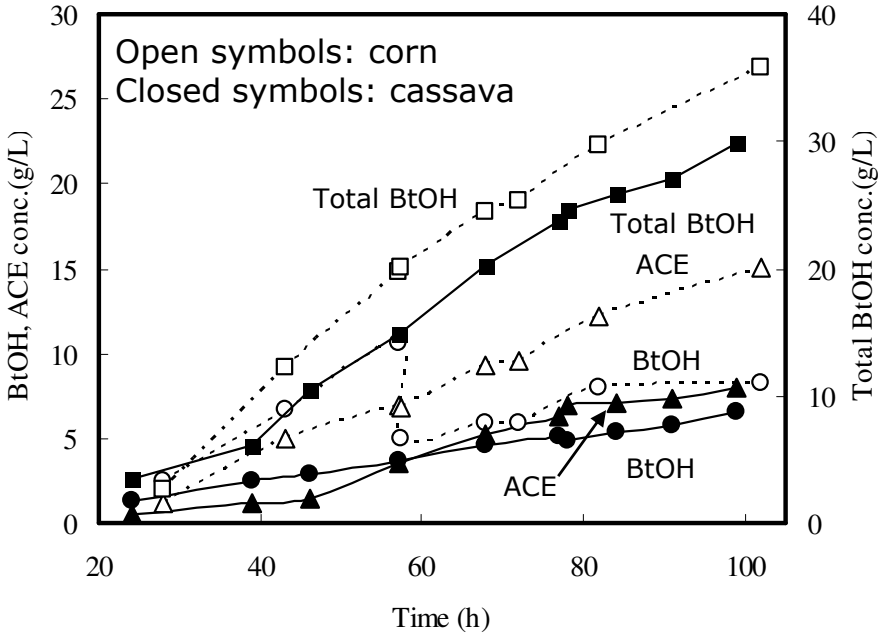
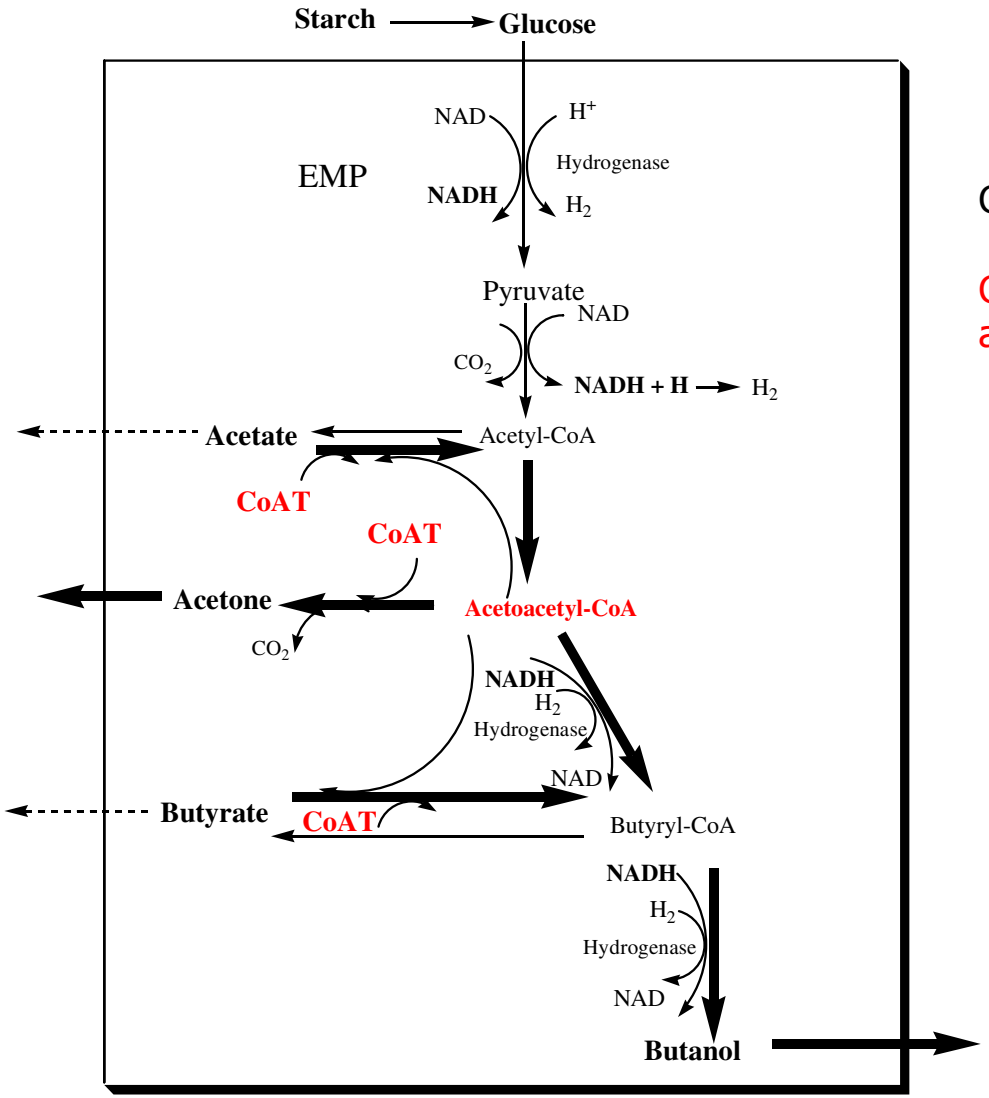


Bio-energy III, ECI, Lanzarote, Spain - Results

Yeast extract stimulates bio-butanol production from cassava



CoAT:CoA-transferase

CoAT be activated when adding yeast extract ??

Bio-energy III, Lanzarote, Spain - Conclusions

1) A novel, integrated fermentation process in production of both "properties improved" bio-diesel for direct use and pure butanol, was proposed.

2) Using a small amount n-octanol to recover BtOH in residual wastes before medium preparation, aimed butanol yield increased from 13% to 21%, easing purification load.

3) The fermentation residual waste could be 100% re-utilized for medium preparation by pre-treating with 3% activated carbon to remove melanoidin.

4) Fully recycling of fermentation residual waste for AB extractive fermentation could be continued for at least 15 runs without performance deterioration.

5) Yeast extract stimulates bio-butanol production from cassava.

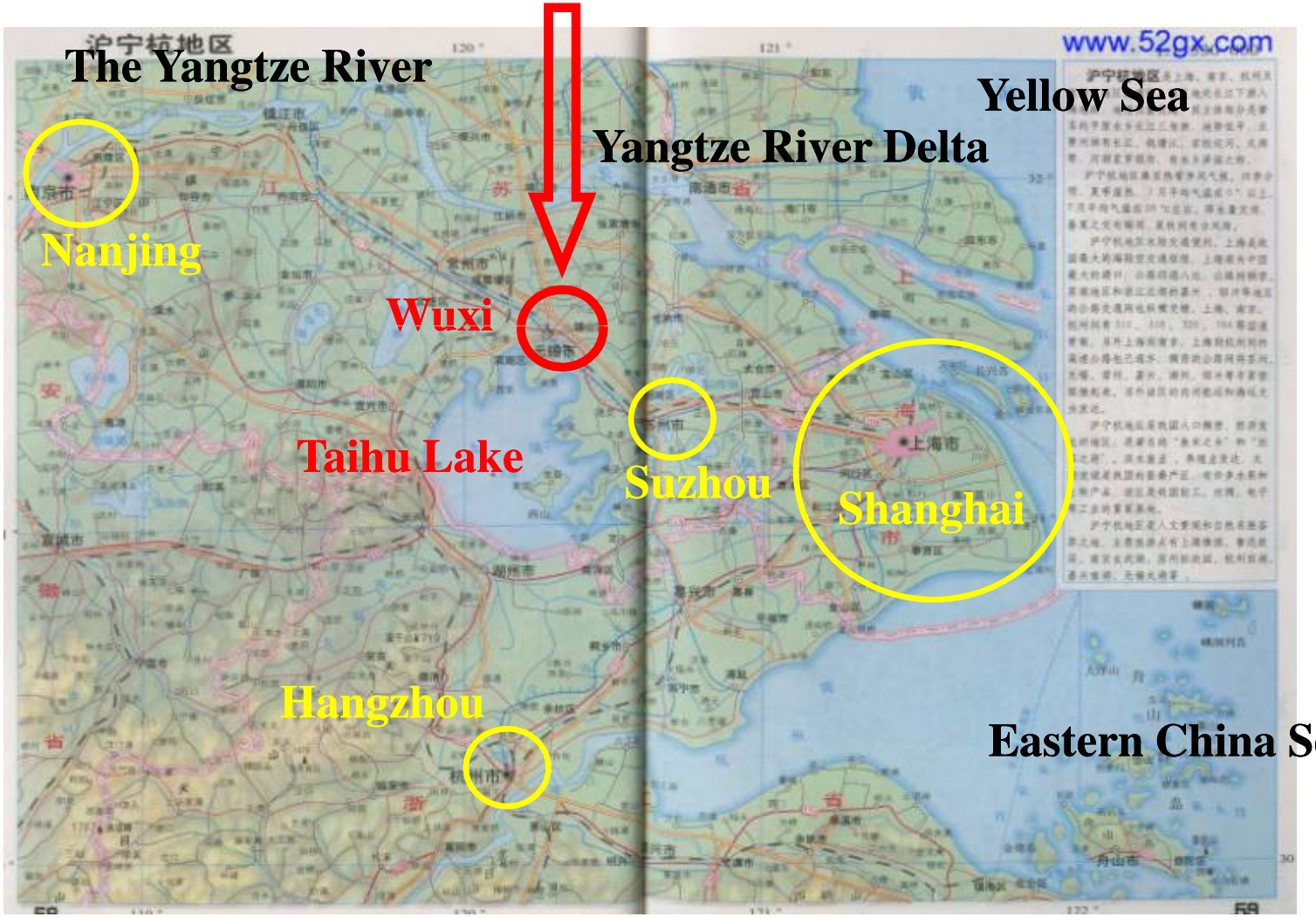
Bio-energy III, Lanzarote, Spain - Acknowledgement

- Thanks for sponsorships from Major State Basic Research Development Program (#2007CB714303) & National Natural Science Foundation Program (#20976072), of China.

- Thanks for the hard experimental works & contribution from following students: Mr. ZG Li, Mr. X Li, Ms. JP Zheng, Ms. L Li.

Bio-energy III, Lanzarote, Spain

Our location – welcome to visit us for communication/consultation



Thank you!