POLITECNICO DI MILANO

ALKALINE PRETREATMENT OF SORGHUM AND WHEAT STRAW FOR INCREASING METHANE PRODUCTION

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DIIAR - Environmental Section

Lignocellulosic substrates

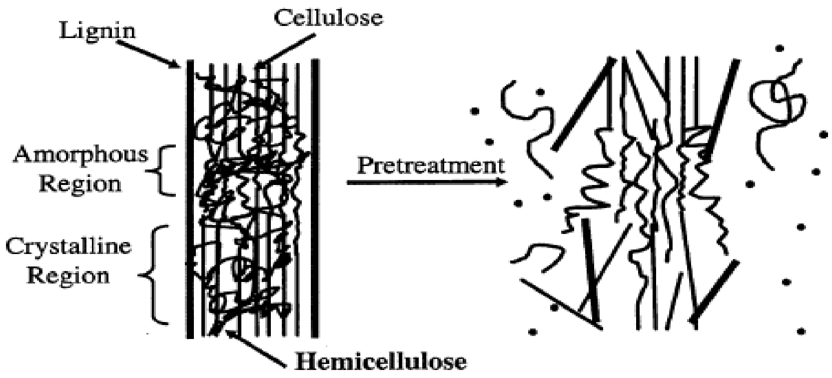
Lignocellulosic substrates can be converted into biomethane… but…

Lignocellulosic substrates are composed of:

- ✓ **Cellulose (20-50 %):** Linear polymer of glucose units linked by β-(1–4)-glycosidic bonds.
- ✓ **Hemicellulose (20-40 %):** Highly branched and complex heteropolymer that contains hexoses, pentoses, and uronic acids.
- ✓ **Lignin (15-25 %):** Aromatic polymer containing phenolic residues.
- ✓ **Other components:** Small quantity

GOALS

- Alter the structure and increase the porosity of the substrate
- Remove lignin
- Reduce the crystallinity of cellulose
- Make cellulose and hemicellulose more accessible for enzymatic hydrolysis



Ref.: Moisier et al., 2005

PRETREATMENT TECHNIQUES

- Physical (milling, ultrasonic,…)
- Thermal (Pressure cooking, Steam Explosion (ST/SE), Liquid Hot Water (LHW),..)
- Chemical (alkaline, acid,..)
- Biological (enzymes and microorganisms)

Objectives

To investigate the effects of alkaline pretreatment on fiber composition and to determine the anaerobic methane production of untreated and pretreated sorghum silage and wheat straw

Materials and Methods - Feedstocks

Parameter	Sorghum silage	Wheat straw
Ø (mm)	0.5-1.5	
TS (g/100g)	96.7	97.6
VS/TS (g/100g)	86.3	92.5
COD/VS	1.2	1.2
NDF-ADF-ADL (g/100gTS)	65.0 - 46.7 – 3.9	73.1 - 50.6 - 5.9
Protein-Fats-Fibres-Ashes (g/100gTS)	9.1 - 1.3 - 35.3-13.0	3.0 - 0.3 - 39.3 -8.6
Cellulose (g/100gTS)	42.9	44.8
Hemicellulose (g/100gTS)	18.3	22.5
Lignin (g/100gTS)	3.9	5.9

Materials and methods –Analytical determinations

Parameter	U.M	Method
TS, VS, COD, CODsol	g/L	APAT-IRSA CNR, 2003
ADF-NDF-ADL, protein-fats- fibres and ashes	g/100gTS	Near - infrared Spectroscopy method Van Soest method (Goering et al., 1970)
Total sugars	g/L	Dubois et al., 1956
Reducing sugars	g/L	Somogy, 1952

Materials and Methods - Alkaline pretreatment

Plastic bottles with a volume of 2L

Sieve (Ø 0.8 mm)

Fiber composition of solid fraction

COD, CODsol, total and reducing sugars (solid/liquid fractions)

Raw substrates	Specific dosage	T (C)	Duration (h)
Sorghum silage and wheat straw	Control (6 gH_2O/gTS)	40	24
	1 gNaOH/100gTS		
	3 gNaOH/100gTS		
	10 gNaOH/100gTS		

Materials and Methods - BMP tests

SUBSTRATES

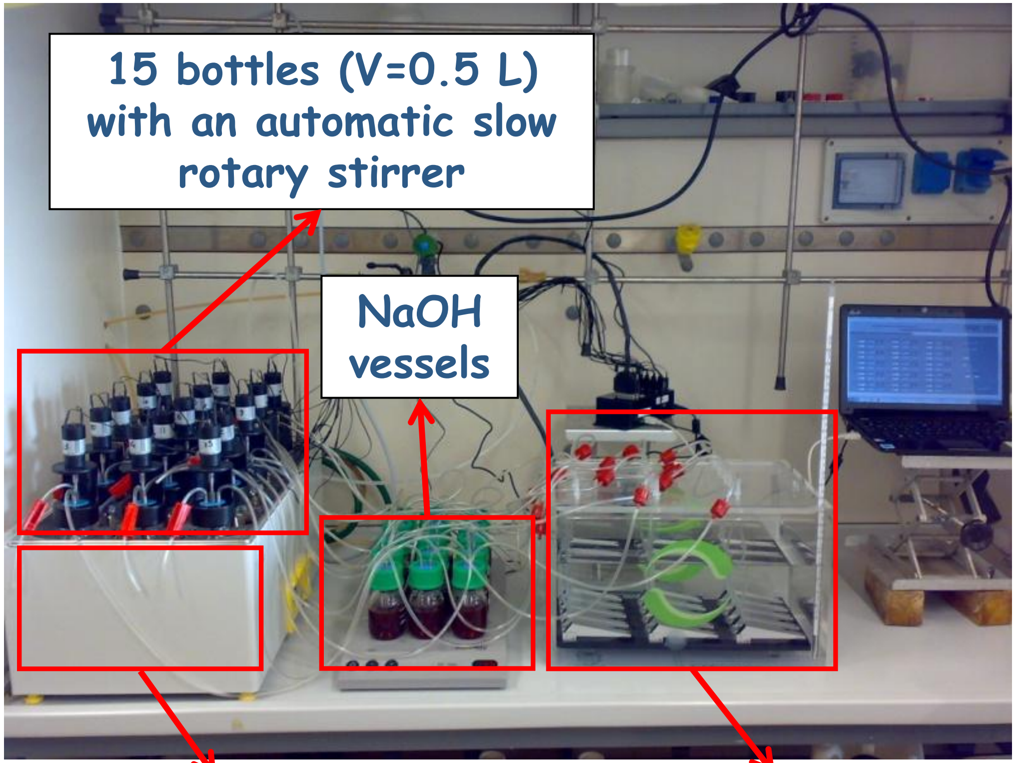
Raw and pretreated substrates

INOCULUM

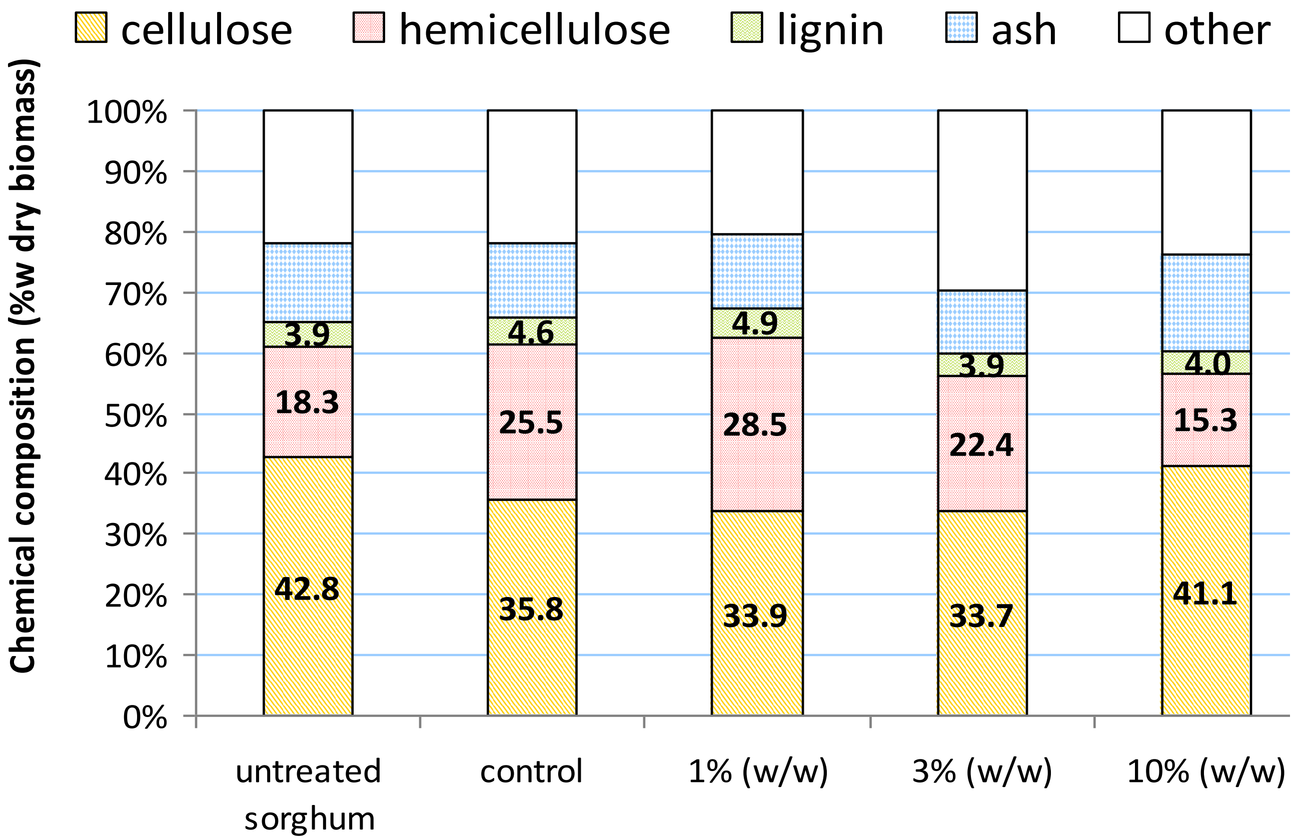
Mix of two digested sludges (WWTP digester and Agro-wastes digester)

INITIAL CONDITIONS

- 5gVS/L inoculum sludge washed with mineral medium
- 0.5 L test volume
- F/M= 0.9-1 gVS/gVS
- T = 35 ± 0.5°C

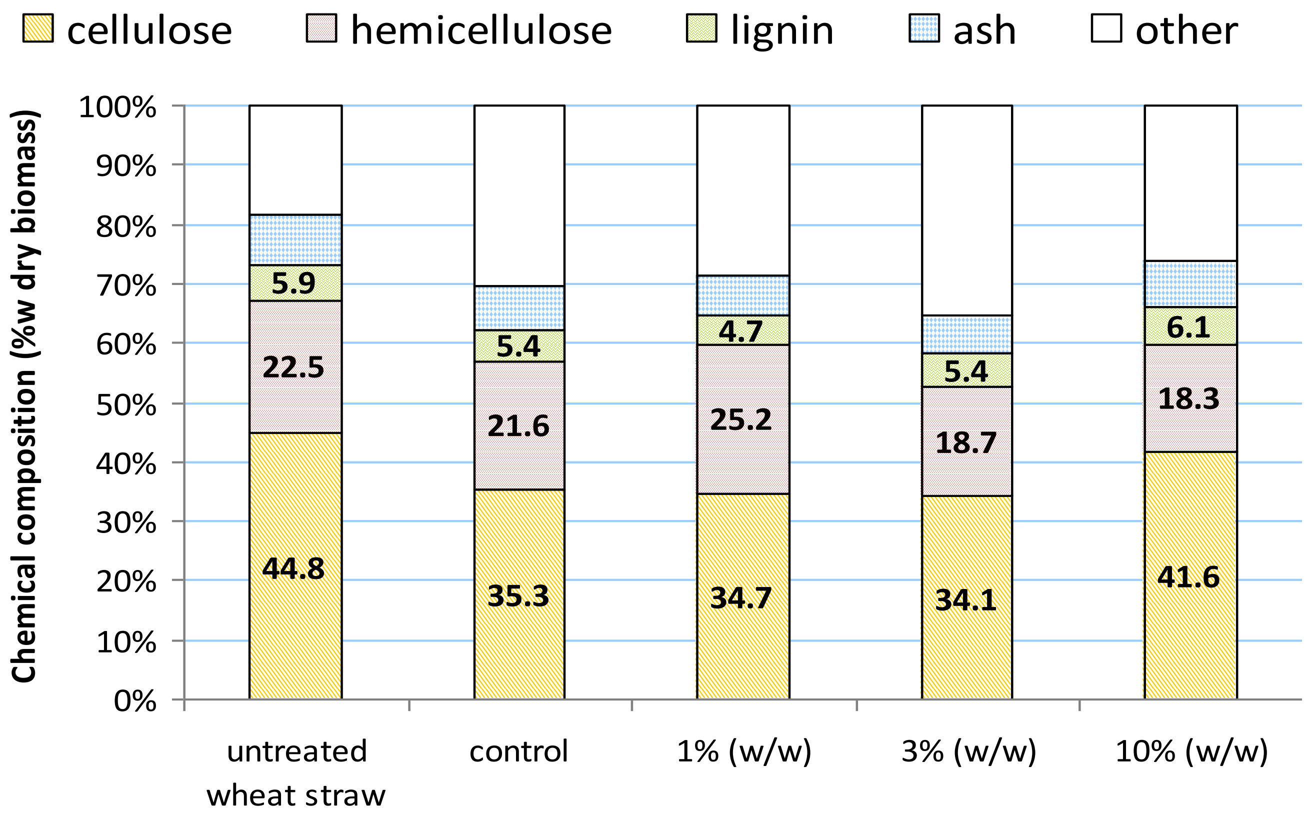


Results and discussion - Chemical composition changes



- Cellulose content reduction
- Hemicellulose content reduction (high alkaline dosage)
- No clear tendency in lignin content

Results and discussion - Chemical composition changes



- A reduction in fiber content is observed for all soaked samples
- No clear tendency in lignin content

Results and discussion – COD solubilization

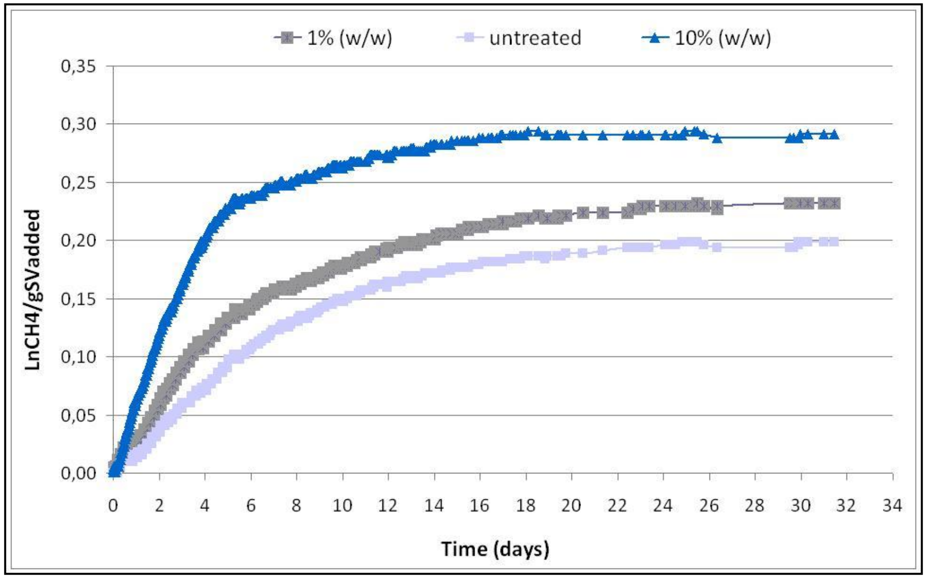
Absolute (g/L) and relative (% of the initial total COD) soluble COD released after 24h soaking.

Feedstock	NaOH dosage (g/100gTS)			
	0	1	3	10
Sorghum	15 *(9%)*	14 *(8%)*	22 *(13%)*	58 *(33%)*
Wheat straw	12 *(7%)*	11 *(6%)*	21 *(12%)*	42 *(24%)*

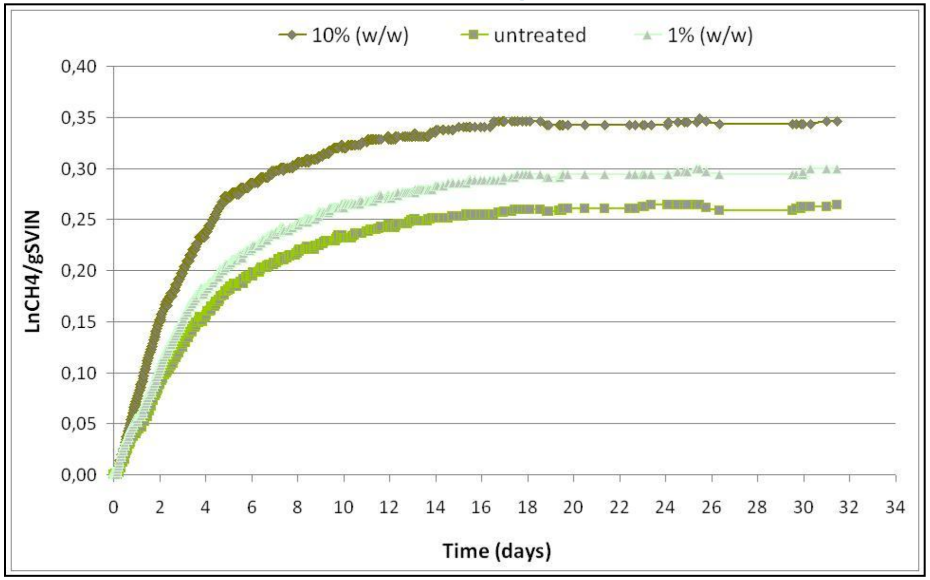
- An increase in NaOH dosage led to a significant increase in COD solubilization.

Results and discussion – BMP tests

Wheat straw



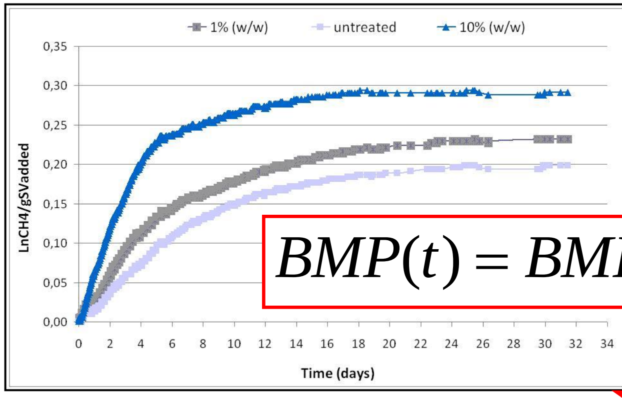
Sorghum



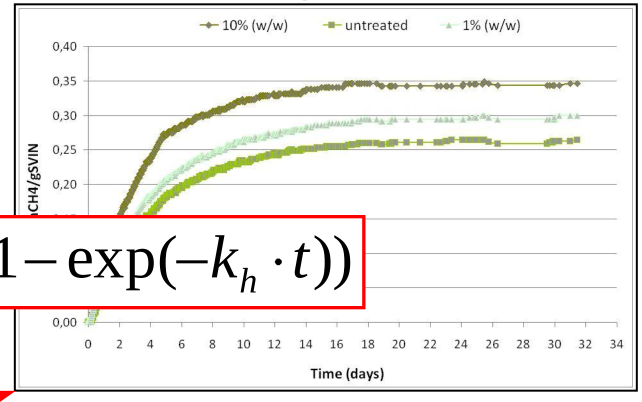
	B (%)	I_{CH4} (%)
untreated sorghum	66%	-
1% (gNaOH/gTS)	73%	+11%
10% (gNaOH/gTS)	86%	+29%
untreated wheat straw	56%	
1% (gNaOH/gTS)	63%	+12%
10% (gNaOH/gTS)	72%	+29%

Results and discussion – BMP tests

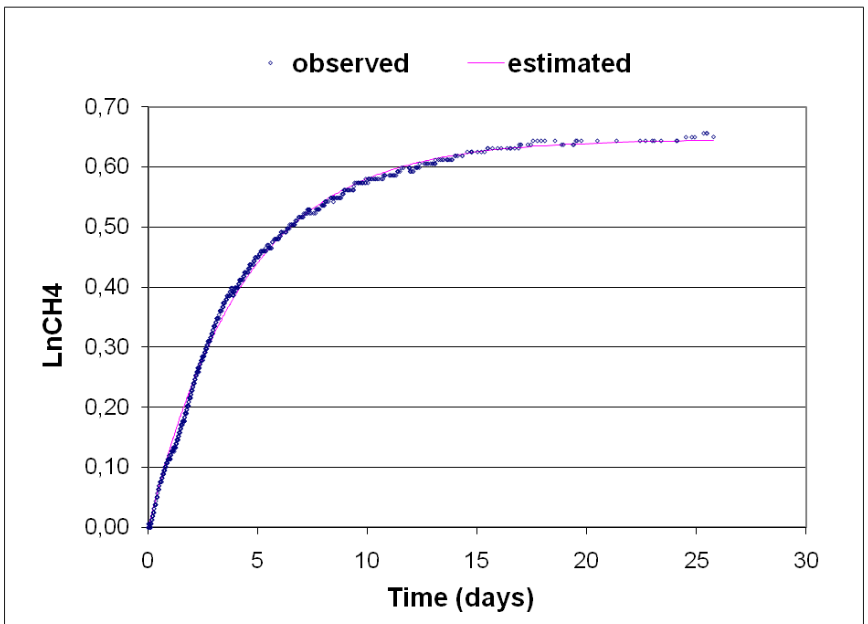
Wheat straw



Sorghum



$$BMP(t) = BMP_{t\to\infty}(1-\exp(-k_h \cdot t))$$



	k_h (d^{-1})	I_{kh} (%)
untreated sorghum	0.21	-
1% (gNaOH/gTS)	0.23	+10
10% (gNaOH/gTS)	0.28	+33
untreated wheat straw	0.10	-
1% (gNaOH/gTS)	0.16	+60
10% (gNaOH/gTS)	0.27	+170

Conclusions

✓ Alkaline pretreatment is a promising process to improve the biodegradability of sorghum and wheat straw

✓ An increase in NaOH loadings led to a significant increase in:

- COD solubilization
- Methane production (up to 29%)
- Hydrolysis kinetic (the first order hydrolysis kinetic constant increased by 33% and by 170% for sorghum and wheat straw, respectively)

Merci