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Assessing straw digestate from anaerobic digestion as feedstock for sugars production

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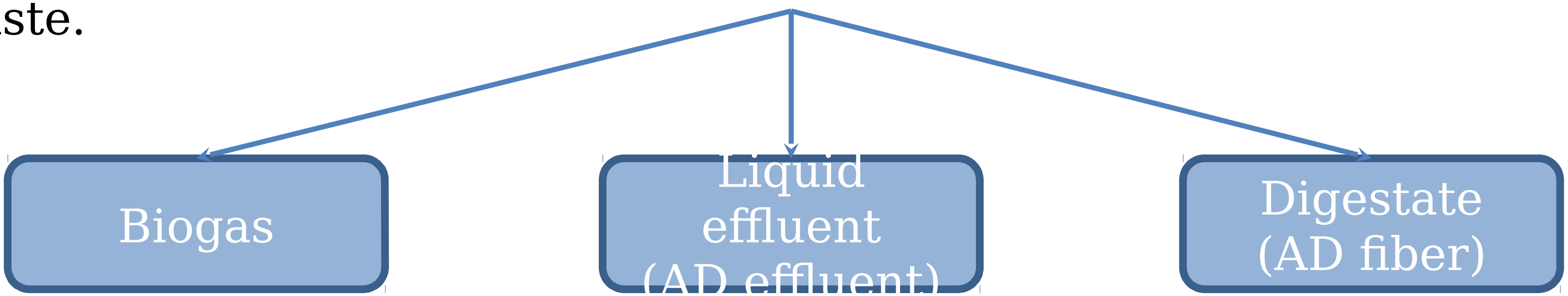
7th International Conference on Sustainable Solid Waste Management, 26-29 June 2019, Heraklion, Crete Island, Greece

Anaerobic Digestion (AD)

Biological conversion process for organic residues into renewable energy, while alleviating environmental concerns associated with the waste.



- Soil amendment
- Animal bedding

Aim

To assess the potential of straw digestate as sugar source

Materials and Methods

Materials and Methods (I)

Raw material: Wheat straw from Aspropyrgos province, Greece

AD fiber sample: Solid digestate after S/L separation from a pilot scale CSTR anaerobic digester (37^{o}C, HRT= 20 days) that treats wheat straw in NTUA.

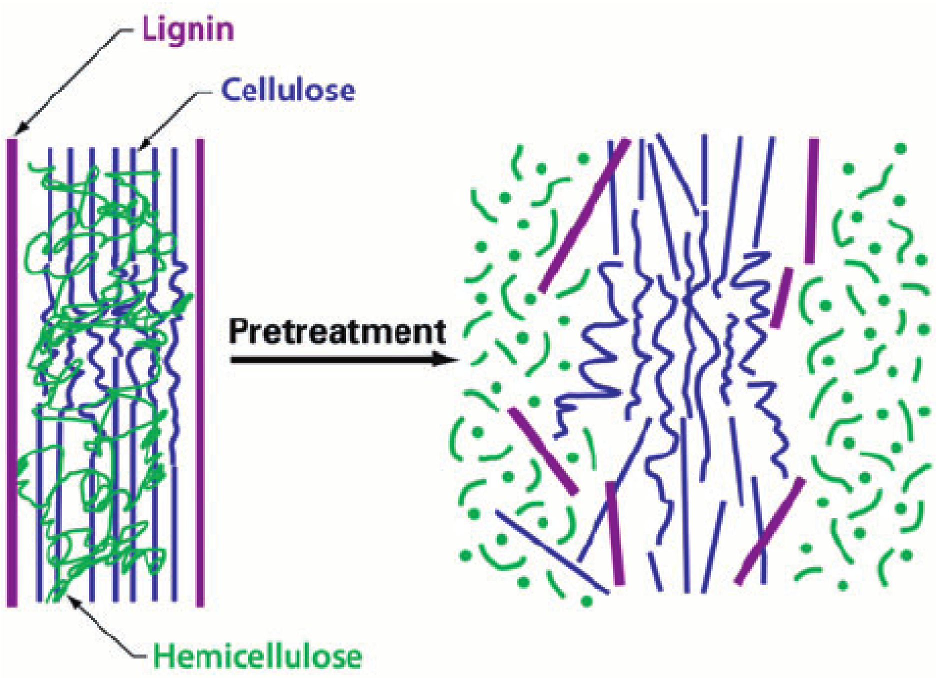
Parameter		Value (% w/w)
Cellulose		24.78
Hemicellulose		11.99
Lignin		18.58
	Klason lignin	17.30
	Acid-soluble lignin	1.28
Ash		27.31

Materials and Methods (II)

Chemical pretreatment: The CSTR AD fiber was pretreated in autoclave with/ without dilute NaOH or H_2SO_4 at 120°C.

Enzymatic hyd

- Untreated an
- 10% w/w dry
- Cellulolytic f
- 50°C and 30(



c2
s)

Liquid Fraction:
TOC, Free glucose, VFA, TPC

emicellulos, AIL,ASL

Materials and Methods (III)

Factorial experimental procedure: 2^3 factorial experiment

Optimization parameter: Saccharification efficiency SG

$$SG\% = \frac{\text{Glucose produced}}{\text{Theoretical glucose produced from the total conversion of carbohydrates}} \cdot 100\%$$

Controlling parameters

- Chemicals’ concentration
- Autoclave retention time
- Enzyme loading during enzymatic hydrolysis

Factorial experiments

Alkaline pretreatment prior to enzymatic hydrolysis

Controlling Parameter	Variation Intervals		
	Low level	High Level	Center
Time autoclave, t_{auto} (h)	1	1.5	1.25
NaOH (%)	2	4	3
CellicCTec2, C_{enz} (μL/ g cellulose)	100	400	250

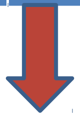
Acidic pretreatment prior to enzymatic hydrolysis

Controlling Parameter	Variation Intervals		
	Low level	High Level	Center
Time autoclave, t_{auto} (h)	1	1.5	1.25
H_2SO_4 (%)	1	3	2
CellicCTec2, C_{enz} (μL/ g cellulose)	100	400	250

Results and Discussion

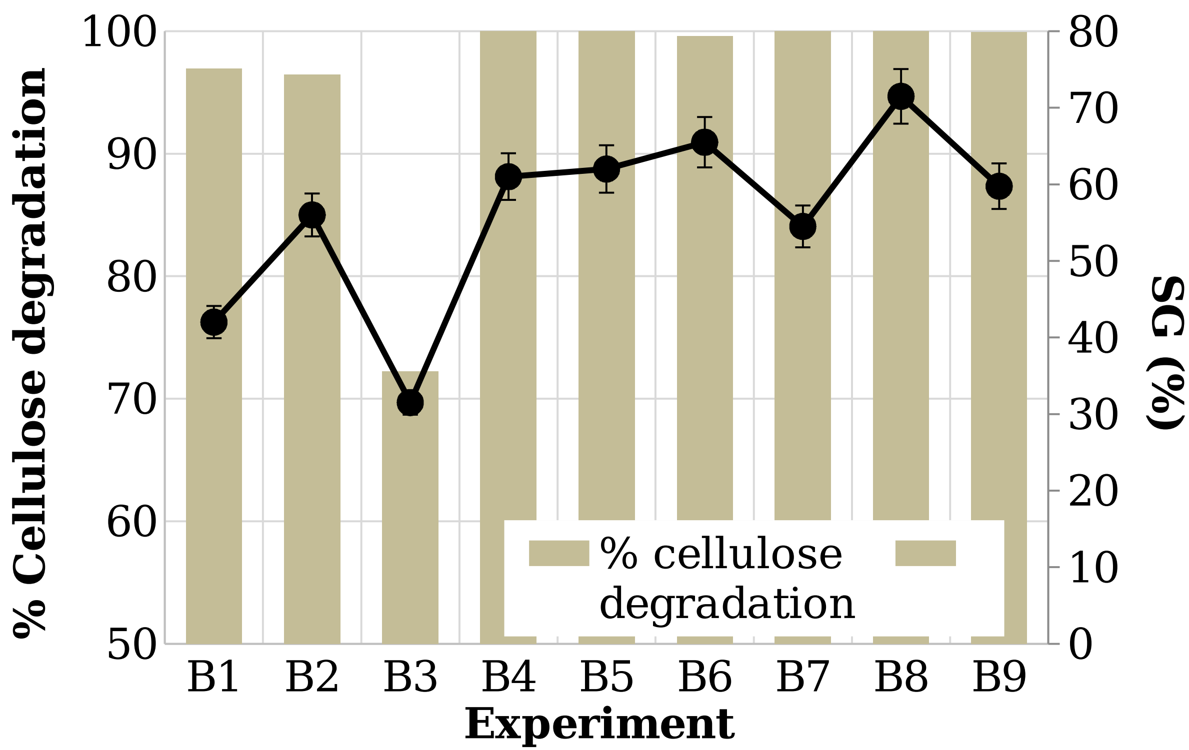
Alkaline pretreatment

t_{auto} (h)	NaOH (%)	%TS hydrolysis			%cellulose degradation			%AIL degradation			%ASL degradation			%hemicellulose degradation		
1	2	30.67	±	2.18	1.76	±	3.68	8.23	±	3.75	62.28	±	2.11	3.45	±	5.92
2	4	23.59	±	2.17	2.20	±	6.83	77.14	±	4.39	75.82	±	1.27	74.36	±	1.59
1.5	3	24.01	±	0.89	5.48	±	9.04	74.27	±	3.48	68.62	±	4.16	43.78	±	16.62
1	4	29.02	±	4.76	1.64	±	7.04	76.40	±	4.77	75.16	±	2.41	44.07	±	13.20
2	3	19.84	±	3.33	4.14	±	1.73	71.28	±	2.75	65.15	±	1.42	44.71	±	2.42

-  in lignin content
- Slight change in cellulose content
- Glucose 1.11-4.78 mg/g digestate
- Volatile Fatty acids 56.95-84.17 mg/g digestate
- Phenolic compounds 2.50-4.61 mg/g digestate

Alkaline pretreatment

Exp	Time (h)	NaOH (%)	Cellic CTec 2 (μL/g)
B1	1	2	100
B2	1.5	4	100
B3	1	4	100
B4	1.5	2	100
B5	1	2	400
B6	1.5	4	400
B7	1	4	400
B8	1.5	2	400
B9	1.25	3	250



Alkaline pretreatment

$$SG_{NaOH}=3.975+32* t_{auto} +0.0525* C_{enz}$$

↑ autoclaving time and/or enzyme loading → ↑ saccharification yield

Max SG_{NaOH} = **76%** for

1.5 h autoclaving time

2% NaOH and

400 μL CellicCTec2/ g cellulose

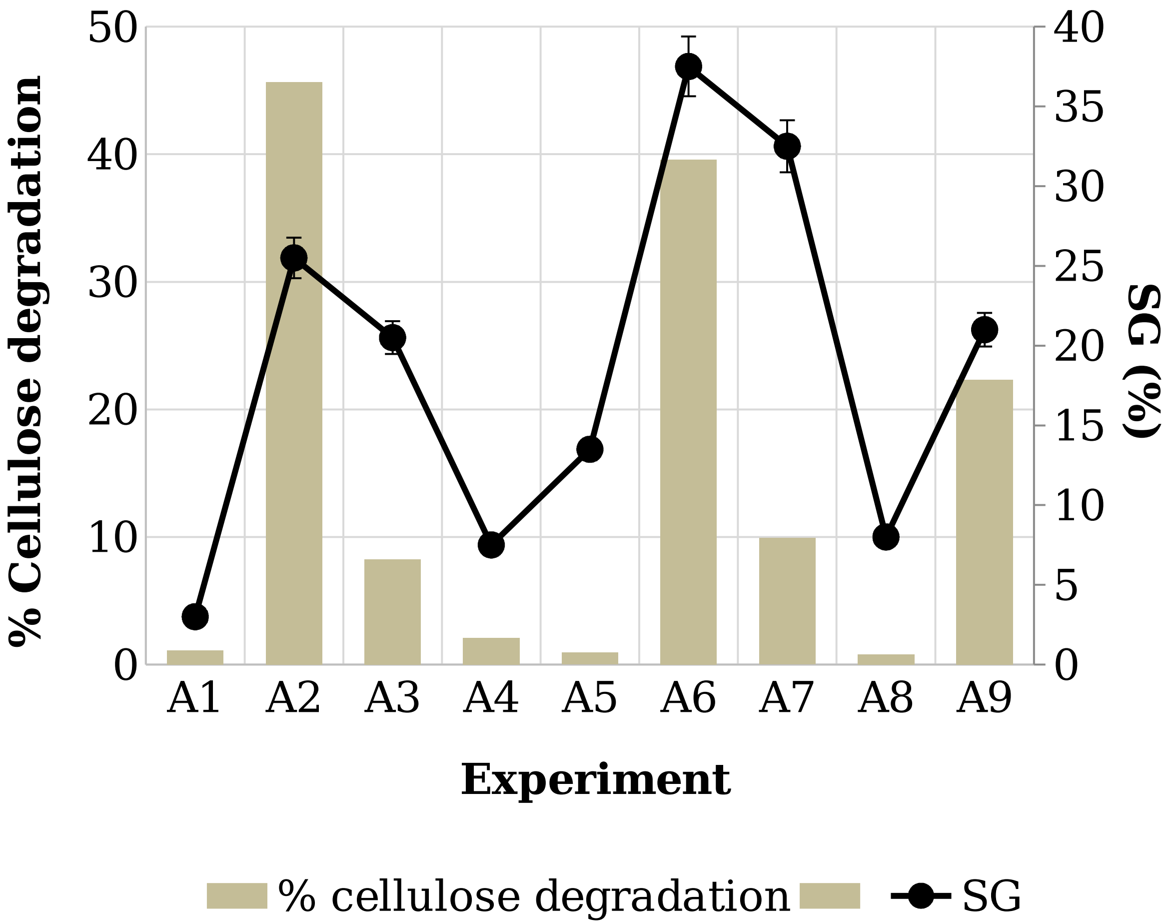
Acidic pretreatment

t_{auto} (h)	H_2SO_4 (%)	%TS hydrolysis	%cellulose degradation	%AIL degradation	%ASL degradation	%hemicellulose degradation
1	1	20.37 ± 0.22	23.79 ± 6.25	9.73 ± 0.49	11.11 ± 1.97	46.47 ± 3.45
2	3	32.02 ± 2.32	15.32 ± 14.04	5.38 ± 0.38	40.68 ± 1.81	66.85 ± 9.56
1.5	2	25.12 ± 1.15	19.85 ± 5.32	7.52 ± 0.29	29.98 ± 2.01	59.17 ± 5.21
1	3	20.88 ± 0.89	35.58 ± 7.29	5.61 ± 5.12	28.83 ± 3.87	65.62 ± 1.45
2	1	13.18 ± 0.87	43.75 ± 16.57	0.69 ± 1.21	6.64 ± 3.63	49.57 ± 8.85

- Insoluble lignin remained almost unaffected
- Volatile Fatty acids 9.92-25.89 mg/g digestate
- Phenolic compounds 0.3-0.54 mg/g digestate

Acidic pretreatment

Exp	Time (h)	H_2SO_4 (%)	Cellic CTec 2 (μL/g)
A1	1	1	100
A2	1.5	3	100
A3	1	3	100
A4	1.5	1	100
A5	1	1	400
A6	1.5	3	400
A7	1	3	400
A8	1.5	1	400
A9	1.25	2	250



Acidic pretreatment

$$SG_{H2SO4} = 11.35+ +0.03^* \, C_{enz}$$

↑ enzyme loading ⟹ ↑ saccharification yield

Max SG_{H2SO4} = **39%** for

1.5 h autoclaving time
3% H_2SO_4 and
400 μL CellicCTec2/ g cellulose

} Harshest pretreatment conditions

Conclusions

Conclusions

- Acid pretreatment along with enzymatic hydrolysis was found to yield low sugars recoveries (2-39%).
- Alkaline pretreatment and enzymatic hydrolysis is a better approach with elevated saccharification yields reaching up to 76%.
- NaOH pretreatment presented in all cases much better performance on saccharification yields than acidic pretreatment.

New integrated system that combines ethanol production with anaerobic digestion simultaneously producing energy in the form of methane and ethanol and improving the overall energy balance

Acknowledgements

The authors acknowledge funding through European Horizon 2020 NoAW (No Agro Waste, Grant no. 688338) project for supporting this work.

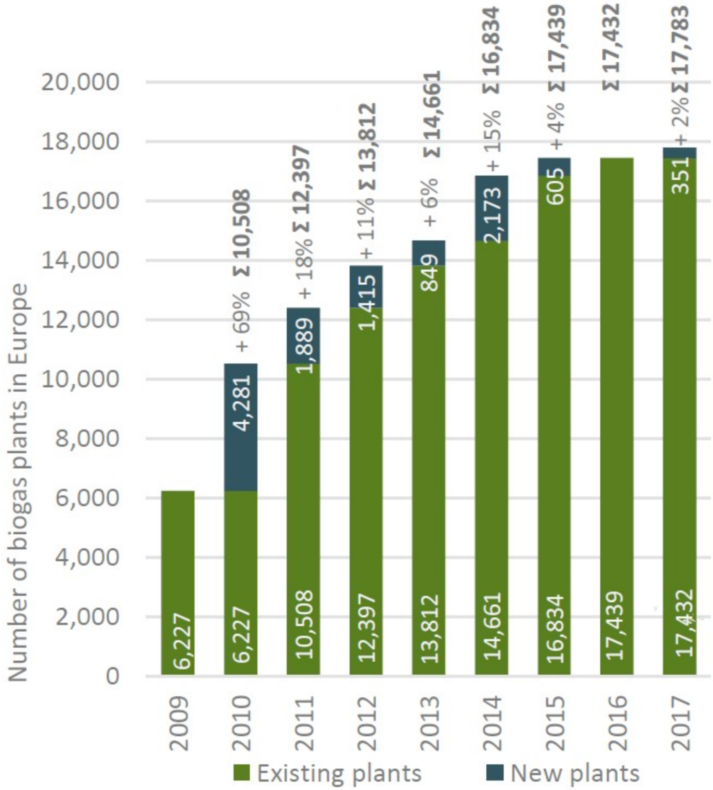

THANK YOU
FOR YOUR
ATTENTION

Anaerobic Plants in Europe

The number of biogas plants in Europe has greatly increased. Between 2009 (earliest EBA data) and 2017, the total number of biogas plants rose from 6,227 to 17,432 installations (+11,205 units).

Most of that growth derives from the increase in plants running on **agricultural substrates**: these went from 4,797 units in 2009 to 12,721 installations in 2017 (+7,924 units, **67%** of the total increase).

Agricultural plants are then followed by biogas plants running on sewage sludge (2,854 plants), landfill waste (1,374 units) and various other types of waste (688 plants).



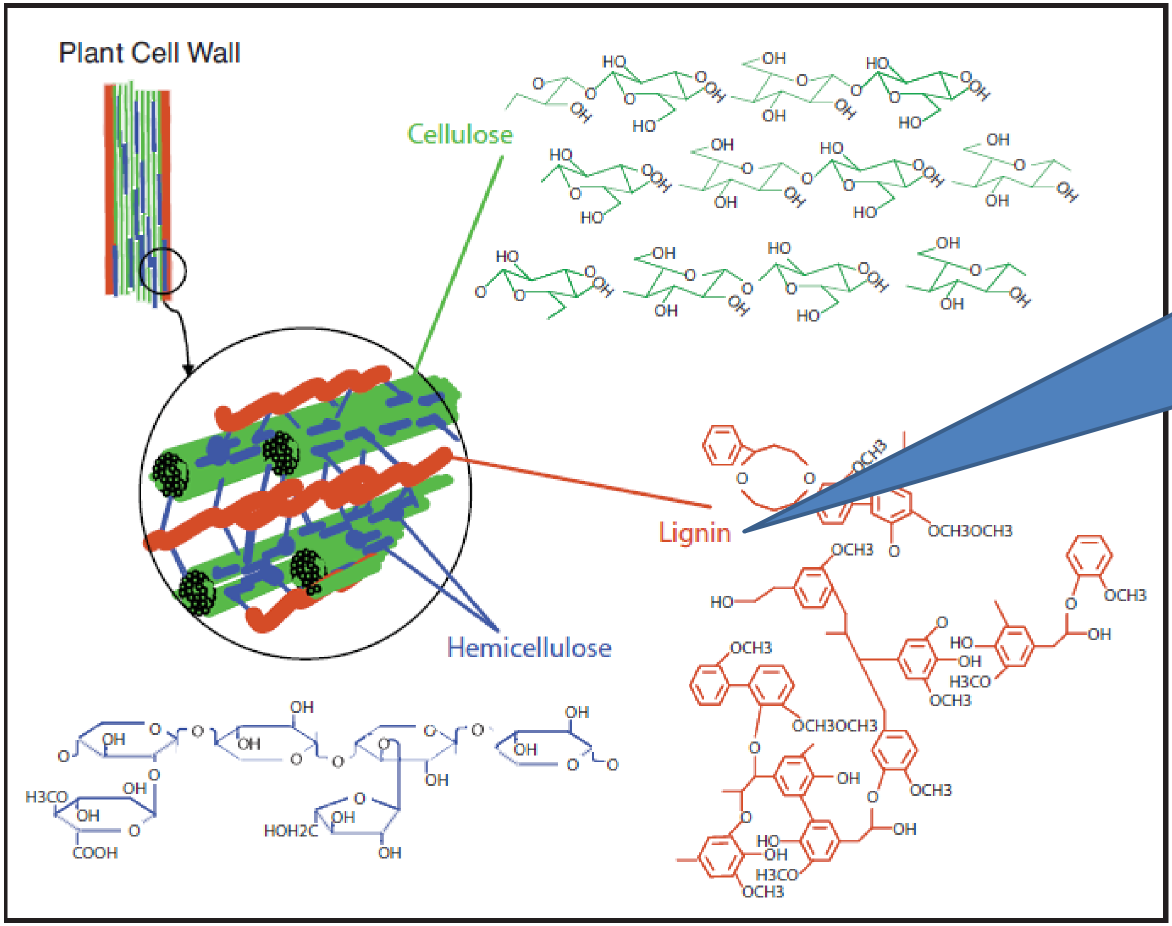
http://biogas.org.rs/wp-content/uploads/2018/12/EBA_Statistical-Report-2018_European-Overview-Chapter.pdf

Challenges of digestate

It is vital that digestate is seen in a holistic way as part of an overall materials processing and re-use system.

- The use of downstream processing to treat digestate may ***consume more energy*** than is likely to be generated by the AD facility.
- Digestate is ***difficult to manage*** due to its fertilising properties, format and high water content.
- There is ***lack of a legal framework***. Many European countries do not have appropriate (if any) legislation concerning digestate, resulting in legal barriers to the use of waste material, its conversion into products or its export abroad.
- There is ***lack of information***. Most farmers are poorly informed (or even misinformed) about the benefits of digestate and other organic fertilisers, often making them hesitant about spreading them on their land. Public authorities should make a conscious effort to explain the advantages of digestate and the adequate management of local resources to build confidence on its use.

Agricultural waste -Lignocellulosic material

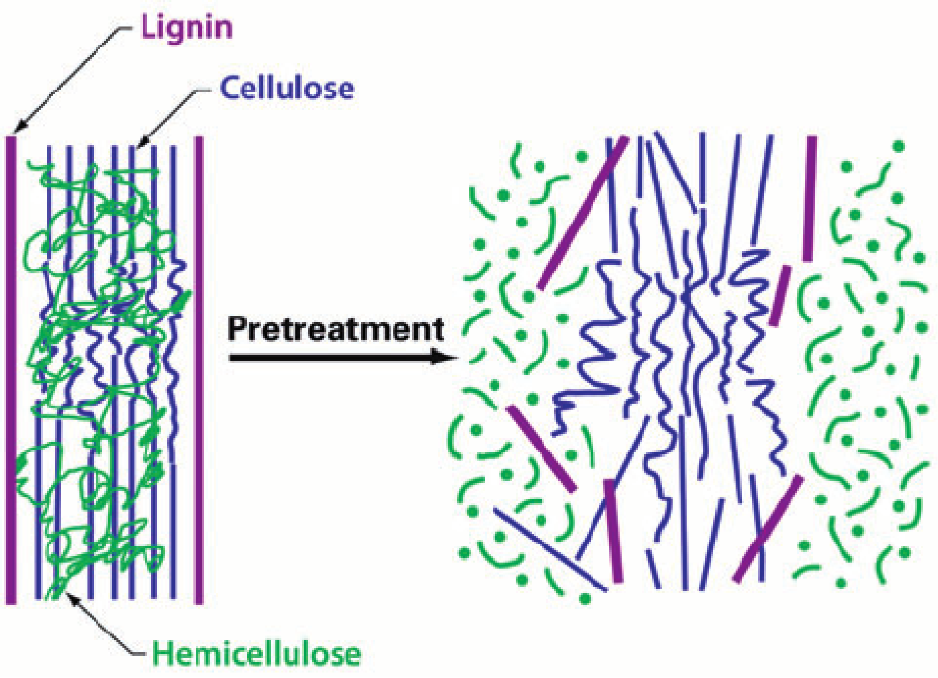


https://www.e-education.psu.edu/egee439/node/606

The major barrier to the enzymatic hydrolysis of cellulose towards the production of fermentable

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

Lignocellulosic material



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