Potato peel as a feedstock for biobutanol production

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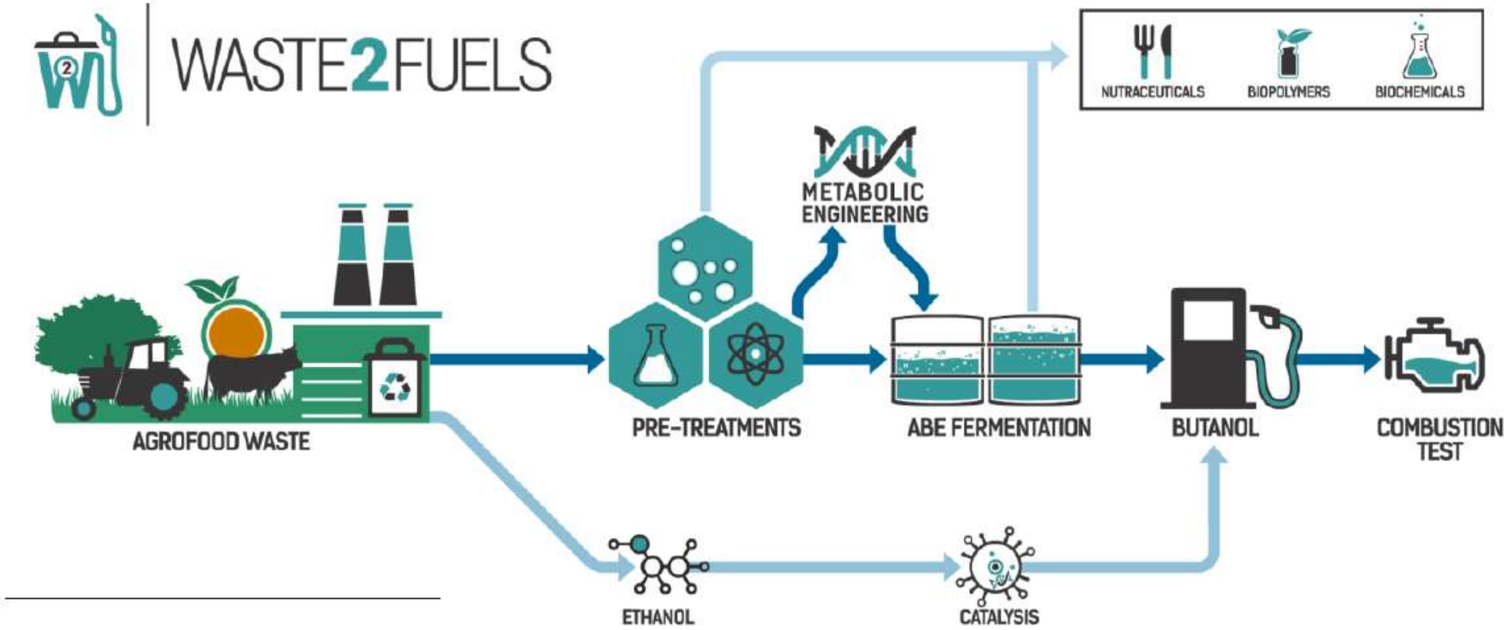
Introduction

Waste2Fuels project

Sustainable production of next generation biofuels from waste streams

- Twenty participants from Spain, Italy, Austria, Ireland, United Kingdom, Greece, Germany, France and Israel.
- From 1 January 2016 to 31 December 2018.



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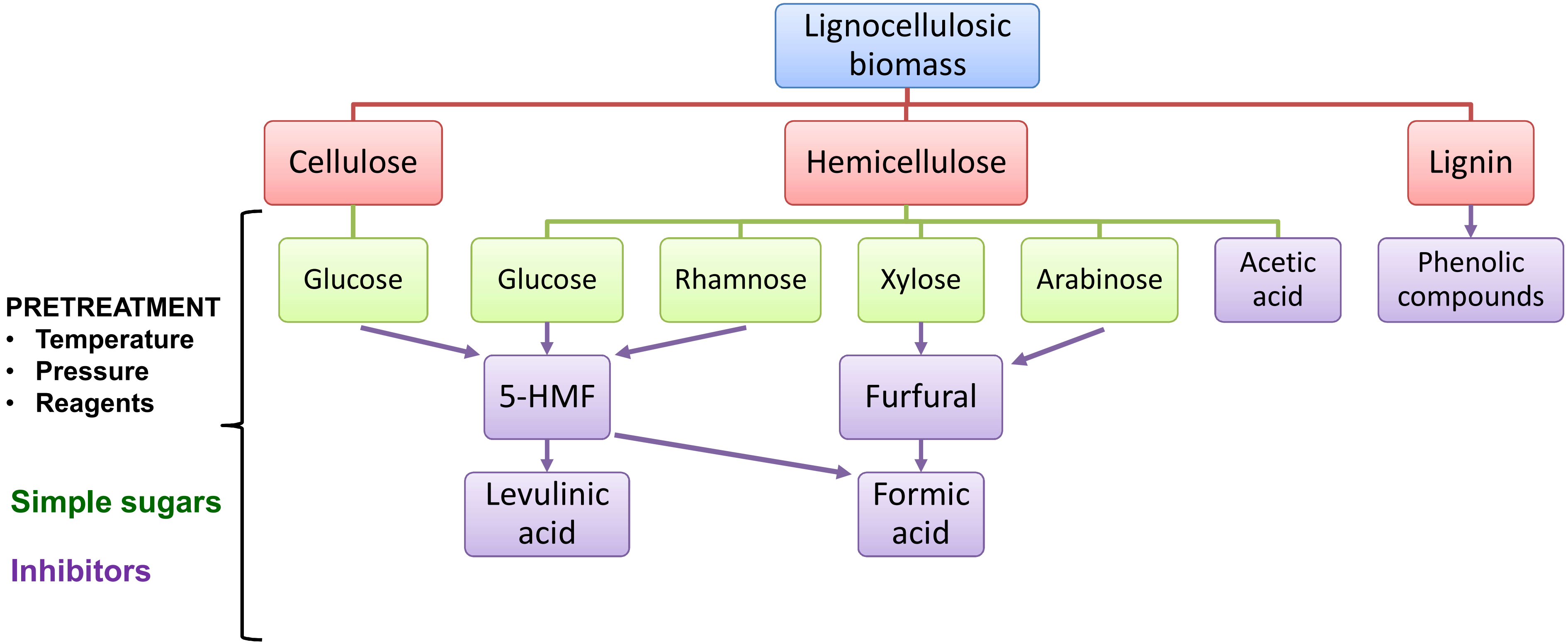
GA no. 654623

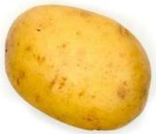
www.waste2fuels.eu

Lignocellulosic wastes

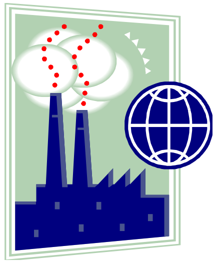


Palmqvist & Hahn-Hägerdal. Bioresource Technology 74 (2000) 25-35.

Potato peel generation



6·10^{7} t/year
in European Union
(FAOSTAT)



3·10^{6} t/year
in European Union
(Ćosić et al., 2016)

- **Animal feed**
- **Fibres**
- **Other applications?**

Objectives

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- Assess potato peels from a snack industry as a possible raw material for biobutanol production.
- Find out the most suitable pretreatment to hydrolyse potato peel.
- Maximise the amount of simple sugars released and minimise the generation of fermentation inhibitors during the pretreatments.
- Check the fermentability of the obtained hydrolysates with butanol-producing bacteria (*Clostridium*).

Methods

Potato peel composition and processing

Components	Amount
Total carbohydrates (%)	43.20
Soluble carbohydrates (%)	0.43
Cellulose (%)	8.3
Hemicellulose (%)	7.41
Starch (%)	23.01
Lignin (%)	32.88
Protein (%)	10.73
Fats (%)	2.45
Ash (%)	7.45
Moisture (%)	5.26
Total phenolic compounds (mg/g)	2.5

Drying at 40 °C

Grinding

Sieving (0.50-1.00 mm)

Pretreatment for potato peel

PHYSICOCHEMICAL PRETREATMENT

- **Autohydrolysis (water)**
- **Alkaline (NaOH, KOH, NH_4OH)**
- **Acid (H_2SO_4, HCl, HNO_3)**
- **Organic solvents (methanol, ethanol, acetone)**
- **Surfactants (CTAB, Tween 80, PEG 6000)**

Biomass ratio 10% (w/w)

Potato peel absorbs water and expands.

→ Pretreatment slurry (solid biomass + liquid hydrolysates)

↓

ENZYMATIC HYDROLYSIS

Citrate buffer 50 mM, pH 5.0, 50°C, 180 rpm, 72 h

Enzymes and doses	
Cellic CTec2	15 mg protein/g glucan
Spirizyme Fuel	16.7 µl/g glucan

↓

Filtration

←

CHEMICAL ANALYSIS

- **Fermentable sugars:** glucose, xylose and arabinose. 👍
- **Inhibitors:** organic acids (acetic, formic and levulinic acids), furans (HMF and furfural) and phenolic compounds. ☹

Fermentation of potato peel hydrolysates

Potato peel hydrolysates from different pretreatments (autoclaved)

Supplemented with:

5 g/L yeast extract | 0.01 g/L $FeSO_4 \cdot 7H_2O$
2.1 g/L NH_4Cl | 0.2 g/L $MgSO_4 \cdot 7H_2O$
0.5 g/L K_2HPO_4 | 0.5 g/L cysteine
0.5 g/L KH_2PO_4 | 5 g/L $CaCO_3$

Inoculum, 3% v/v
($\sim 5 \cdot 10^8$ cells/mL)

pH 6.0

Gaseous N_2 bubbled, 5 min

Strains	*C. beijerinckii* CECT 508
	C. acetobutylicum DSM 1732, DSM 1733 and DSM 1738
	C. saccharobutylicum DSM 13864
	C. saccharoperbutylacetonicum DSM 2152

Incubation
35ºC
100 rpm
72-144 h

Results

Selection of the best reagents for each pretreatment

All the reagents were applied at fixed conditions (121 °C, 2 h) to pretreat potato peel in an autoclave:

Treatment type	Reagent	Total sugars (g/l)	Total inhibitors (g/l)	Selected reagent
Autohydrolysis	-	-	-	-
Acid (2% w/w)	H_2SO_4	30.7 ± 2.15 [a]	2.73 ± 0.23 [ab]	HNO_3
	HCl	29.6 ± 0.95 [a]	3.20 ± 0.26 [b]	
	HNO_3	41.2 ± 1.11 [b]	2.45 ± 0.21 [a]	
Alkali (2% w/w)	NaOH	30.1 ± 5.44 [a]	6.16 ± 1.85 [a]	NH_4OH
	KOH	35.0 ± 1.34 [ab]	4.65 ± 0.05 [ab]	
	NH_4OH	43.2 ± 0.49 [b]	2.11 ± 0.03 [b]	
Organic solvent (40%)	Ethanol	34.6 ± 0.70 [a]	0.74 ± 0.03 [a]	Acetone
	Methanol	37.0 ± 0.60 [b]	0.88 ± 0.02 [b]	
	Acetone	35.5 ± 0.10 [a]	0.96 ± 0.03 [c]	
Surfactant (3% w/w)	Tween 80	43.7 ± 2.13 [a]	4.65 ± 0.18 [a]	PEG 6000
	PEG 6000	38.6 ± 0.98 [b]	0.87 ± 0.06 [b]	
	CTAB	38.3 ± 2.43 [b]	1.00 ± 0.03 [b]	

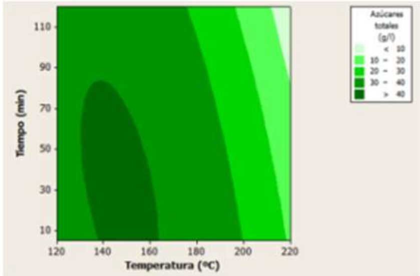
The most efficient reagent of each group was selected to perform a Response Surface Methodology (RSM) experiment, whose aim was:

- To maximise sugar release
- To minimise inhibitor generation.

Optimisation of pretreatment conditions

High pressure reactor
40 g potato peel
360 g aqueous solution

Parameter optimisation (RSM):

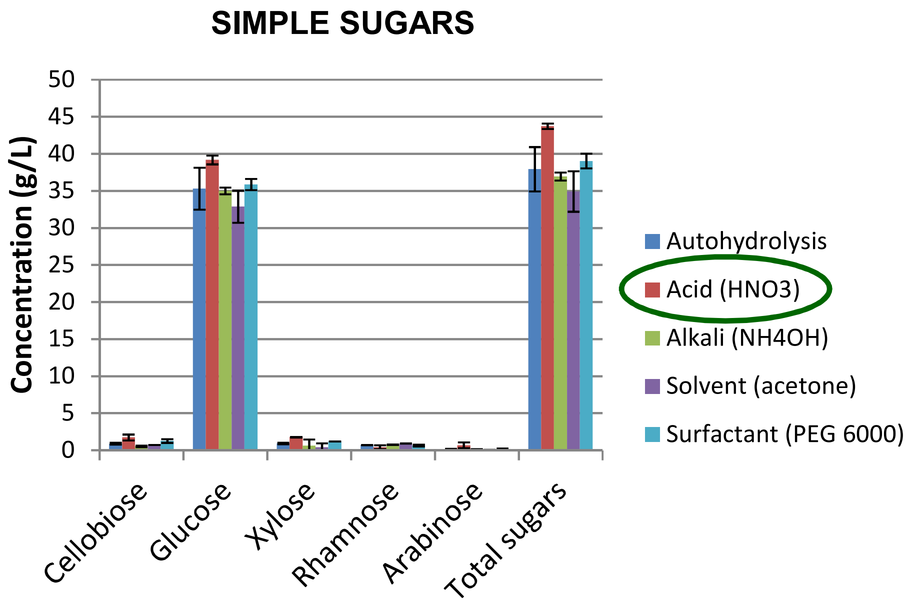


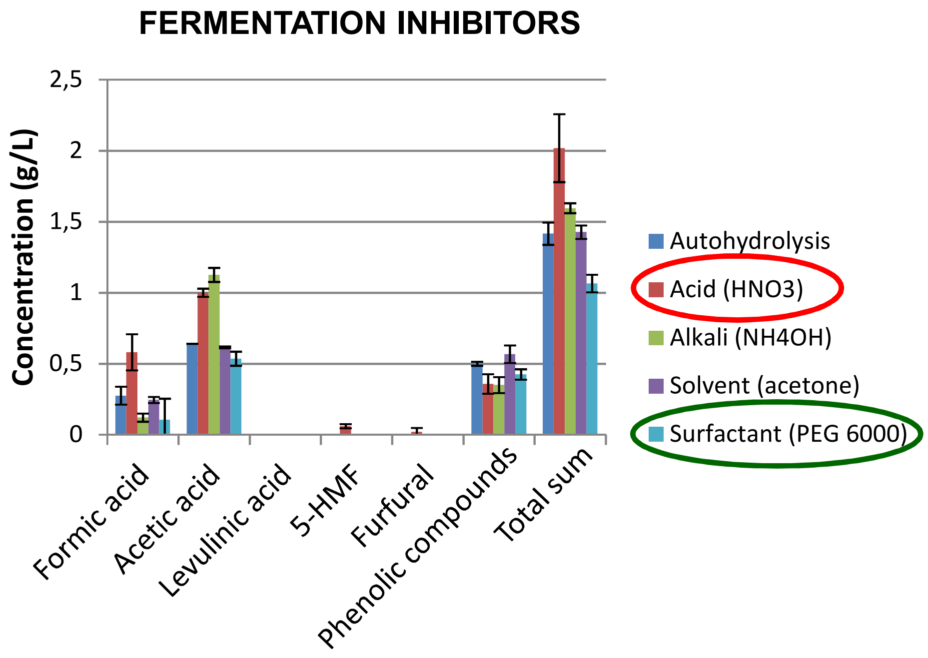
- Temperature
- Time
- Reagent concentration

	Physicochemical treatment optimal conditions (RSM)			Experimental responses (physicochemical + enzymatic)	
	T (°C)	t (min)	Reagent (%, w/w)	Total sugars (g/l)	Total inhibitors (g/l)
Autohydrolysis	140	56	-	37.9 ± 2.99	1.41 ± 0.08
Acid (HNO_3)	110	83	1.81	43.7 ± 0.37	2.02 ± 0.24
Alkali (NH_4OH)	112	29	0.50	36.9 ± 0.55	1.59 ± 0.03
Solvent (acetone)	128	85	10.0	34.9 ± 2.74	1.43 ± 0.05
Surfactant (PEG 6000)	146	5	1.92	39.0 ± 1.00	1.06 ± 0.06

Optimisation of pretreatment conditions

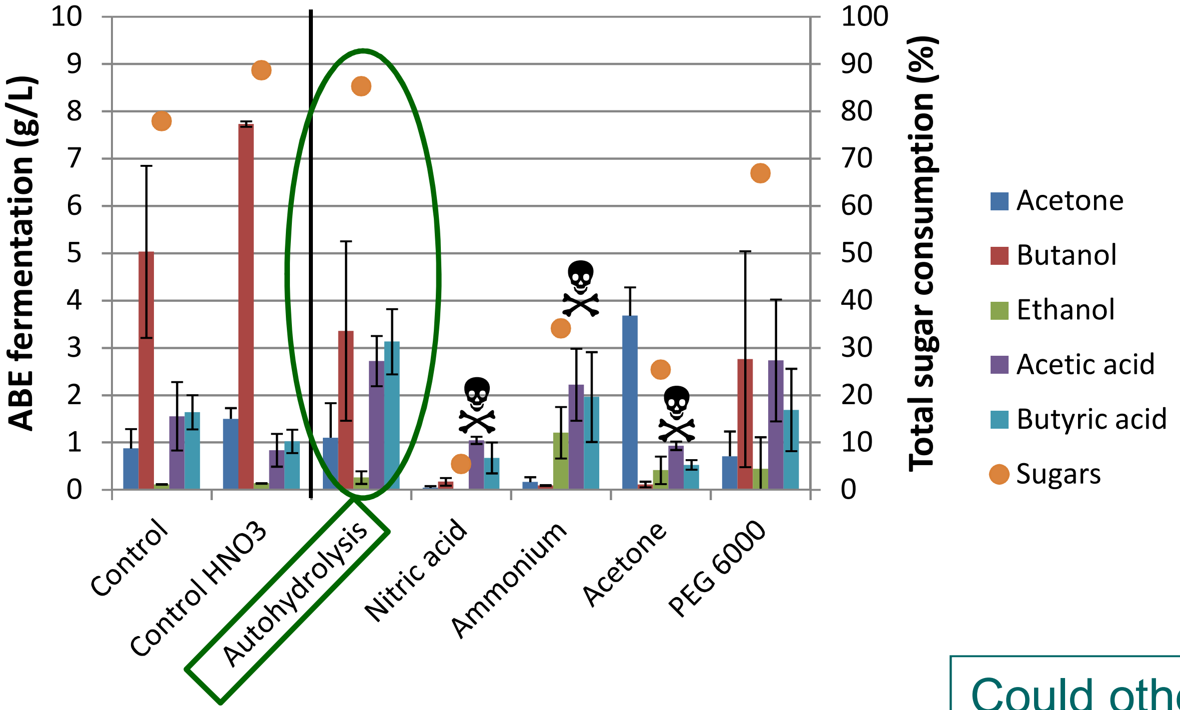
Sugars and inhibitors produced under optimal RSM conditions:





Fermentation – Effect of the pretreatment

Strain: *Clostridium beijerinckii* CECT 508 (= NCIMB 8052)



1.1 g/L acetone
3.4 g/L butanol
0.3 g/L ethanol
2.7 g/L acetic
3.1 g/L butyric

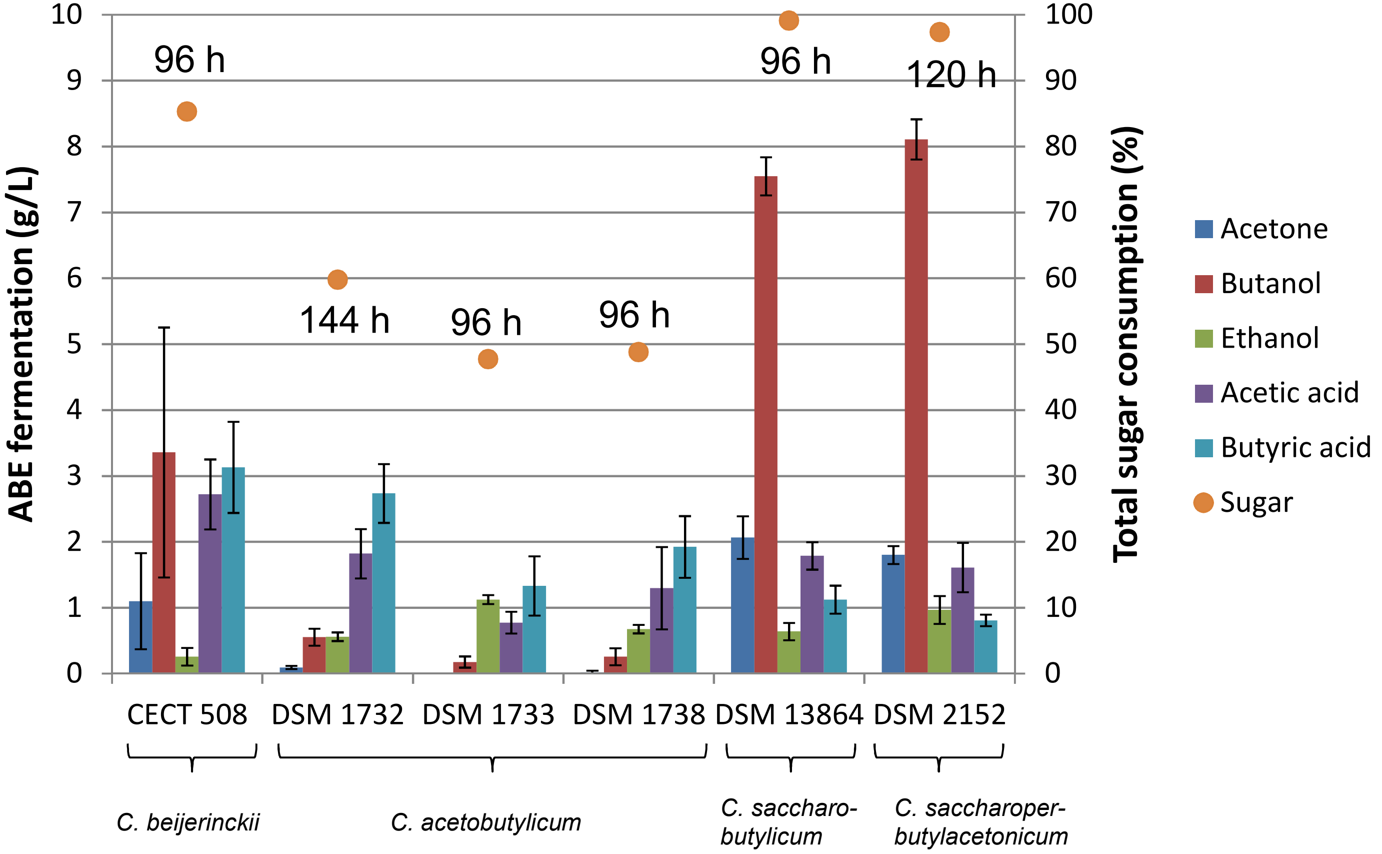
85% total sugar consumption

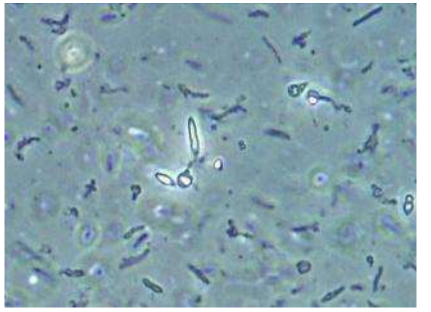
96 h fermentation

Could other strains perform better?

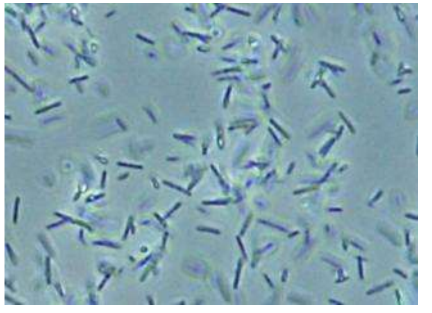
Fermentation – Effect of the strain

Pretreatment: Autohydrolysis





C. saccharobutylicum DSM 13864



C. saccharoperbutylacetonicum DSM 2152

Conclusions

Conclusions

- Potato peel from a snack factory proved to be a suitable feedstock for biobutanol production.
- Potato peel can be pretreated by autohydrolysis (10% biomass-to-solvent ratio) and a subsequent enzymatic hydrolysis.
- Only two out of six strains were able to obtain promising butanol concentrations: *C. saccharobutylicum* DSM 13864 and *C. saccharoperbutyl-acetonicum* DSM 2152.
- The hydrolysate was directly fermentable without the need of a detoxification step, thanks to a statistical optimisation process to maximise sugar release and minimise inhibitor generation during the pretreatment.
- Further research is needed before the use of agro-food wastes as feedstocks for biobutanol production is economically feasible at industrial scale.

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