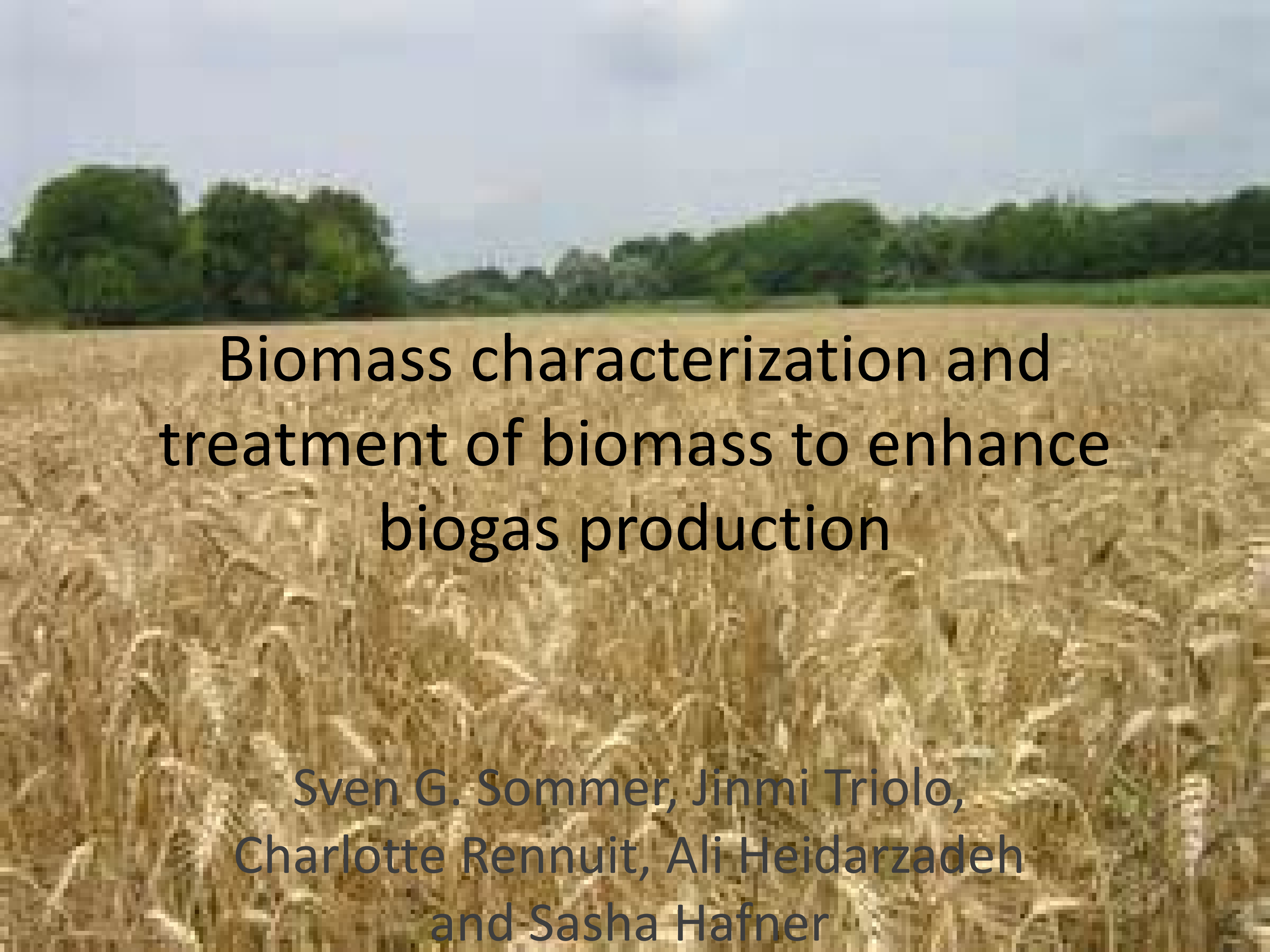
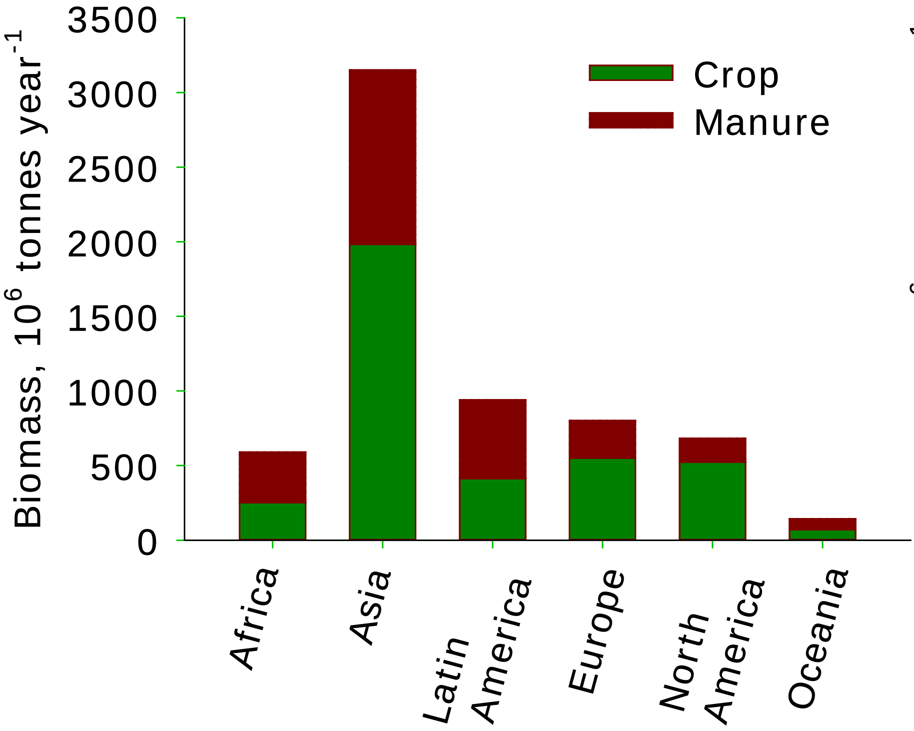
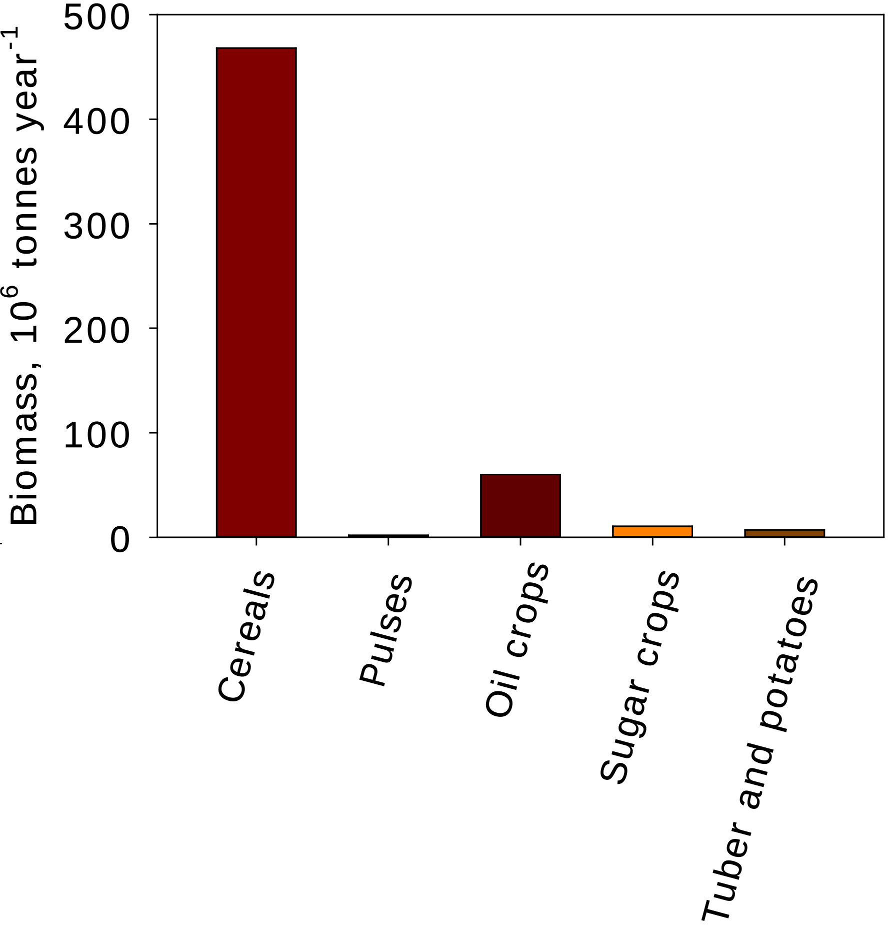


Biomass characterization and treatment of biomass to enhance biogas production

Sven G. Sommer, Jinmi Triolo,
Charlotte Rennuit, Ali Heidarzadeh
and Sasha Hafner

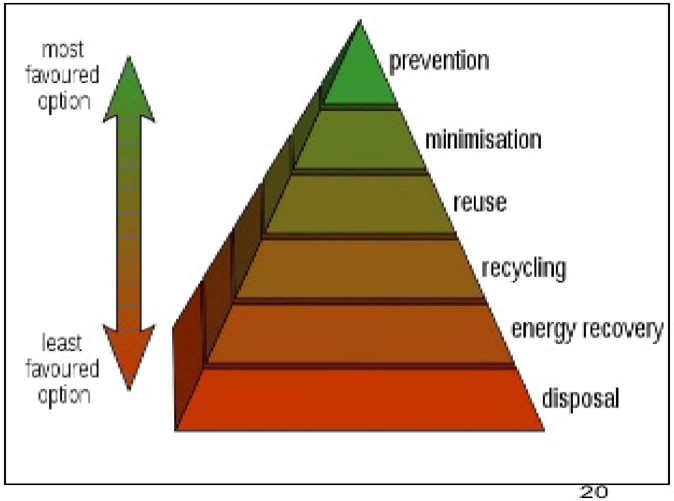
Biomass residue production

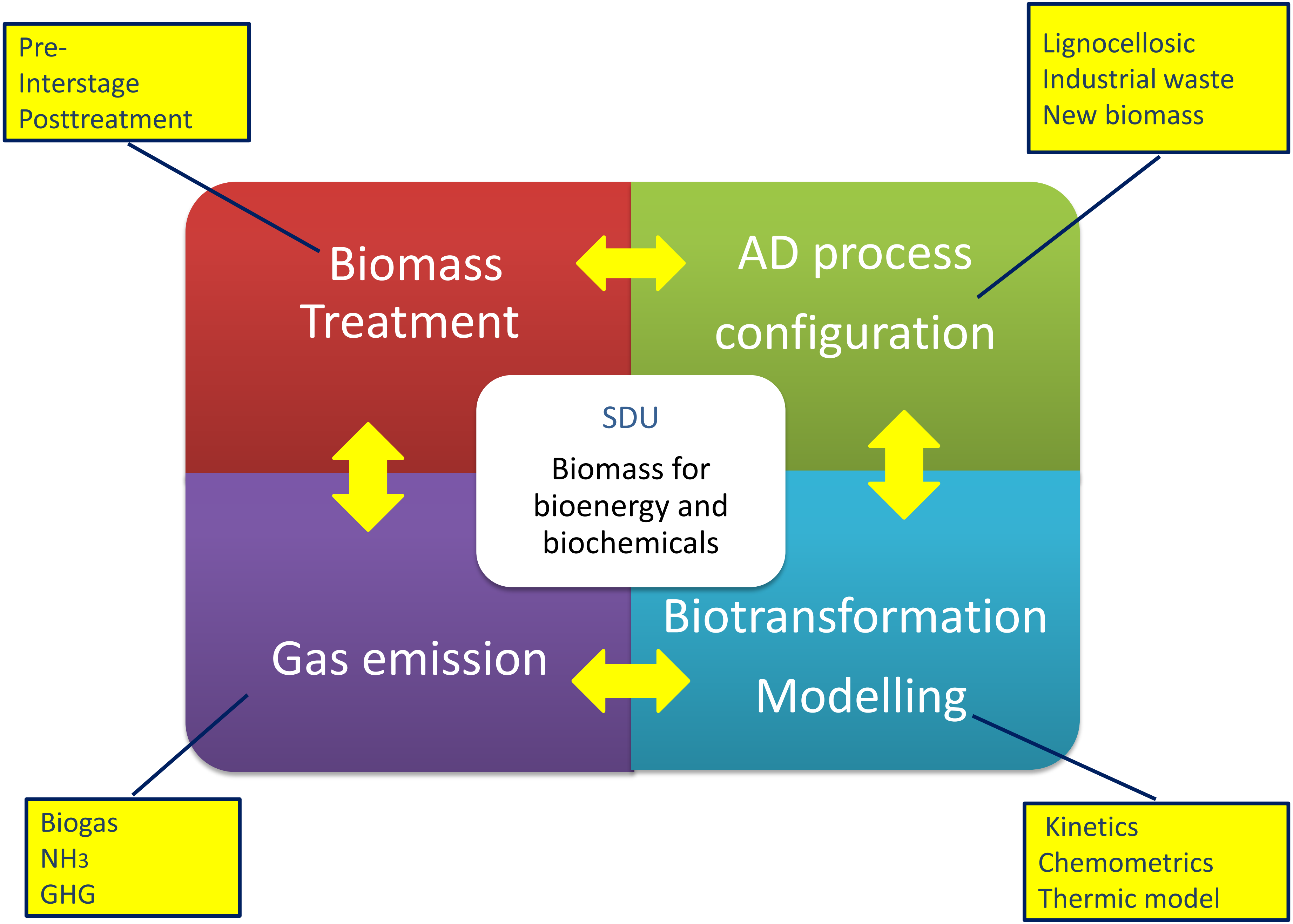

World
Crop residues and manure


Europe
Crop residues

Success variables

- Cost
- Energy balance
- Yield (mass balance)
- Externalities (Reduced odour and pathogens, enhance fertilizer efficiency, recycling, ..)
- Waste treatment hierarchy





Pre-
Interstage
Posttreatment

Lignocellosic
Industrial waste
New biomass

Biomass Treatment

AD process configuration

SDU

Biomass for bioenergy and biochemicals

Gas emission

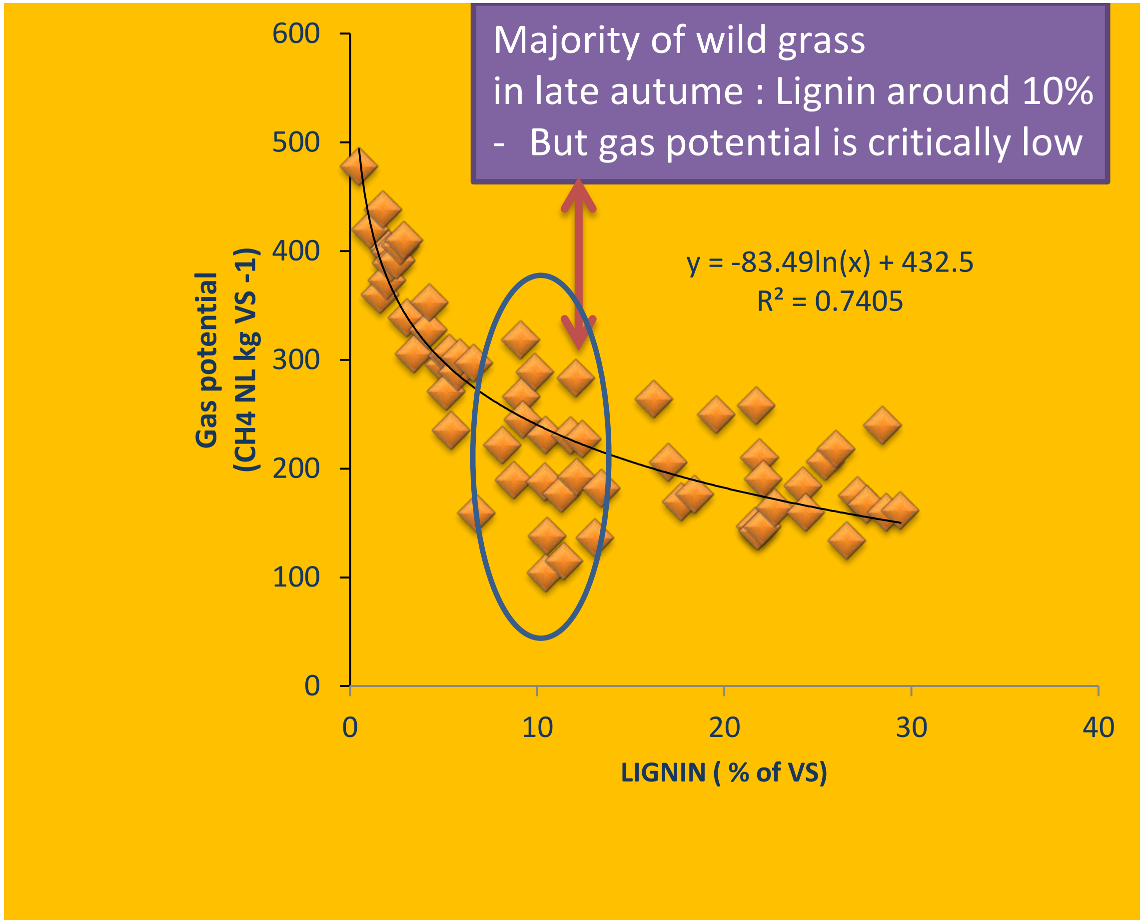
Biotransformation Modelling

Biogas
NH_3
GHG

Kinetics
Chemometrics
Thermic model

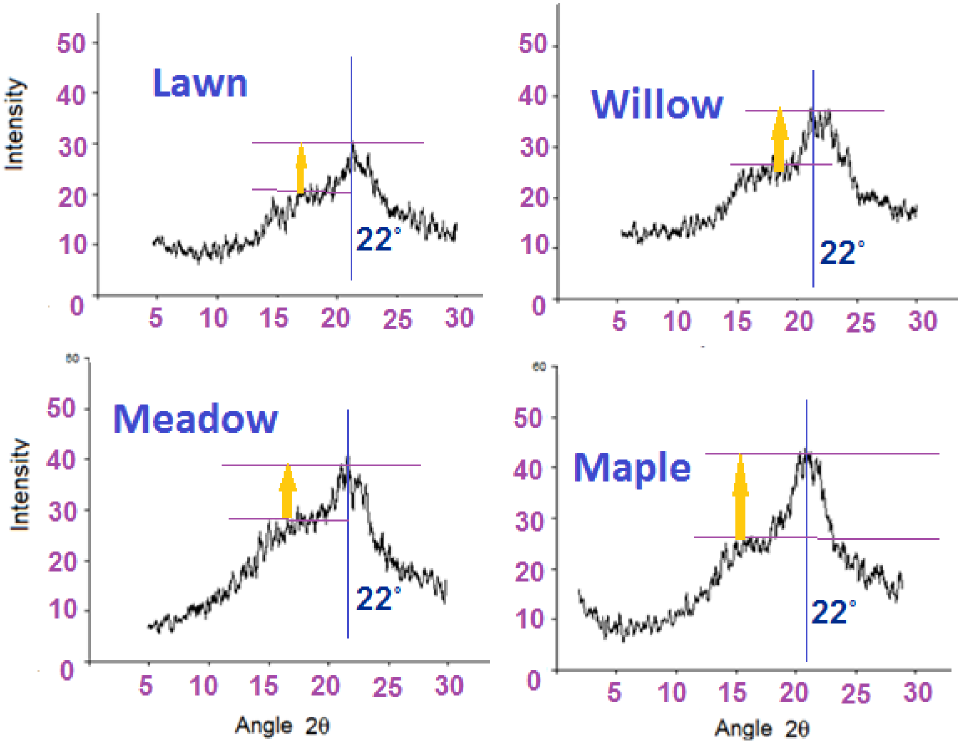
Effects of lignin on gas potentials
Triolo J.

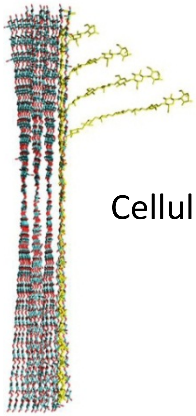
Plant biomass



Majority of wild grass
in late autume : Lignin around 10%
- But gas potential is critically low

Recalcitrant carbon pools of plant biomass
Triolo J.





Cellulose crystal

Cellulose crystal

Plant physilogical age

Cellulose crystallisation ↑

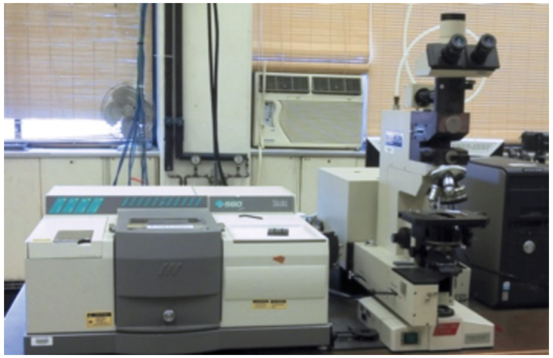
Digestibility
Biogas potential ↓

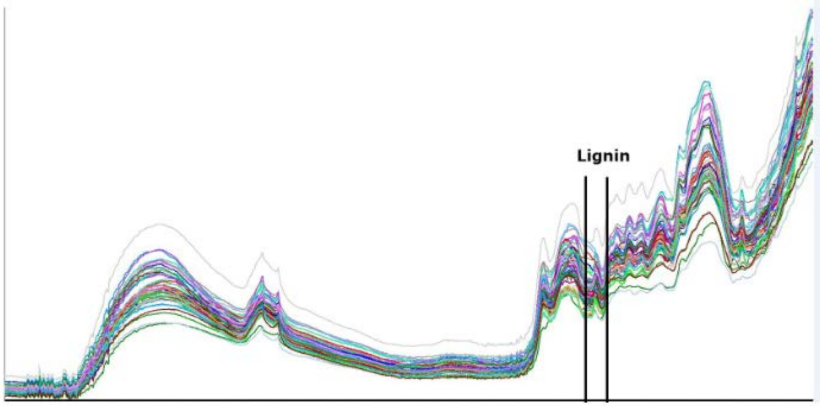
Crystallinity index (CI) measured by x ray diffraction

Sample	Willow	Birch	Maple	Lawn	Meadow
CI	43.0(4.2)	58.8(1.0)	52.0(2.8)	32.6(9.8)	44.4(5.3)

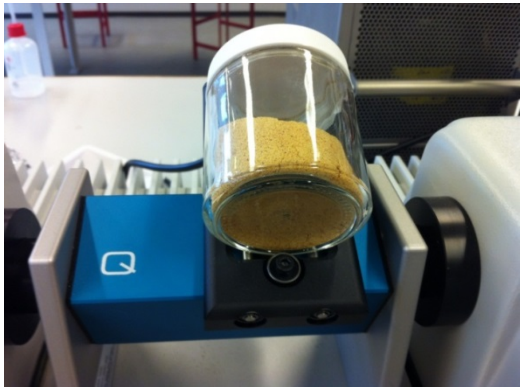
Will spectroscopy replace conventional wet characterisation?

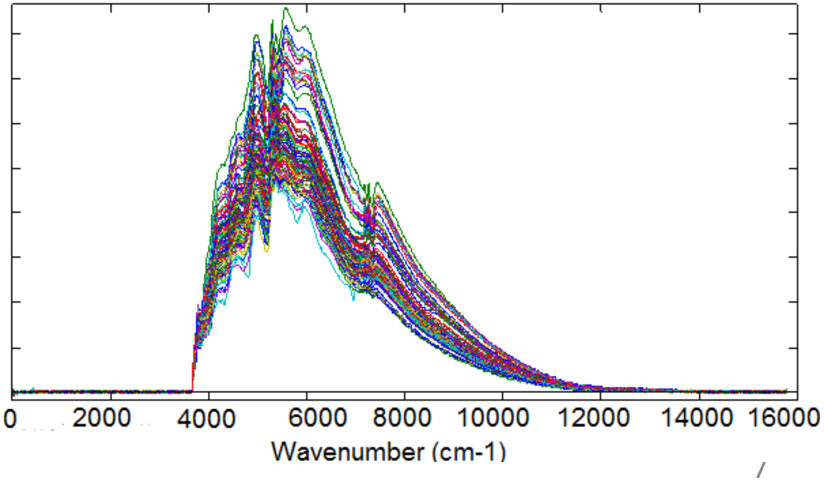
Fourier transform photoacoustic spectroscopy





Near infrared Spectroscopy

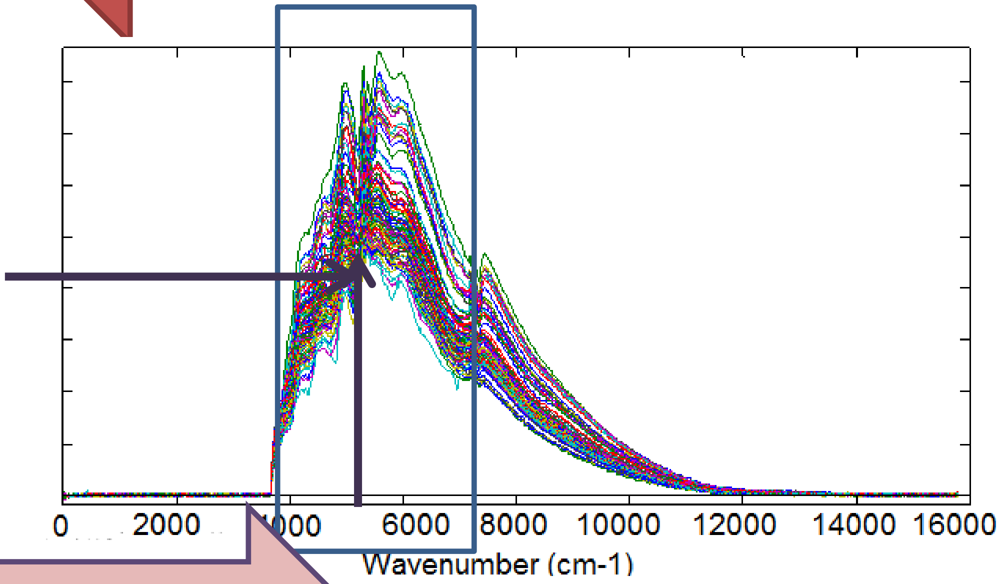




Rapid analysis

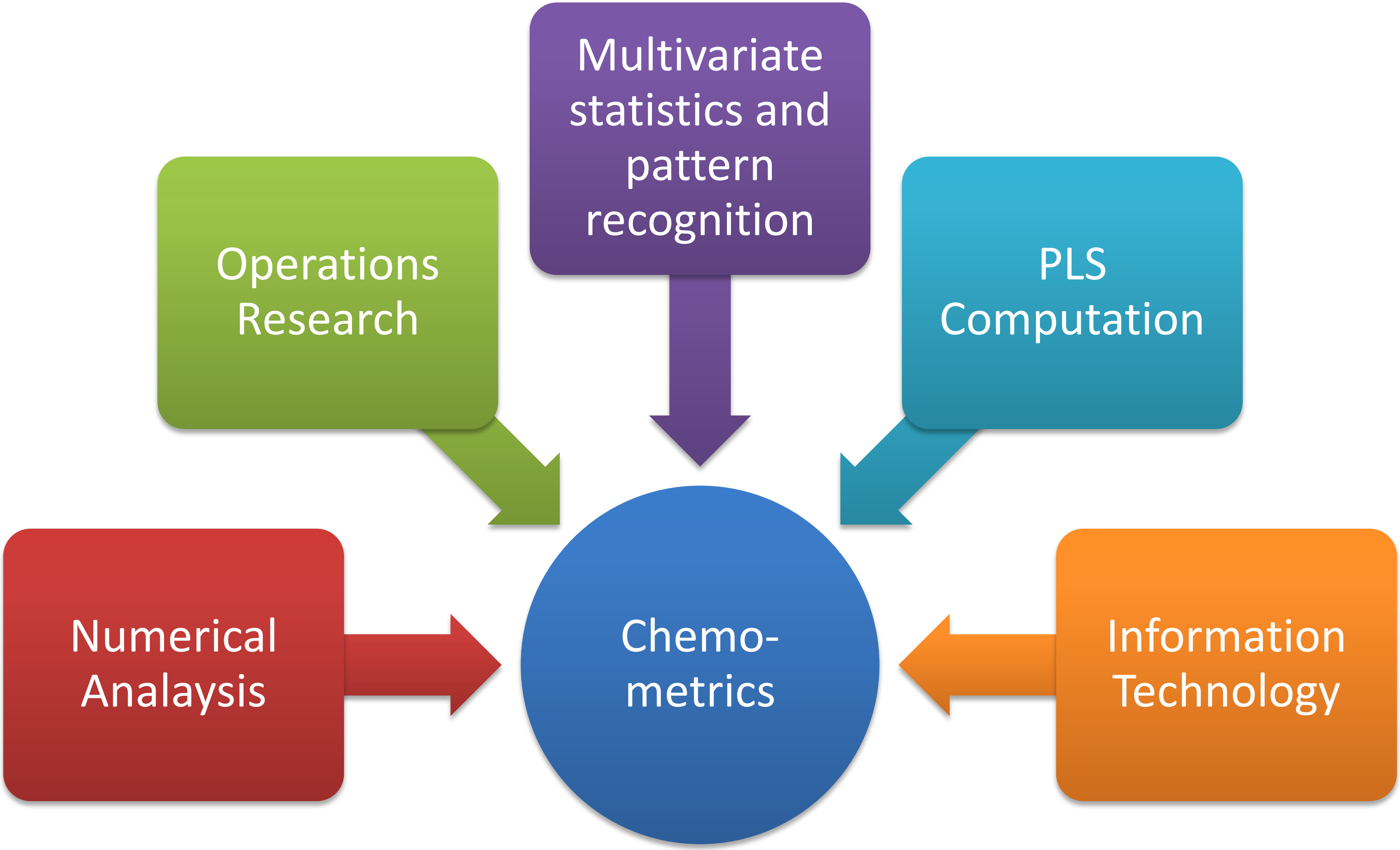
Materials	Wave number cm^{-1}
Moisture	6920
Starch, Cellulose	5807
Protein	5767
Oil	5685
Starch, Cellulose	5624
Cellulose	5501
Moisture	5155
Urea	5045
Starch	4762
Protein, Starch	4675
Protein	4587
Protein, Starch,	4566
Urea, Lactose	4529
Cellulose, Fiber	4405
Oil	4329
Fiber, Ash	4281
Cellulose	4264

Wavenumber (cm^{-1}) of organic carbon composition



Multivariables
from each wavenumber

Methodology – Chemometrics


Multivariate statistics and pattern recognition

Operations Research

PLS Computation

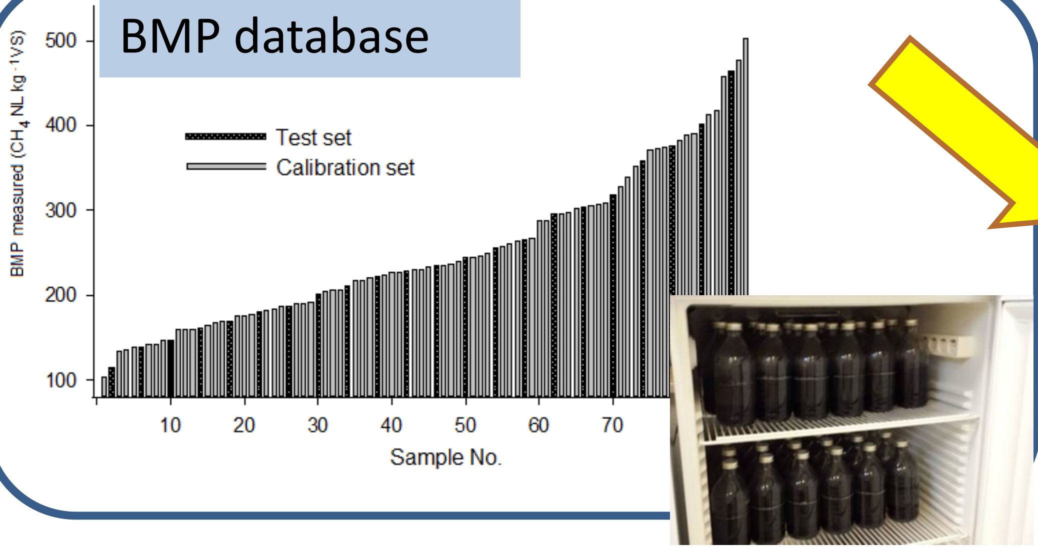
Numerical Analaysis

Chemo-metrics

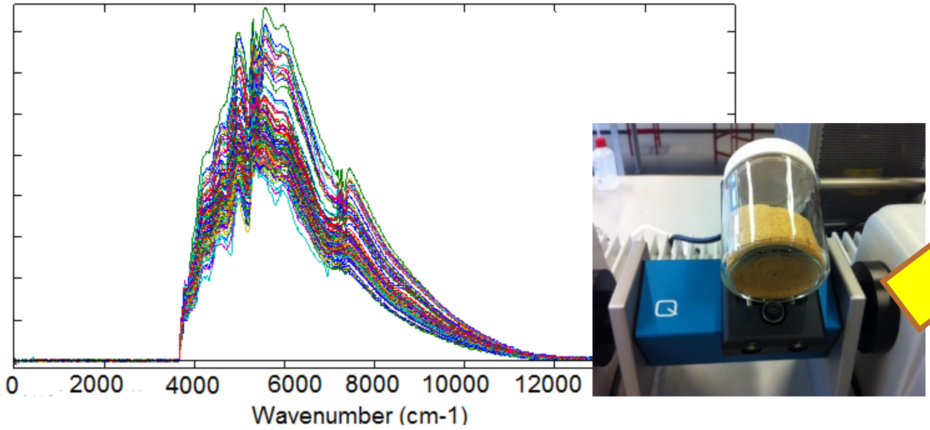
Information Technology

Rapid analysis by spectroscopic calibration

BMP database



NIR Spectra

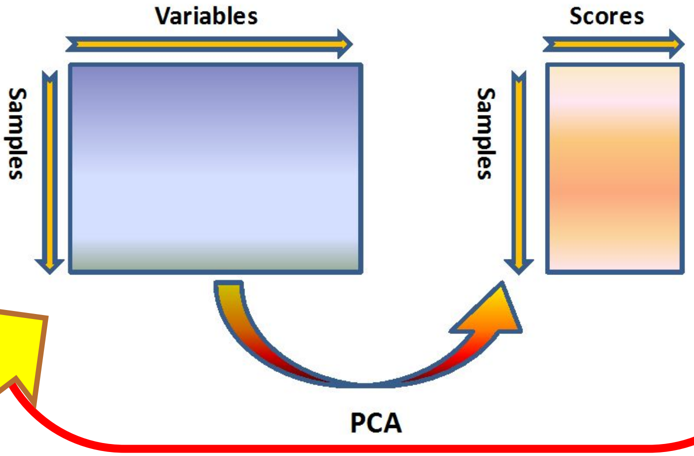


Model Calibration

where

$$\overline{X} = (\overline{x}_1 \quad \overline{x}_2 \quad \cdots \quad \overline{x}_n), \qquad rep(\overline{X}) = \begin{pmatrix} \overline{x}_1 & \overline{x}_2 & \cdots & \overline{x}_n \\ \overline{x}_n & \overline{x}_2 & \cdots & \overline{x}_n \\ \vdots & \vdots & \ddots & \vdots \\ \overline{x}_n & \overline{x}_2 & \cdots & \overline{x}_n \end{pmatrix} \quad (2)$$

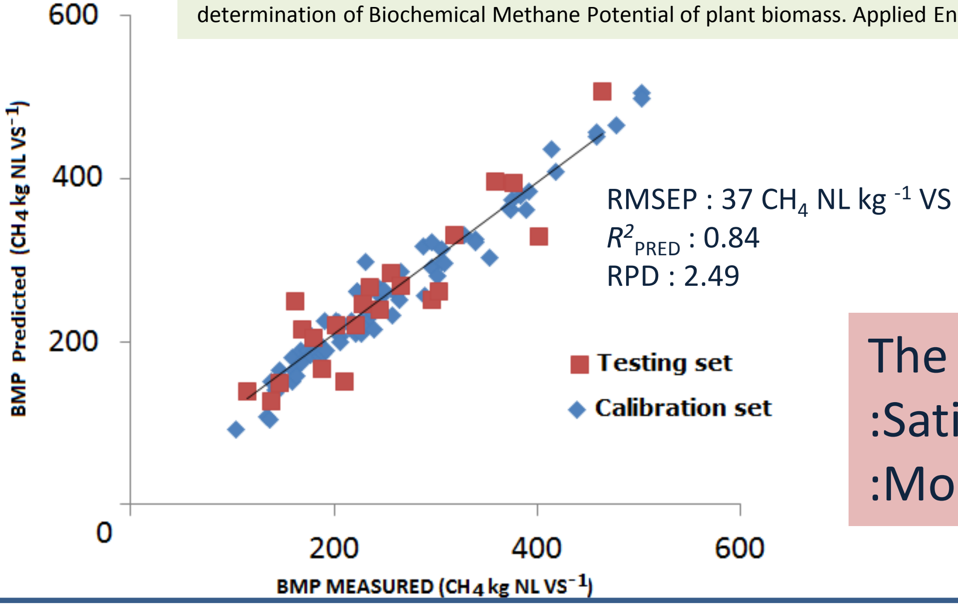
$$\overline{x}_i = \frac{1}{m}\sum_{j=1}^{m} x_{ij} ,$$



NIR

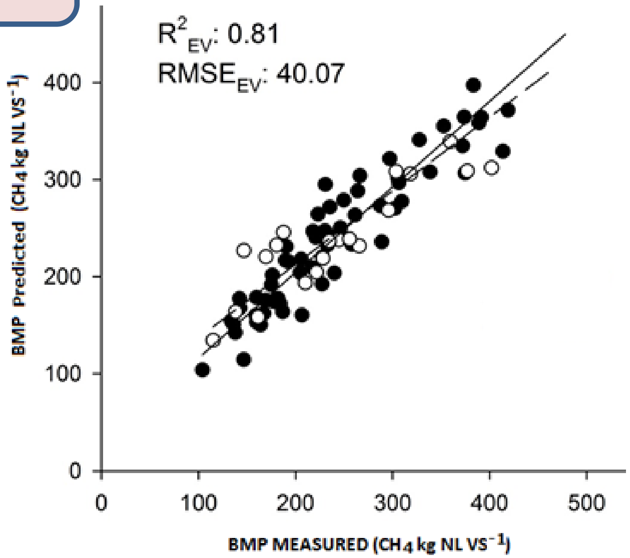
BMP model

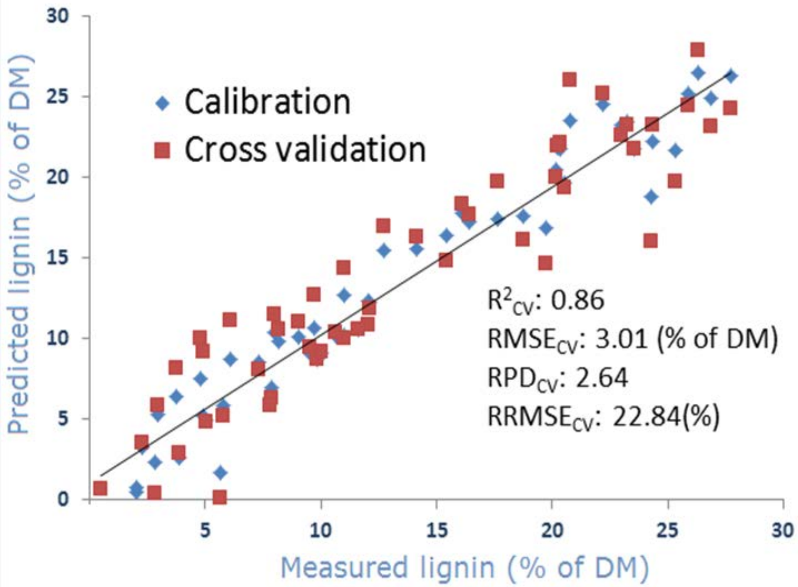
Triolo JM, Ward AJ, Pedersen L, Løkke MM, Qu H, Sommer SG (2014) Near Infrared Reflectance Spectroscopy for rapid determination of Biochemical Methane Potential of plant biomass. Applied Energy, 116, 52-57



The Model precision
:Satisfactory
:Moderately successful

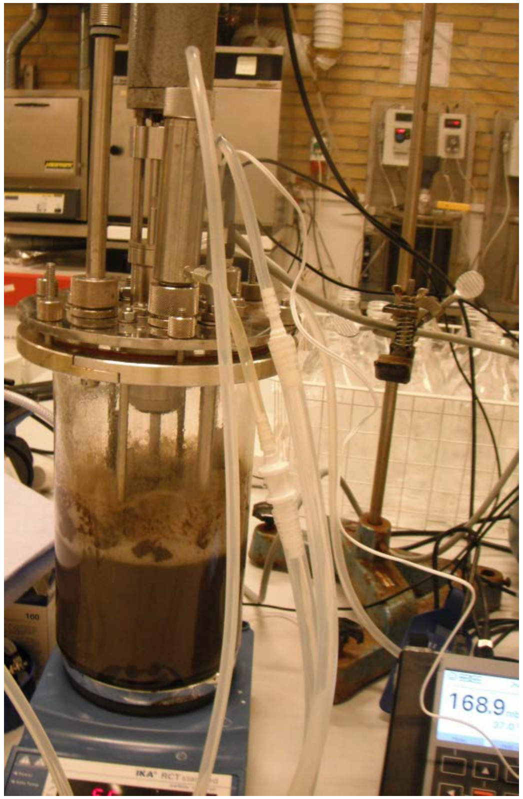
FTIR-PAS





Bekiaris, G., Triolo, J.M., Peltre, C.l., Pedersen, L., Jensen, L.S., Bruun, S.(2015). Rapid estimation of the biochemical methane potential of plant biomasses using Fourier transform mid-infrared photoacoustic spectroscopy. Bioresource Technology, 197, 475–481

Inter-stage treatment for increasing methane production from recalcitrant biomass



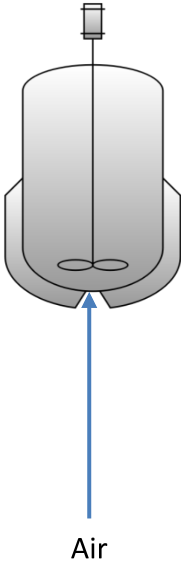
Inter-stage treatment ?

→ Thermophilic aerobic digestion (TAD)

Shown to have a strong effect on organic matter degradation with waste water sludge*

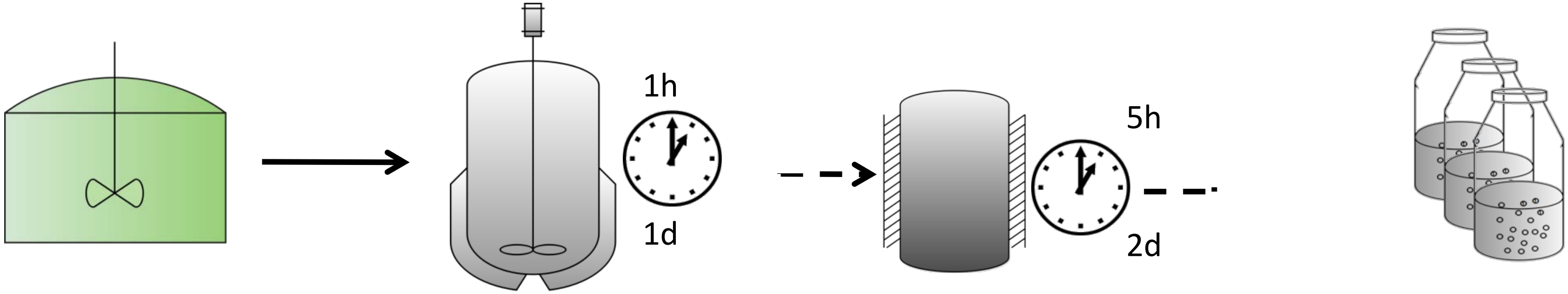
+

Use of the complementarity of aerobes and anaerobes



*Jang et al. 2014, Dumas et al. 2010

Methodology: overview



Anaerobic digestion 1

Aerobic Digestion (TAD)

Anoxic Incubation

Anaerobic digestion 2

37°C
~28 days

55°C
≤1 day

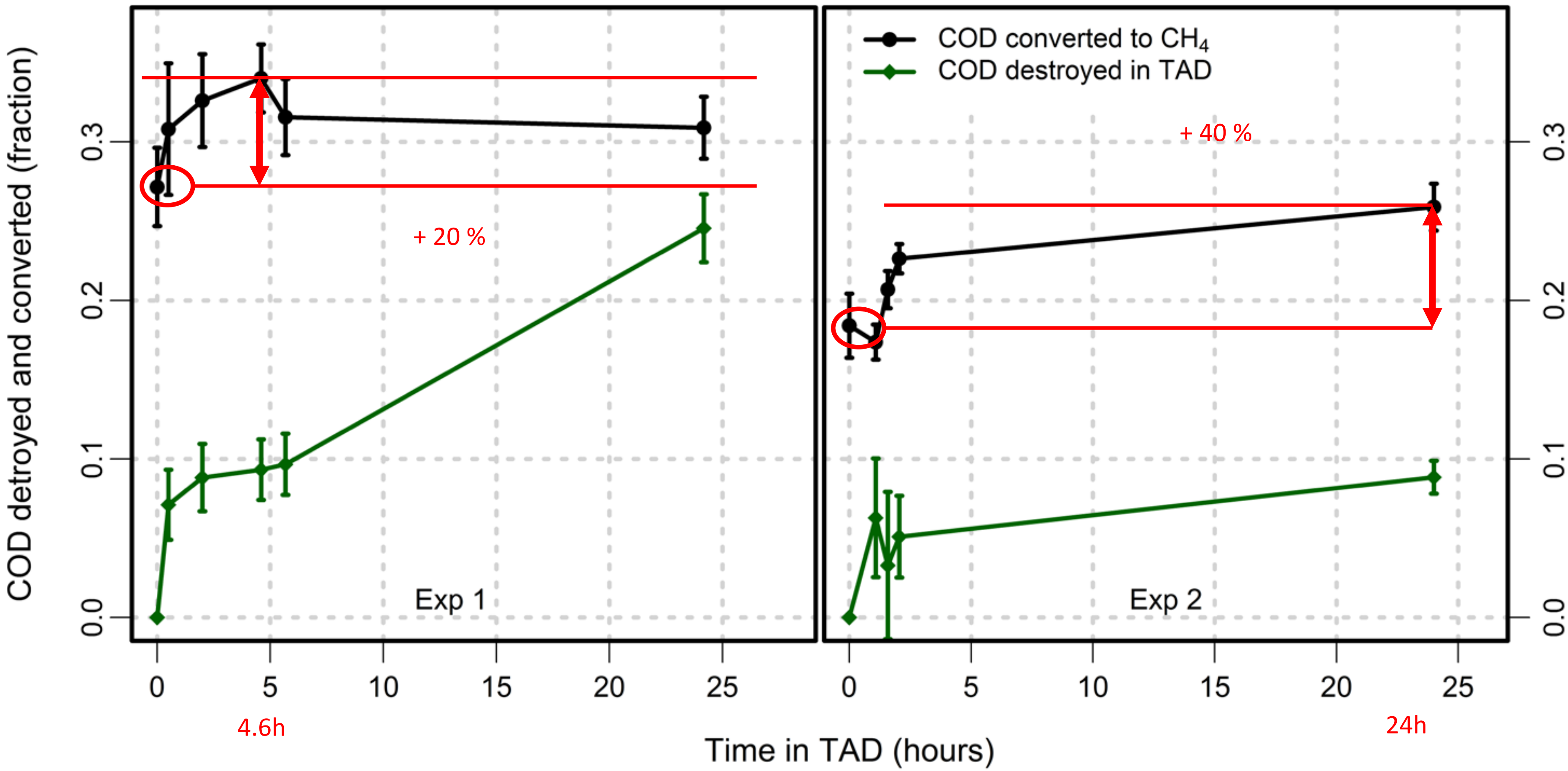
3-4°C 5h-3days

55°C 5h-2days

37°C
20 days

Inter-stage TAD: results

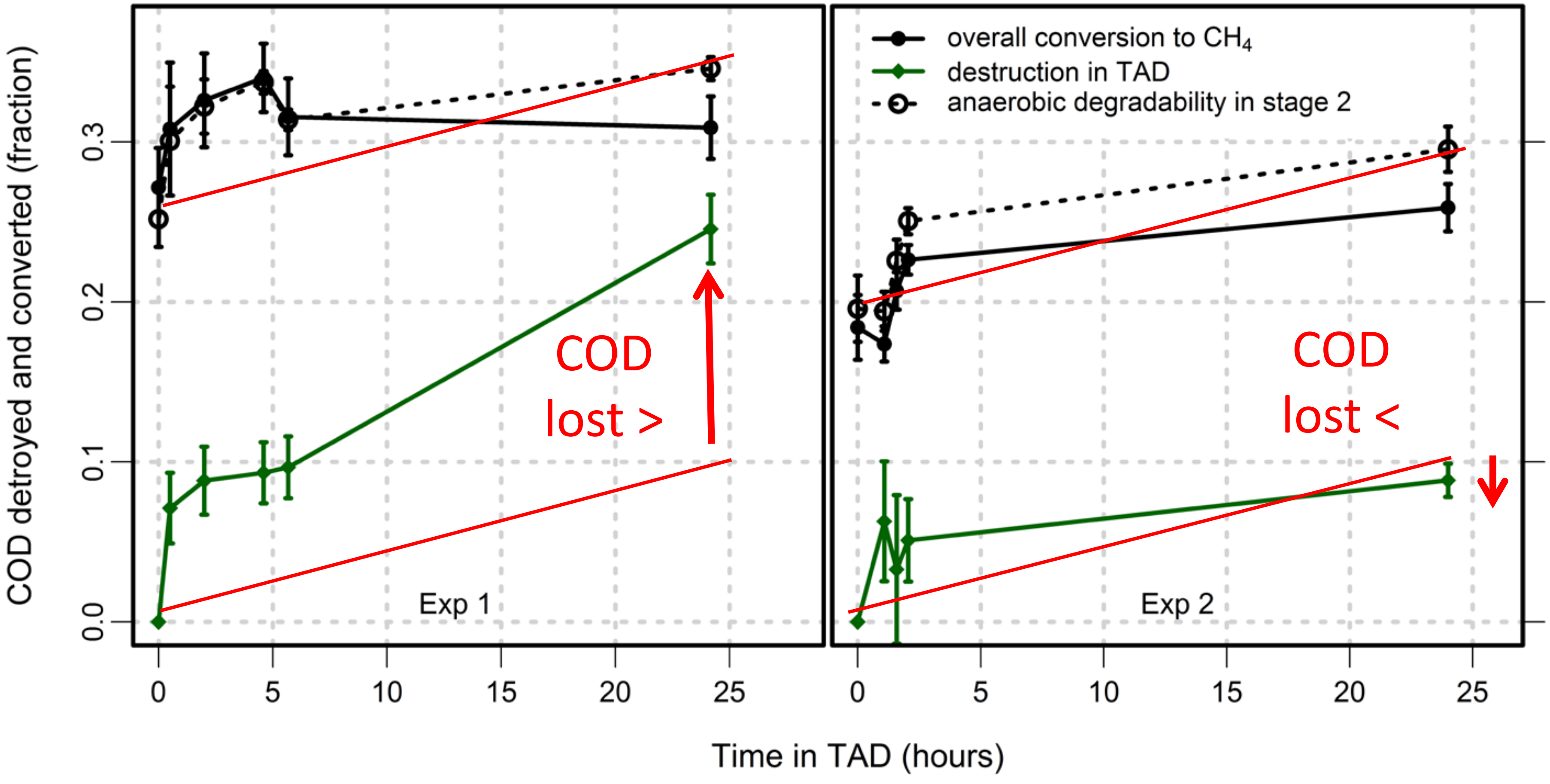
Effect on COD transformation



Overall improvement in methane production

Inter-stage TAD: results

Effect on anaerobic degradability



COD lost >

COD lost <

↑ Methane production = anaerobic degradability > COD lost

COENSILING

Synergetic co-fermentation effect of lignocellulosic and green biomass on biogas production

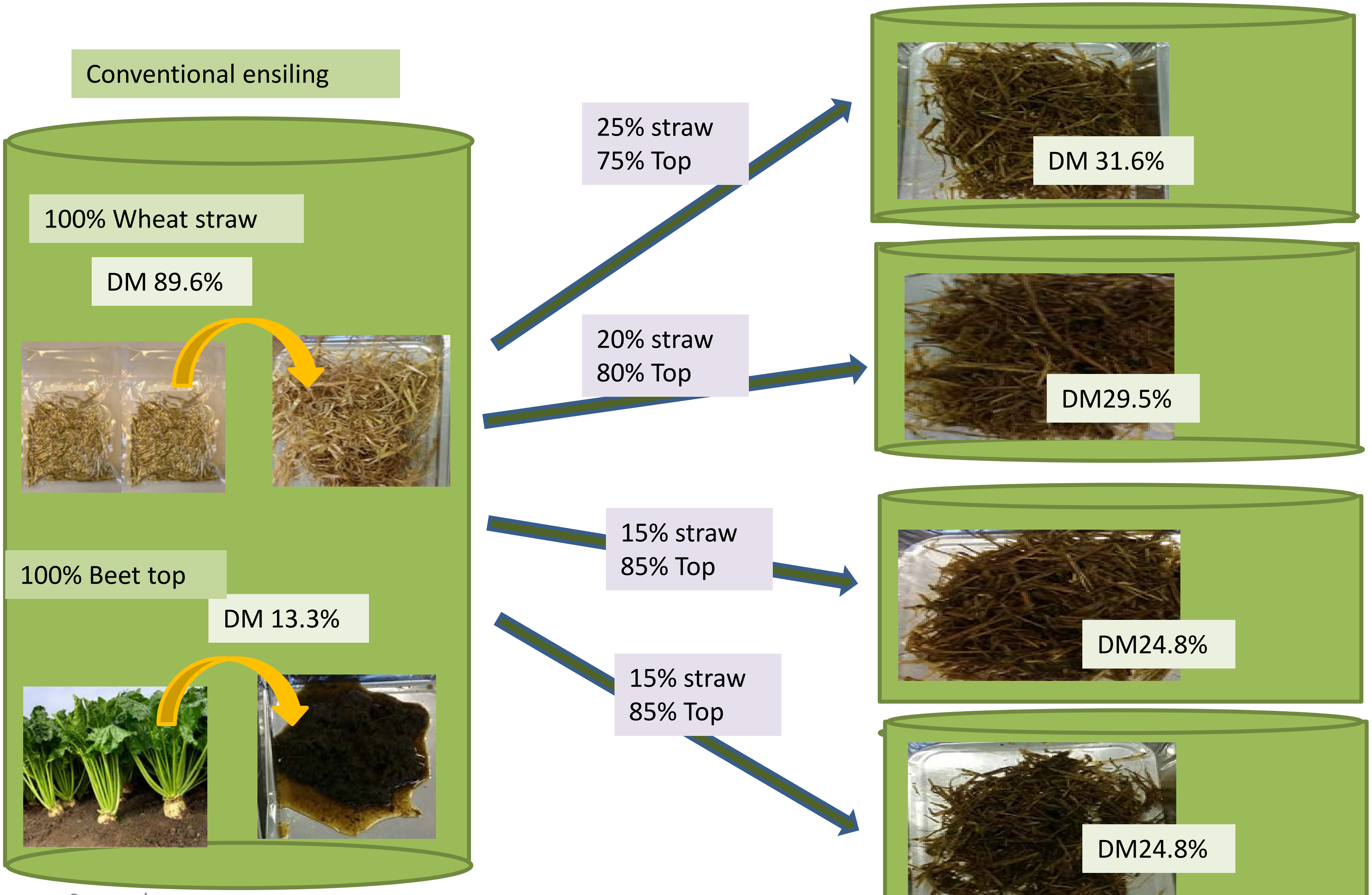
Fermentation pathway and gross energy losses during ensiling

Lactic Acid Bacteria	**Energy loss (%)**
Glucose, Fructose + 2ADP →2Lactate + 2ATP	0.7
Glucose + ADP → Lactate +EtOH + CO_2 + ATP	1.7
2Citric acid + ADP → Lactate + 3 Ace + 3CO_2	1.5
Malate → Lactate + CO_2	1.8

Clostrida	
2Lactate + ADP → Butyrate + CO_2 + 2H_2 + ATP	18.4

Yeast	
Glucose + ADP → 2EtOH + 2CO_2 + ATP	0.2

Pretreatment -Synergetic co-fermentation



Conventional ensiling

100% Wheat straw

DM 89.6%

100% Beet top

DM 13.3%

25% straw
75% Top

DM 31.6%

20% straw
80% Top

DM29.5%

15% straw
85% Top

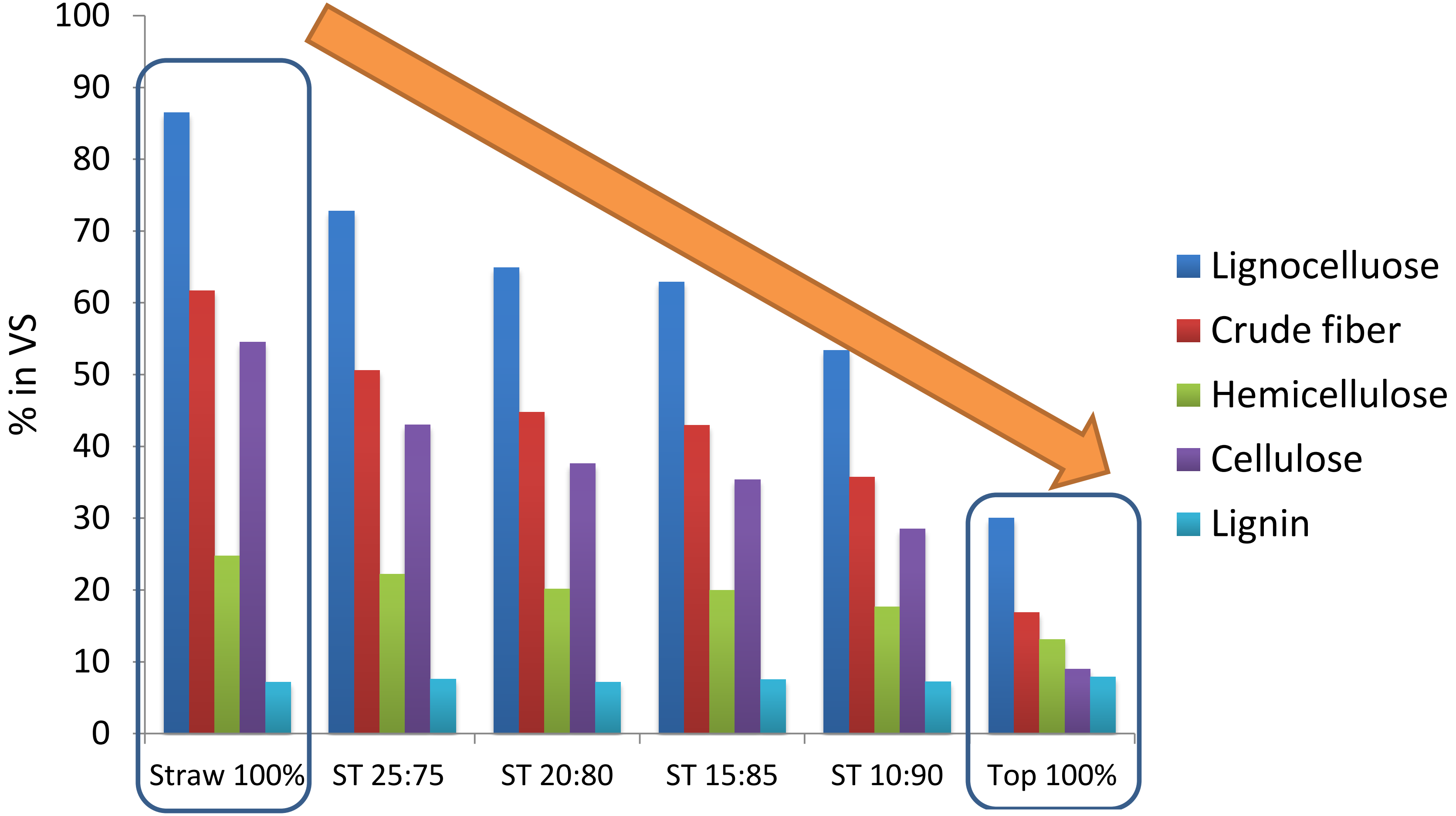
DM24.8%

15% straw
85% Top

DM24.8%

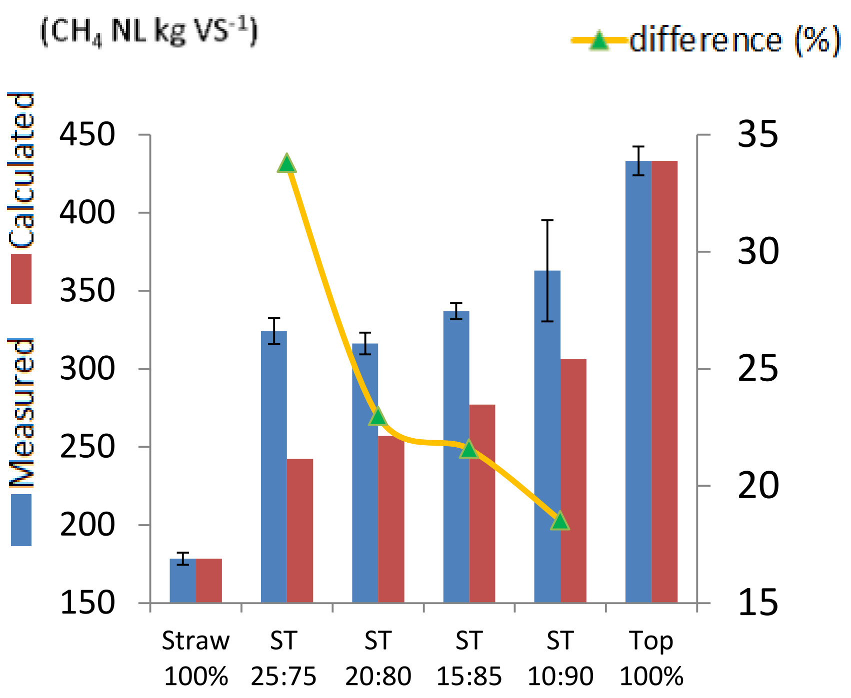
Carbohydrate biopolymers content

Wheat straw (Low moisture + high lignocellulose)
Suger beet top (High moisture + Low lignocellulose)

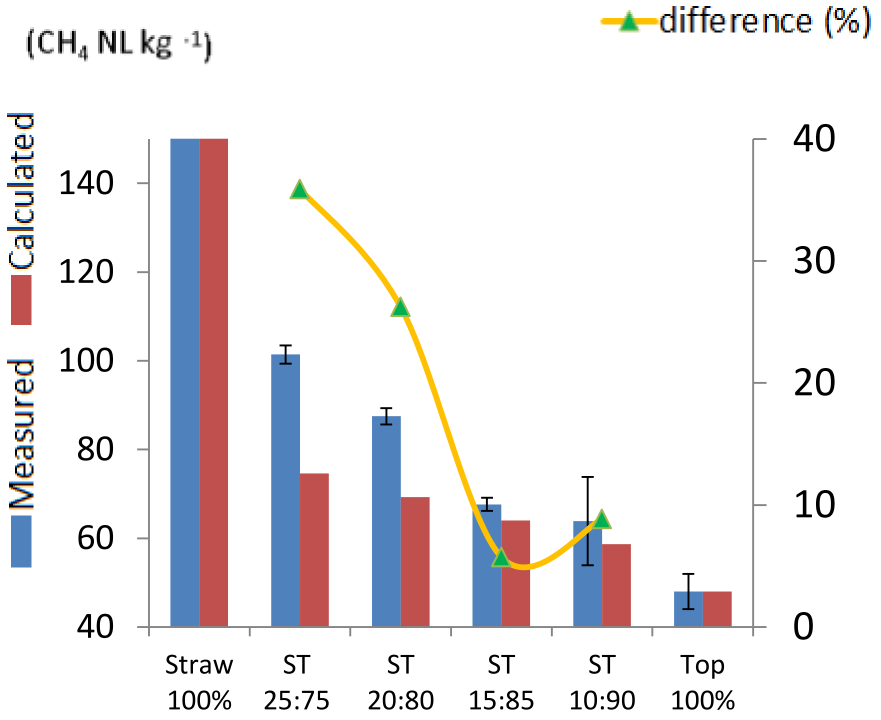


Increased methane yield

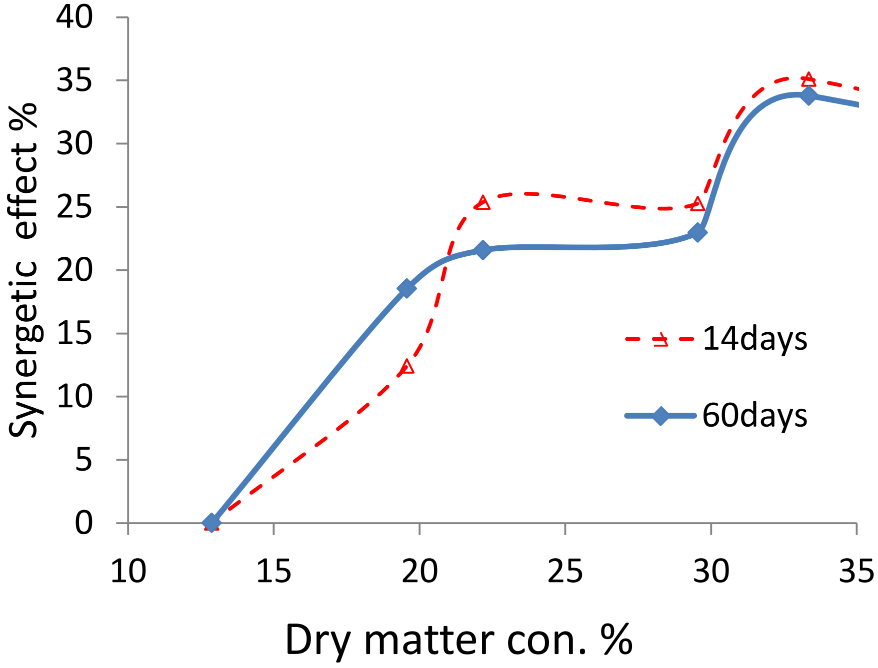
Maximum Methane yield per kg VS



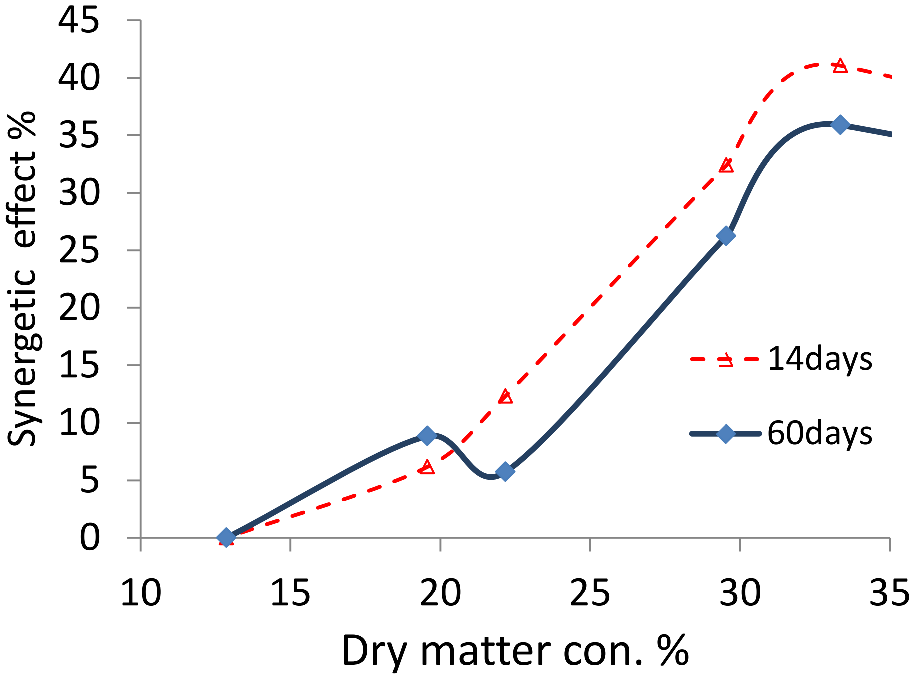
Maximum Methane yield per kg silage



Synergetic effect VS dry matter



Increased methane yield (%) (per kg VS)



Increased Methane yield (%) per kg silage)

- ❑ Great effect on increasing methane yield and biodegradability
  *Increased gas yield: CH_4 NL kg^{-1} : 35.1%

- ❑ Promising biological pretreatment method