National Technical University of Athens
School of Chemical Engineering
Unit of Environmental Science & Technology

Effect of alkaline pretreatments on the enzymatic hydrolysis of wheat straw

N. Kontogianni, E. M. Barampouti, S. Mai, D. Malamis, M. Loizidou*

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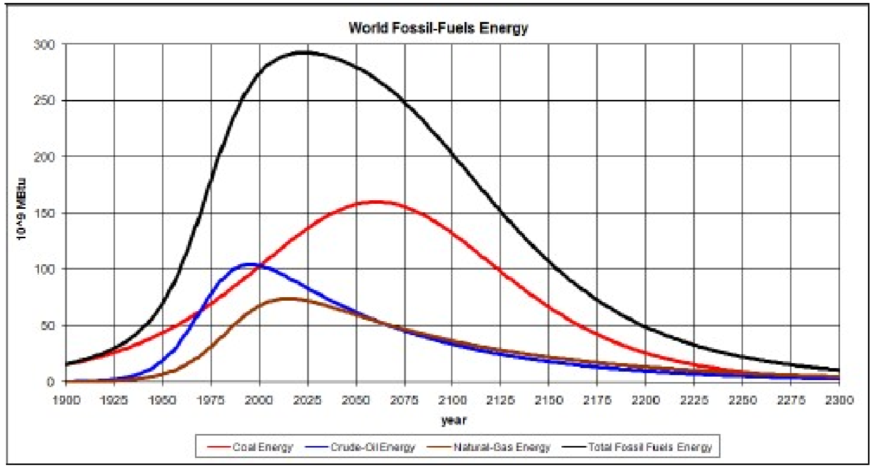
World Energy

Depletion of fossil fuel

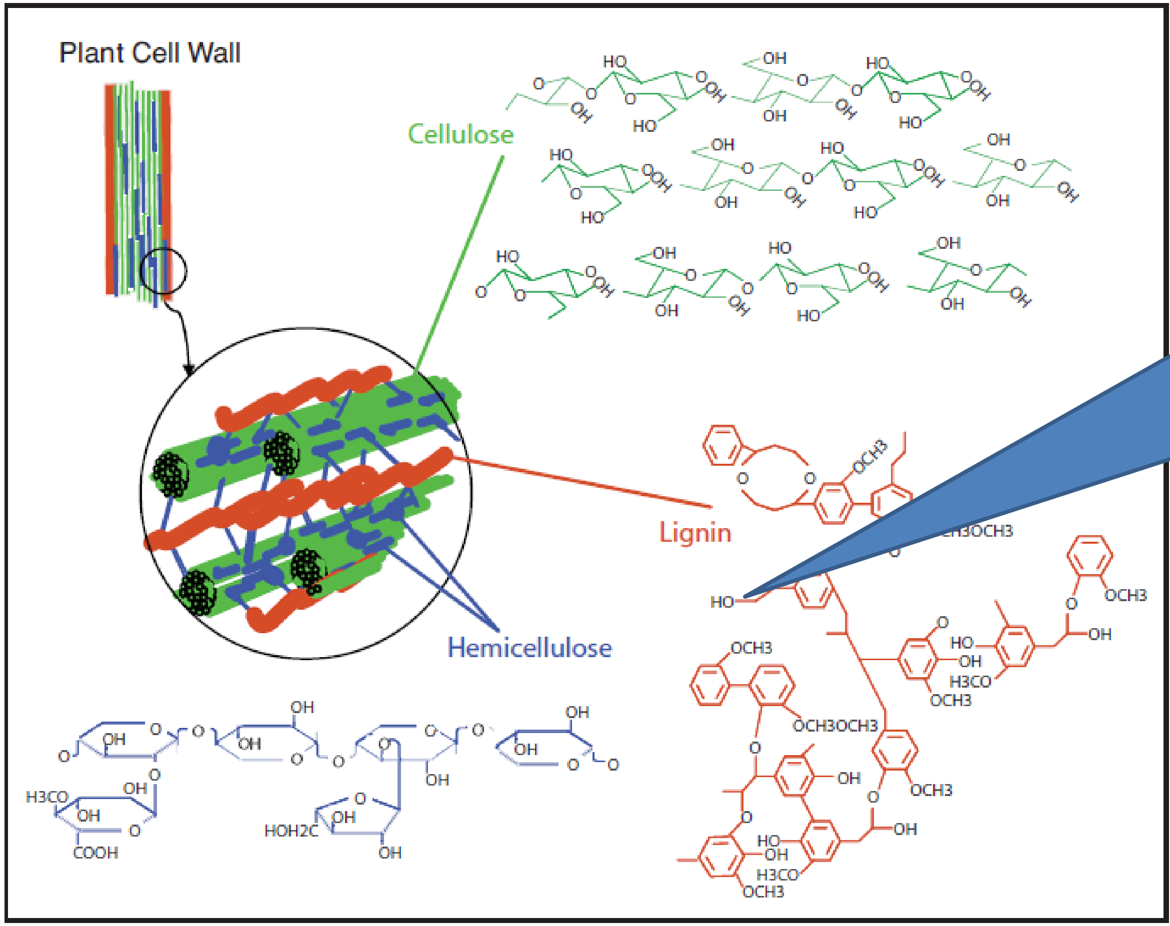


http://www.roperld.com/science/energyfuture.htm

Biofuels

- **1st generation**: grain or food sources
- **2nd generation**: lignocellulosic sources and algae biomass

Agricultural waste -Lignocellulosic material

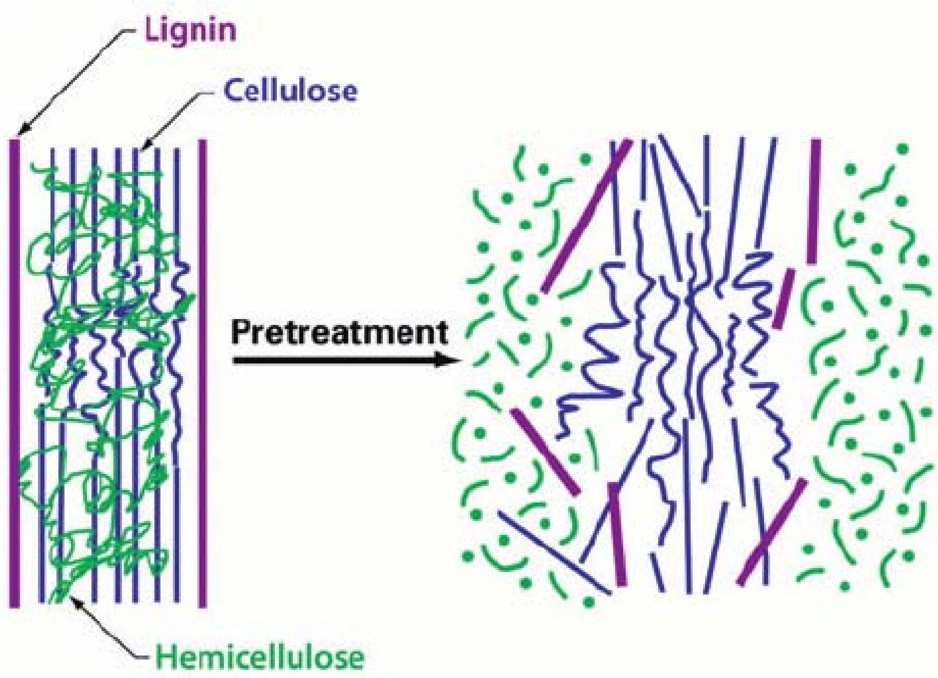


https://www.e-education.psu.edu/egee439/node/606

The major barrier to the enzymatic hydrolysis of carbohydrates towards the production of fermentable sugars

corn stover on a field credit: USDOE-NRE
https://www.greenoptimistic.com

Lignocellulosic material- Pretreatments



Removal of lignin is favorable to reducing the recalcitrance of lignocellulose for enzymatic attack.

Aim

Comparison of the effects of ten alkaline pretreatment methods vis-à-vis improving enzymatic hydrolysis of wheat straw

Materials and Methods

Raw material - Wheat straw

Origin: from Aspropyrgos province. Greece

Preparation:

1. Milled (FRITSCH Cutting mill Pulverisette 15) to 1 mm

Parameter		Value (% w/w)
Cellulose		33.8
Hemicellulose		45.1
Lignin		16.4
	Klason lignin	15.4
	Acid-soluble lignin	1.0
Ash		4.7

Pretreatment techniques of wheat straw

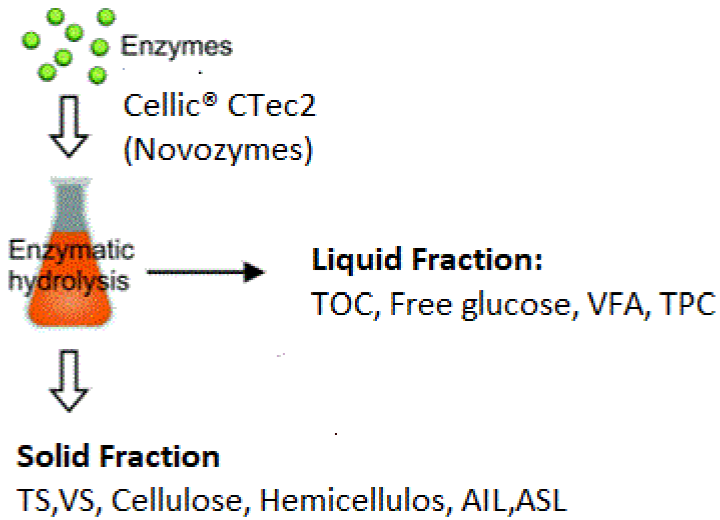
(i) alkaline peroxide 5%
(ii) alkaline peroxide 10%
(iii) dilute NaOH 0.5M
(iv) dilute NaOH 0.5M autoclaving
(v) methylamine 25 %w/w
(vi) methylamine 25 %w/w autoclaving
(vii) Na_2CO_3 0.5M
(viii) Na_2CO_3 0.5M autoclaving
(ix) ammonia 25 %w/w
(x) ammonia 25 %w/w autoclaving

Pretreatment techniques of wheat straw

A/A	Reagent	T	Solid :Liquid (w/w)	Time
i	H_2O_2 (5%) NaOH (pH=11,5)	50°C	1:20	1h
ii	H_2O_2 (10%) NaOH (pH=11,5)	50°C	1:20	1h
iii	NaOH 0.5M	50°C	1:10	96 h
iv	NaOH 0.5M	121°C	1:10	1h
v	CH_5N 25 %w/w	50°C	1:10	96 h
vi	CH_5N 25 %w/w	121°C	1:10	1h
vii	Na_2CO_3 0.5M	50°C	1:10	96 h
viii	Na_2CO_3 0.5M	121°C	1:10	1h
ix	NH_3 25 %w/w	50°C	1:10	96 h
x	NH_3 25 %w/w	121°C	1:10	1h

Enzymatic hydrolysis

- Raw material and pretreated solids
- 10% w/w dry solid
- 15μL g^{-1} dry solid (CellicCTec2)
- 50°C and 300 rpm for 96 h



Results and Discussion

Degradation of solid fractions after pretreatments

	%TS hydrolysis			%cellulose degradation			%AIL degradation			%ASL degradation			%hemicellulose degradation		
i	**11.68**	±	0.02	**11.06**	±	0.96	**31.63**	±	0.06	**0.76**	±	2.87	**5.22**	±	0.49
ii	**28.05**	±	0.20	**1.88**	±	1.37	**89.6**	±	0.68	**43.99**	±	0.9	**17.69**	±	2.21
iii	**30.07**	±	0.36	**4.45**	±	1.11	**75.06**	±	5.03	**36.48**	±	4.66	**30.66**	±	8.26
iv	**36.47**	±	2.78	**33.52**	±	3.44	**84.86**	±	0.45	**49.86**	±	5.72	**9.29**	±	7.89
v	**29.84**	±	0.03	**22.3**	±	5.63	**76.38**	±	1.06	**99.22**	±	0.09	**8.66**	±	9.46
vi	**26.09**	±	4.73	**24.8**	±	2.33	**70.78**	±	4.23	**99.03**	±	0.19	**3.84**	±	2.61
vii	**11.59**	±	0.37	**4.87**	±	1.76	**38.51**	±	6.92	**16.99**	±	2.16	**1.31**	±	1.72
viii	**11.05**	±	8.65	**3.71**	±	1.10	**59.81**	±	4.15	**38.93**	±	6.63	**0.50**	±	3.75
ix	**26.75**	±	1.49	**44.41**	±	7.35	**57.31**	±	2.53	**99.21**	±	0.01	**0.90**	±	1.10
x	**25.00**	±	2.16	**17.11**	±	1.17	**44.83**	±	7.55	**99.24**	±	0.04	**24.41**	±	2.71

(i) alkaline peroxide 5%, (ii) alkaline peroxide 10%, (iii) NaOH 0.5M, (iv) NaOH 0.5M autoclaving, (v) methylamine 25 %w/w, (vi) methylamine 25 %w/w autoclaving, (vii) Na_2CO_3 0.5M, (viii) Na_2CO_3 0.5M autoclaving, (ix) ammonia 25 %w/w, (x) ammonia 25 %w/w autoclaving.

Components of liquid fractions after pretreatments

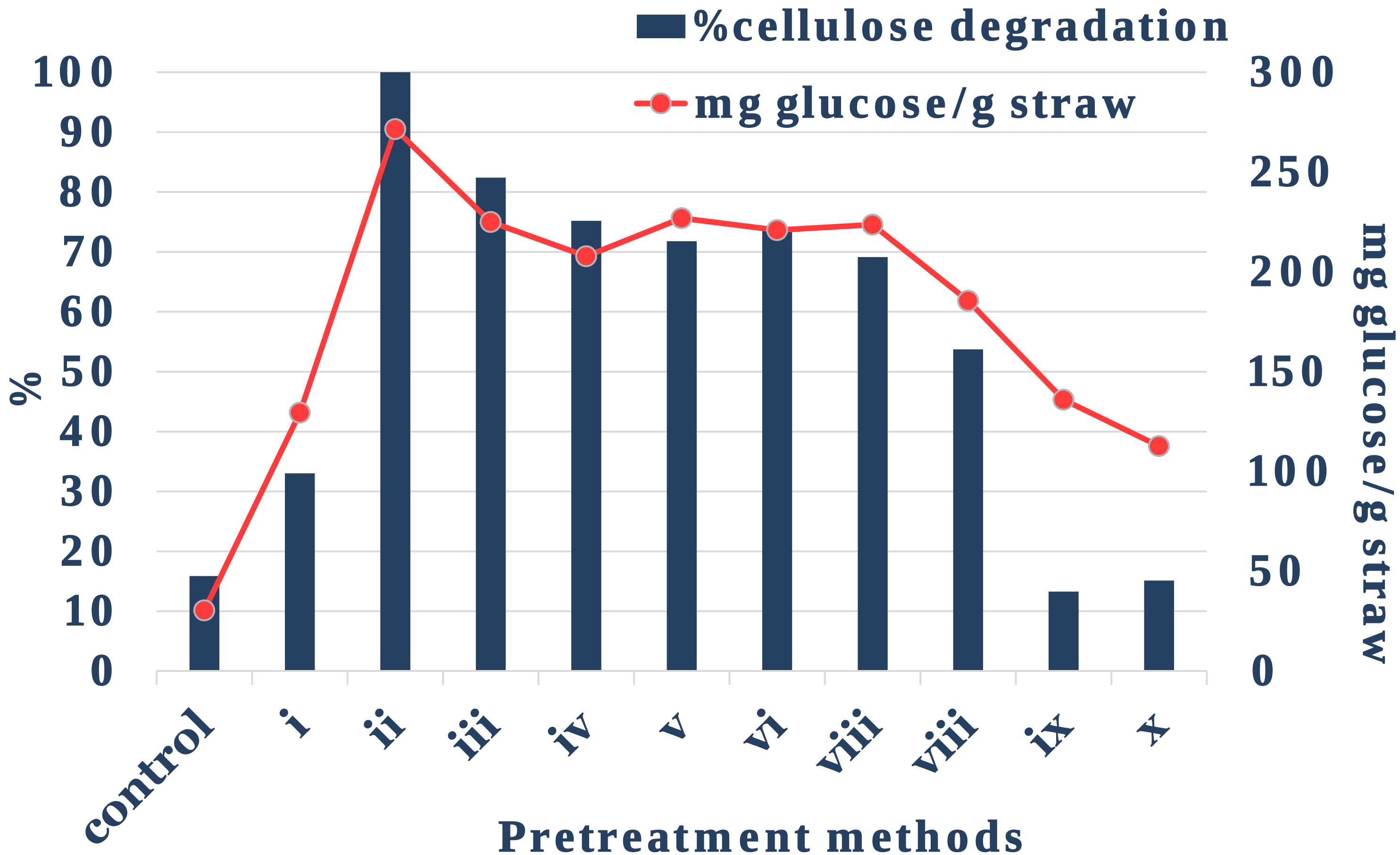
	Glucose (mg /g straw)			VFA (mg /g straw)			TPC (mg /g straw)		
i	0.88	±	0.04	18.10	±	0.28	0.27	±	0.01
ii	0.15	±	0.03	34.50	±	0.57	0.68	±	0.02
iii	0.02	±	0.03	33.55	±	1.63	2.13	±	0.04
iv	0.62	±	0.06	98.30	±	14.99	5.60	±	0.14
v	1.50	±	0.14	64.10	±	39.46	5.56	±	0.37
vi	2.10	±	1.27	28.10	±	4.95	4.60	±	0.76
vii	n.d.	±	0.00	28.20	±	3.39	1.07	±	0.07
viii	0.70	±	0.94	80.85	±	4.45	2.91	±	0.16
ix	0.90	±	0.14	38.30	±	9.76	3.63	±	0.44
x	1.20	±	0.00	35.50	±	1.27	3.61	±	0.38

(i) alkaline peroxide 5%, (ii) alkaline peroxide 10%, (iii) NaOH 0.5M, (iv) NaOH 0.5M autoclaving, (v) methylamine 25 %w/w, (vi) methylamine 25 %w/w autoclaving, (vii) Na_2CO_3 0.5M, (viii) Na_2CO_3 0.5M autoclaving, (ix) ammonia 25 %w/w, (x) ammonia 25 %w/w autoclaving.

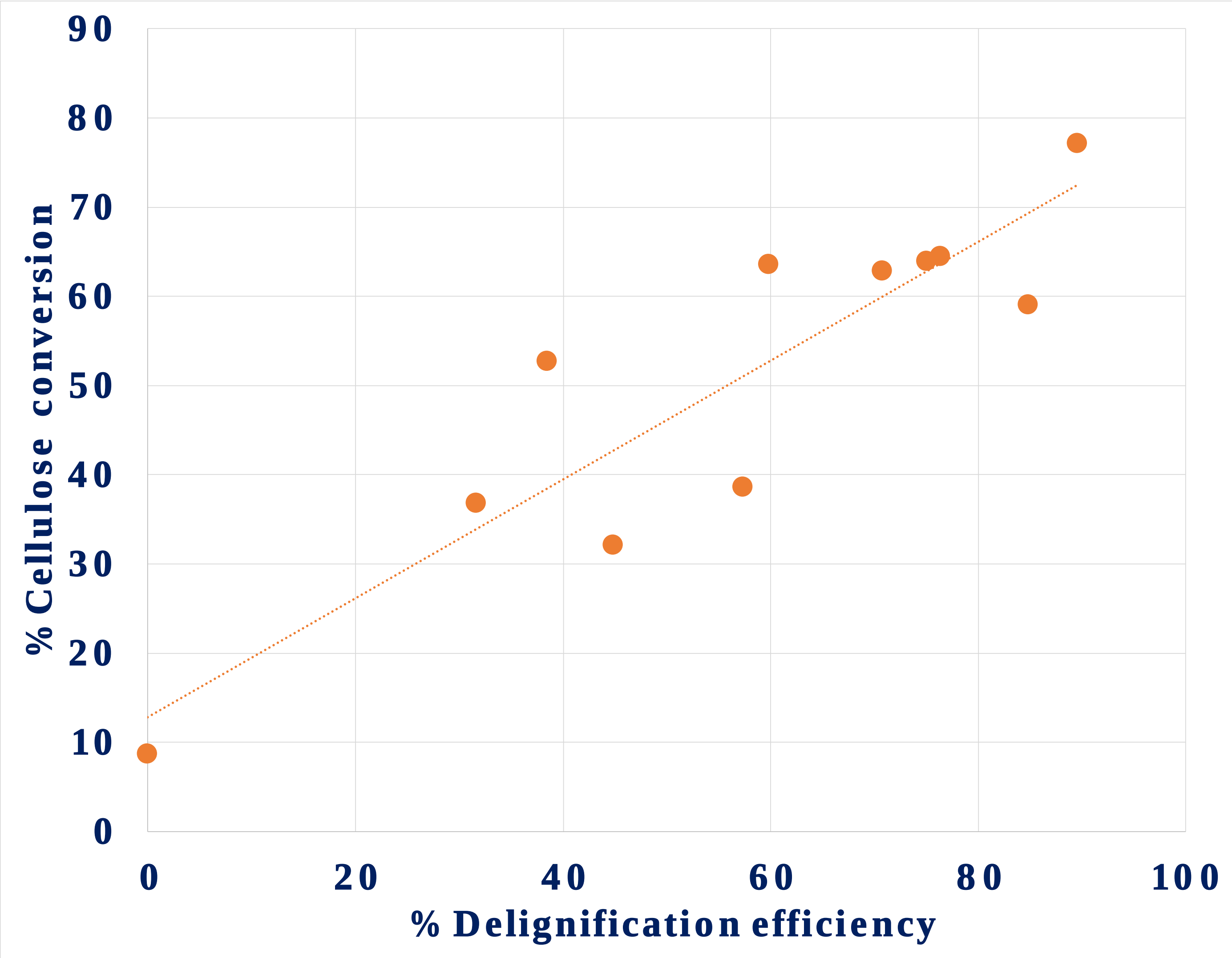
Effect of pretreatments on saccharification

	%TS hydrolysis	%cellulose degradation	%AIL degradation	%ASL degradation	%hemicellulose degradation
-	23.61 ± 0.62	15.89 ± 1.21	13.42 ± 0.15	33.61 ± 2.16	37.43 ± 8.12
i	31.18 ± 0.12	33.03 ± 1.08	20.18 ± 0.08	53.74 ± 1.87	46.56 ± 0.99
ii	95.82 ± 0.25	100.0 ± 2.02	100.0 ± 0.78	100.0 ± 0.87	100.00 ± 3.11
iii	77.39 ± 0.39	82.40 ± 8.92	18.40 ± 4.13	78.72 ± 5.68	82.43 ± 6.15
iv	80.72 ± 3.18	75.20 ± 7.58	9.94 ± 0.63	80.67 ± 8.65	91.81 ± 10.12
v	74.08 ± 1.13	71.79 ± 6.98	3.12 ± 0.95	74.08 ± 2.17	85.68 ± 9.26
vi	69.58 ± 2.53	74.03 ± 9.21	13.93 ± 1.11	65.38 ± 3.84	77.59 ± 7.68
vii	10.36 ± 2.42	53.73 ± 5.36	10.25 ± 1.18	44.49 ± 2.02	37.29 ± 7.98
viii	65.61 ± 6.85	69.13 ± 9.13	1.15 ± 2.21	62.62 ± 6.21	63.88 ± 5.68
ix	40.50 ± 1.87	13.29 ± 5.45	2.16 ± 1.23	45.47 ± 1.65	66.23 ± 6.21
x	36.17 ± 1.68	15.12 ± 1.27	5.73 ± 1.35	46.17 ± 1.74	61.16 ± 2.68

After enzymatic hydrolysis



(i) alkaline peroxide 5%, (ii) alkaline peroxide 10%, (iii) NaOH 0.5M, (iv) NaOH 0.5M autoclaving, (v) methylamine 25 %w/w, (vi) methylamine 25 %w/w autoclaving, (vii) Na_2CO_3 0.5M, (viii) Na_2CO_3 0.5M autoclaving, (ix) ammonia 25 %w/w, (x) ammonia 25 %w/w autoclaving.


90
80
70
60
50
40
30
20
10
0
% Cellulose conversion
0
20
40
60
80
100
% Delignification efficiency

Conclusions

Conclusions

1. Alkaline pretreatments tested proved to promote delignification reactions.
2. ⇧ the delignification efficiency at the pretreatment → ⇧ the glucose recovery at the enzymatic hydrolysis
3. Alkaline treatment with:

   hydrogen peroxide 10% w/w → 73% glucose yield

   NaOH 0.5M → 60%

↓

These pretreatments are efficient for enhancing the enzymatic digestibility of lignocellulosic crop residues to levels approaching the theoretical maximum.

Acknowledgements

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THANK YOU
FOR YOUR
ATTENTION