

Venice 2010 THIRD INTERNATIONAL SYMPOSIUM ON ENERGY FROM BIOMASS AND WASTE

PRE-TREATMENT EXPERIMENTS FOR THE USE OF *CYNARA CARDUNCULUS L.* AS A SUBSTRATE FOR THE PRODUCTION OF BIOGAS



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CYNARA CARDUNCULUS L.



Mediterranean perennial crop with annual growth cycle, sprouting every autumn (10 months period).

Adapted to dry and hot regions, it is an crop for biomass production.

The deep rooting system allows exploitation of profile (up to 7m depth).



Water stress strategy: the cardoon above-ground biomass dries off in summer.

- In scientific trials the average production is 20 tons/ha.year of dry material, with 40% stalks, 25% leaves, and 35% capitula.

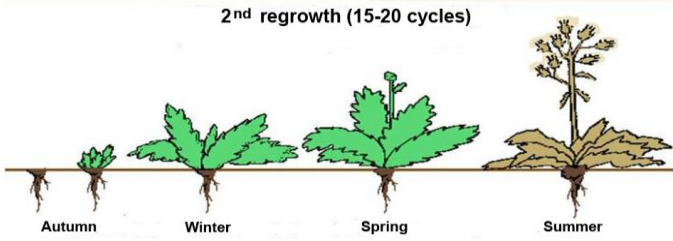
[Gominho and Pereira, 2008]







CYNARA CARDUNCULUS L.



2nd regrowth (15-20 cycles)



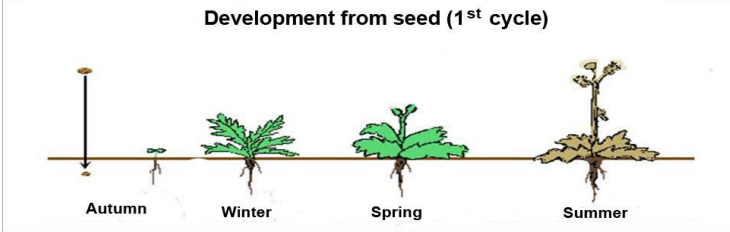









[Gominho and Pereira, 2008]

CYNARA CARDUNCULUS L.





Development from seed (1st cycle)




[Gominho and Pereira, 2008]




The biomass produced in the successive phases of the growth cycle has different potential uses such:


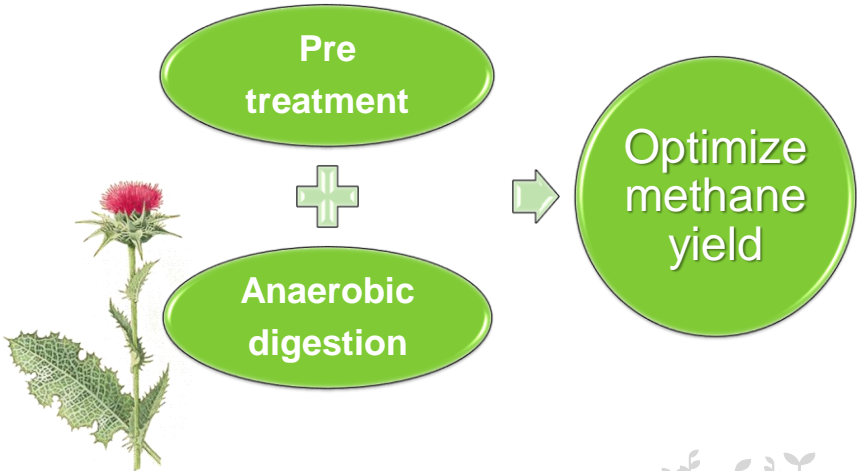


- Solid bio-fuel
- Food oil
- Biodiesel
- Paper and pulp
- Fiber boards
- Drugs (cynarine, silymarine, antioxidants)
- Green fodder
- Rennet for cheese-maker
- Fresh/processed vegetable
- Gardening

[Gominho and Pereira, 2008]




Objective





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graph LR
    Plant[Thistle Plant] --> Pre[Pre treatment]
    Pre --> Plus[+]
    Plus --> Ana[Anaerobic digestion]
    Ana --> Arrow[→]
    Arrow --> Yield((Optimize methane yield))
  
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Material and methods



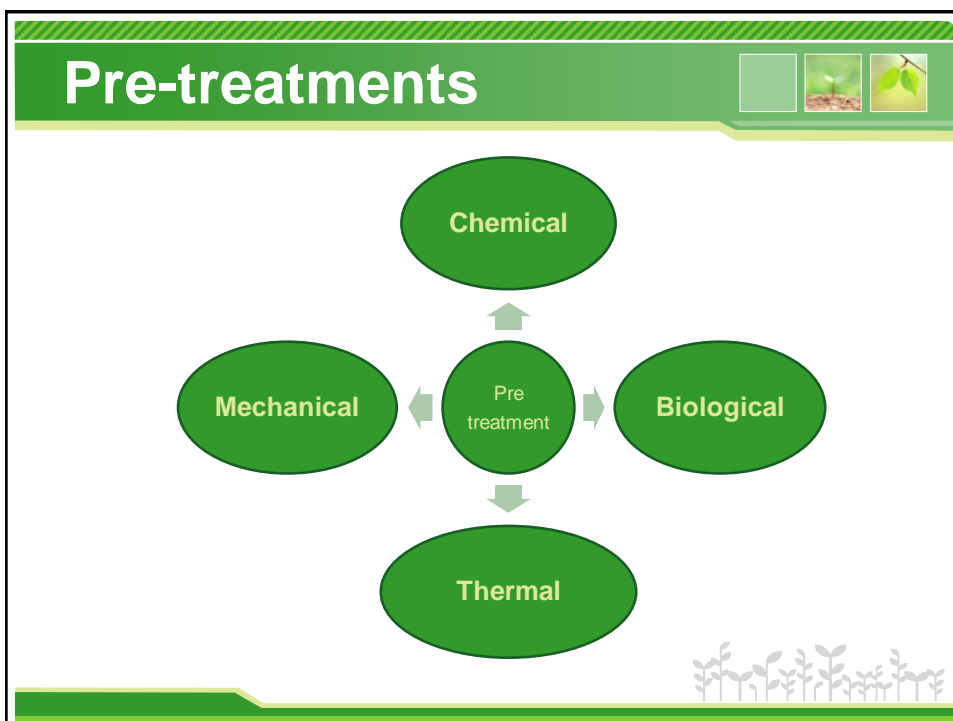


Substrat

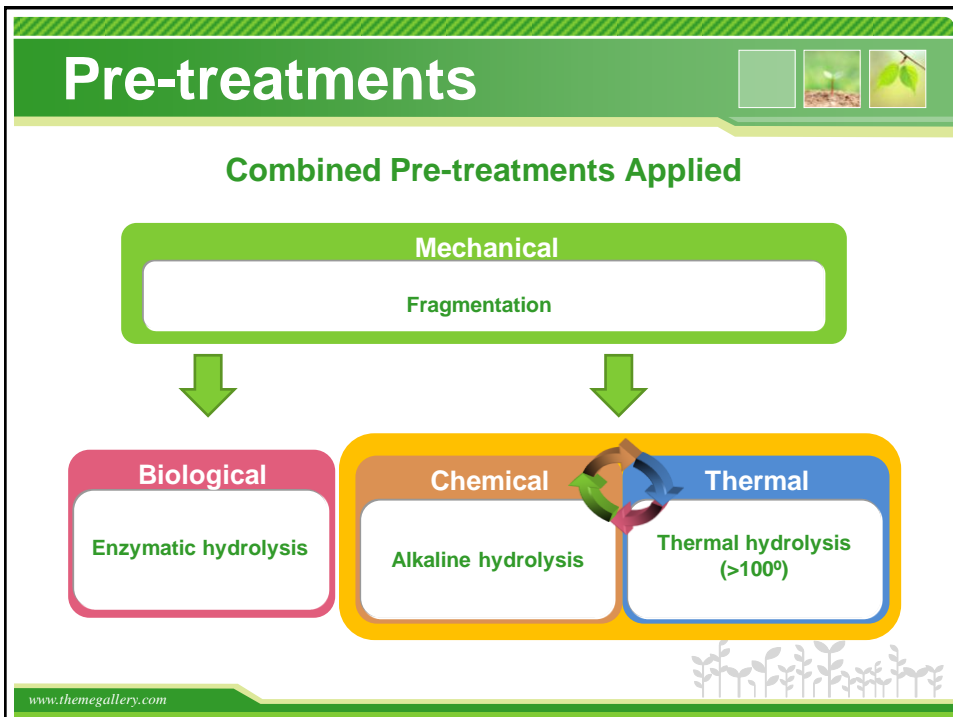
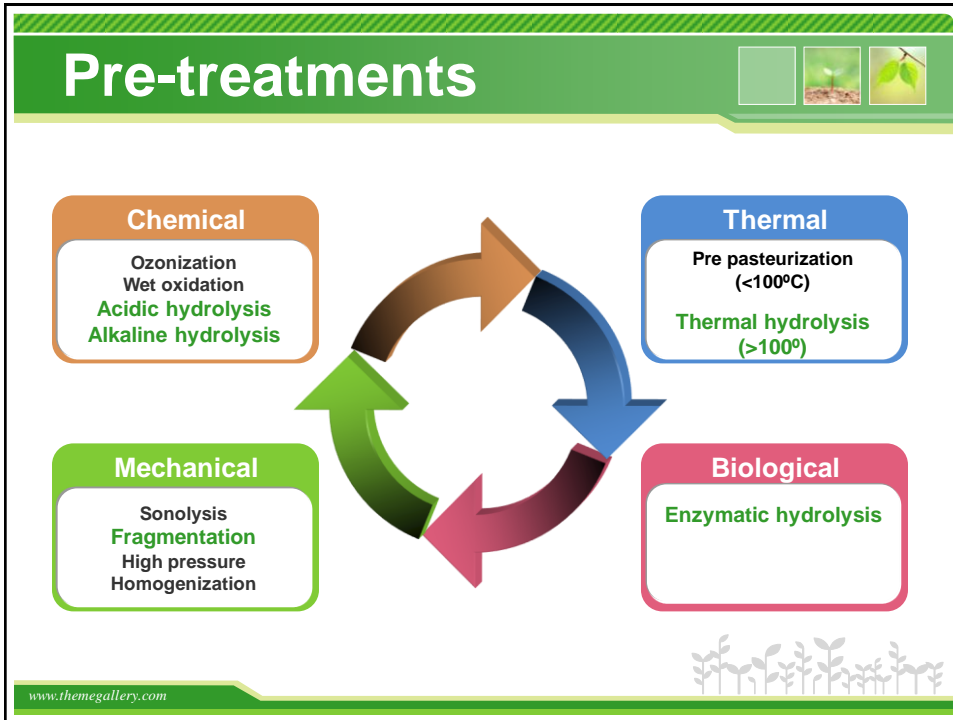
- *Cynara cardunculus* L. stalks (ISA experimental field)



Inoculum

- WWTP (Lisbon) sludge from anaerobic digester





Batch experience



Two Batch systems



300 ml working volume
12 days of incubation time (37 °C)



Batch experience



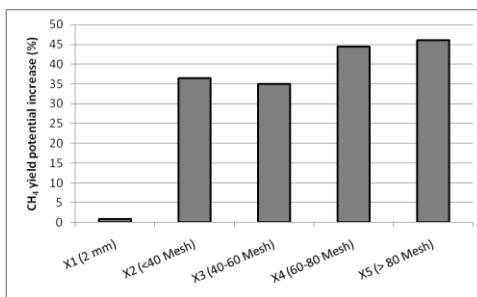
2000 ml working volume
33 days of incubation time (37 °C)



Batch experience: Influence of Mechanical Pre-treatment



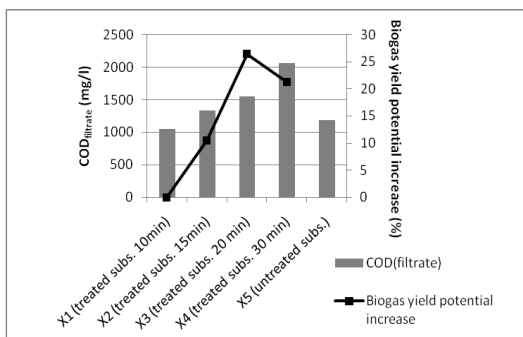
Mechanical: *Cynara* stalks particle fragmentation



Batch experience: Influence of Thermal Hydrolysis



Different reaction times: 10 min (X1), 15 min (X2), 20 min (X3), 30 min (X4) and 0 min (X5) were tested at 160 °C.



10 min



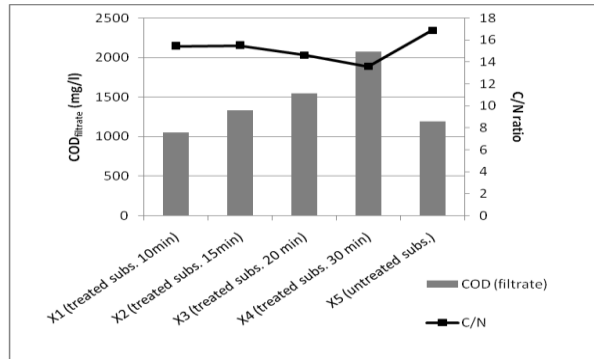
15 min



Batch experience: Influence of Thermal Hydrolysis



Influence of Thermal pre-treatment time on carbon solubilization and on C/N ratio



Batch experience: Influence of Thermal Chemical Pre-treatment



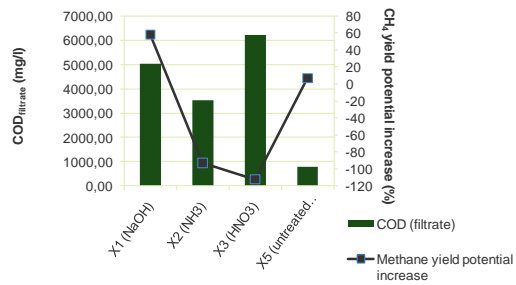
Different chemical solutions were used: NaOH (14%) (X1), NH₃(aq) (1.5%) (X₂), HNO₃ (1%) (X₃)



NH₃



HNO₃



Batch experience: Influence of enzymatic Pre-treatment on the anaerobic digestion process



Enzymatic pre-treatment (during 40 h and 60 h)



Celluclast

+

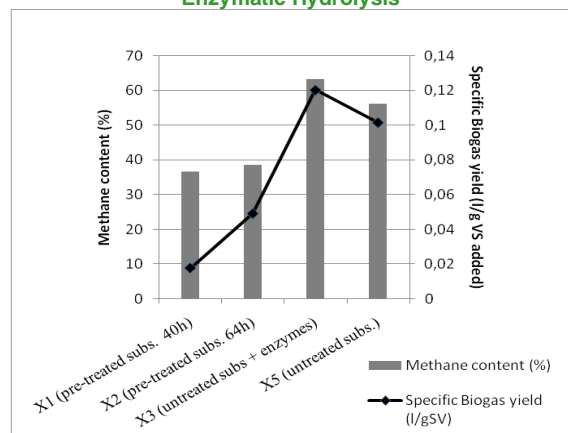
Novozymes 188



Batch experience: Influence of Enzymatic Hydrolysis



Enzymatic Hydrolysis






Methane content and Specific biogas yield obtained after 12 days of incubation time



Batch experience: Final assay

Thermal chemical pre-treatment with NaOH within 20 min of thermal (160 °C) reaction time.

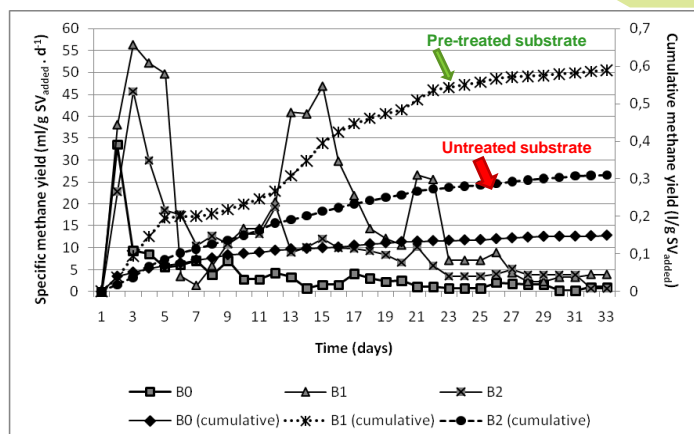


Batch experience: Final assay

	Pre-treated substrate	Untreated substrate
Before Anaerobic digestion		
After Anaerobic digestion		



Batch experience: Final assay



Specific and cumulative methane yield during the *Final assay* (B_0 -reactor containing inoculum, control; B_1 - reactor containing pre-treated substrate + inoculum; B_2 - reactor containing untreated substrate)

Conclusions

- ✓ The use of **cardoon stalks** as substrate **increased biogas production**;
- ✓ **Mechanical pré-treatment** lead to an increase of biogas and methane yield around 30% between 2 mm and 0.42 mm (40 mesh) particle sizes;
- ✓ **Chemical pre-treatment with NaOH** showed the best results in terms of carbon solubilization, VS reduction, biogas and methane yield increment;
- ✓ **Thermal chemical pre-treatment with NaOH** was very effective even for larger particle sized *Cynara* stalks;

Conclusions (cont.)



- ✓ **Thermal chemical pre-treatment with NaOH** improved the **biodegradability** of substrate, leading to an increment of biogas and methane yields;
- ✓ **Mechanical pre-treatment and the addition of enzymes** (exo-1,4- β -D-glucanase and endo-1,4- β -D-glucanase and 1,4- β -D-glucosidase) enhanced hydrolyses of the substrate improving inoculums efficiency however more experiments are required within higher incubation time.



Future Research



Despite the results achieved in the Final assay in terms of cumulative methane yield, there is still research work to be developed in terms of validating the most suitable pre-treatment for *Cynara cardunculus* L. in Mediterranean countries and test it in a pilot-scale.



