

Pyrolysis of residual biomass: Biochar conversion yield and synthesis gas quality

M. Poppenwimmer¹, H. Raupenstrauch¹, R. Muñoz² & R. Navia^{2,3}

¹Chair of Thermal Processing Technology, University of Leoben, Austria

²Scientific & Technological Nucleus in Bioresources, University of La Frontera, Temuco, Chile

³Department of Chemical Engineering, University of La Frontera, Temuco, Chile



Introduction



Fondef Project D07I1096

TECHNOLOGICAL BASIS FOR THE DEVELOPMENT OF THE ECOFERTILIZERS INDUSTRY THROUGH THE USE OF BIOCHAR PRODUCED FROM RESIDUAL BIOMASS



Problems & Opportunity

In-situ residual biomass burning

- Most of the agricultural biomass wastes are being burned in-situ after harvesting.
- 1 burned ton of biomass generates about 1,5 ton CO₂ to the atmospheric environment.

Acid soils

- 5,1 million ha volcanic ash-derived soils for agricultural use in the South of Chile, from which a high percentage is acid.

Nitrogen-based fertilizers

- Low nitrogen efficiency use by current fertilizers in agricultural soils (40%)
- Up to 3 times nitrogen dosage in forestry soils

Forest & agriculture residual biomass

- At least up to 1.0 million ton/y residual agricultural biomass (in the Araucanía Region)
- At least up to 1.5 million ton/y residual forestry biomass (in the Araucanía Region)

Residual biomass samples

Wheat straw



Oat shell



Wheat shell



Oregon pine



		oat shell	oregon pine	wheat shell	wheat straw
Dry Substance DS	[%]	91.7	85.2	89.0	91.7
Moisture Content	[%]	8.3	14.8	11.0	8.3
Glowing Loss	[%]	87.1	82.4	93.9	94.2
Ash Content of DS	[%]	12.9	17.6	6.1	5.8
Fuel Value H_O of DS	[kJ/kg]	18662	19957	19167	18275
Calorific Value H_U of DS	[kJ/kg]	17198	18291	17516	16897
Calorific Value H_U of original substance	[kJ/kg]	15558	15232	15322	15299
Carbon C of DS	[%]	47.45	50.58	46.10	46.57
Hydrogen H of DS	[%]	5.60	5.51	5.95	5.28
Nitrogen N of DS	[%]	0.19	0.00	2.66	0.31
Total Sulfur Compound S_{tot} of DS	[%]	0.01	0.01	0.21	0.06
Chlorine Content Cl of DS	[%]	0.17	0.10	0.21	0.51
Volatile Components of DS	[%]	72.19	73.56	70.99	71.48

Pyrolysis laboratory trials



Temperature: 310°C
Time: 2 h
Particle size: 1.4 - 2.4 mm

Biochar conversion yield

/heat straw



/heat shell



Oregon pine



Oat shell



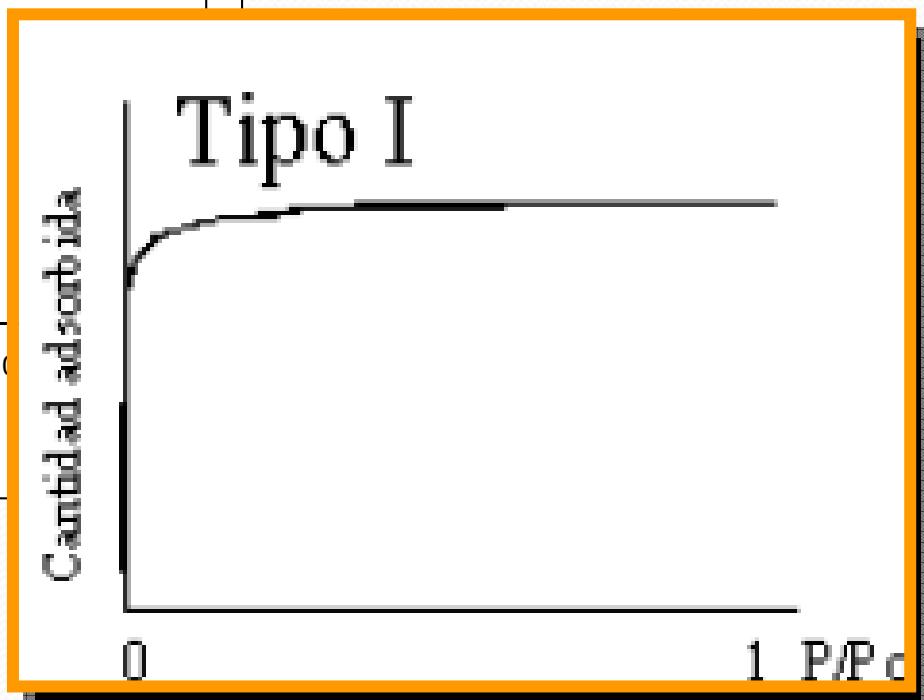
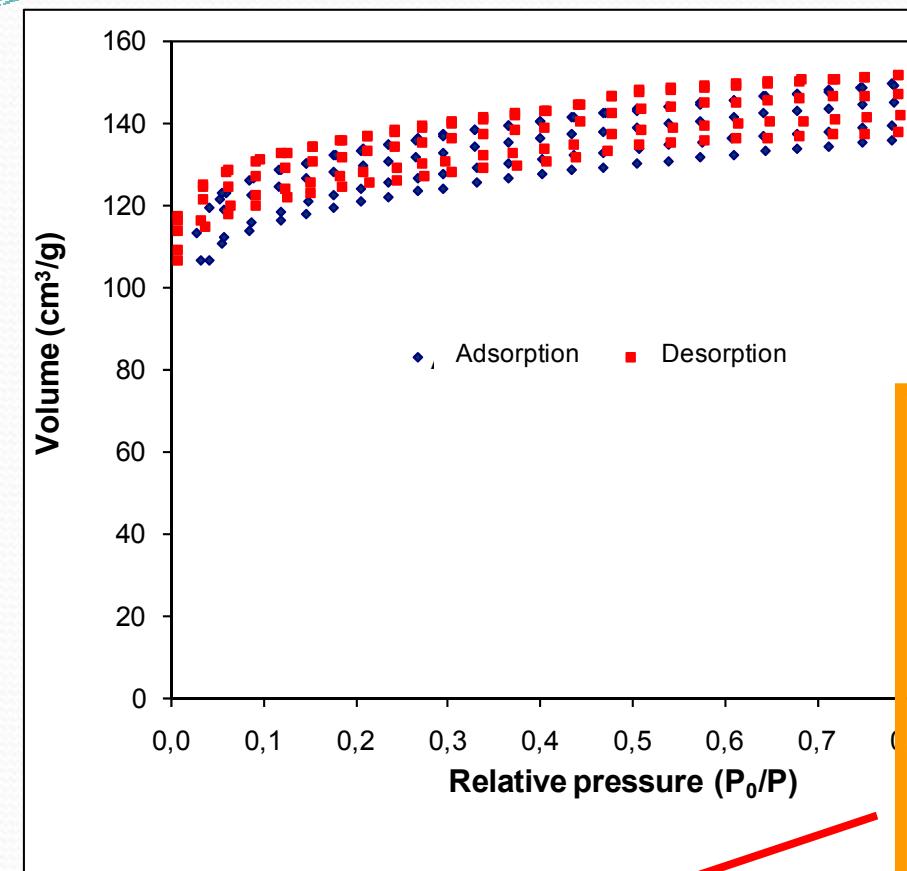
Sample	Biochar conversion yield (%)
Wheat straw	59,6 ± 1,0
Wheat shell	53,1 ± 2,6
Oregon pine	59,2 ± 0,1
Oat shell	53,2 ± 3,2

Biochar quality

Specific surface area
Pore volume
Pore size distribution

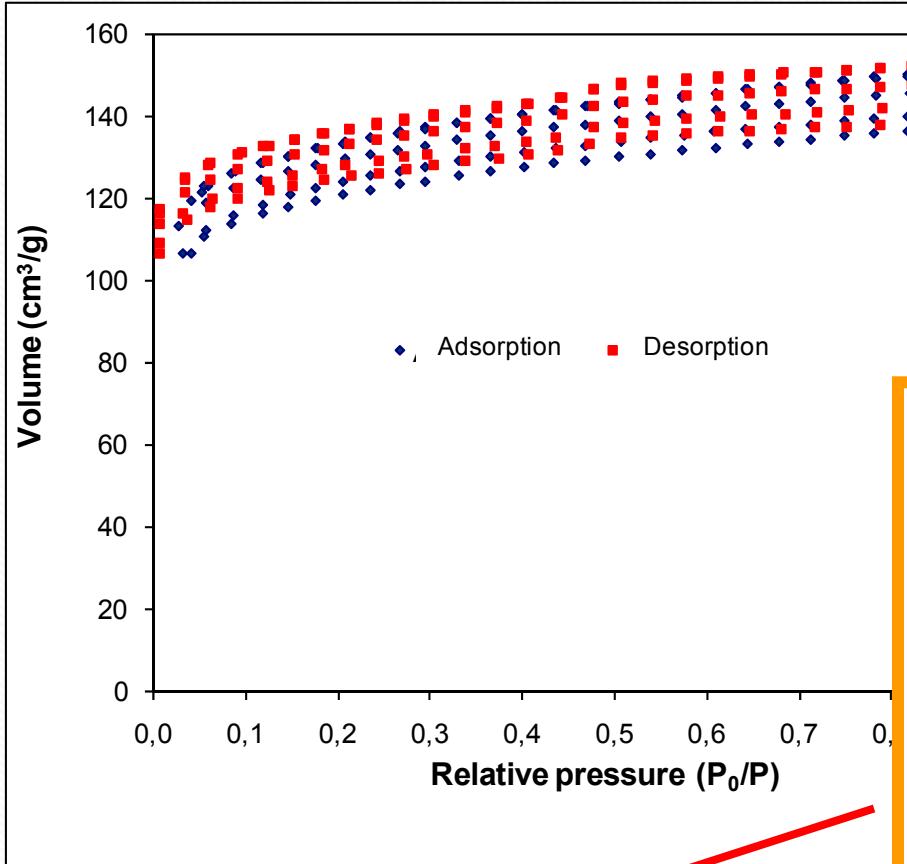


Biochar quality: N₂ adsorption isotherm

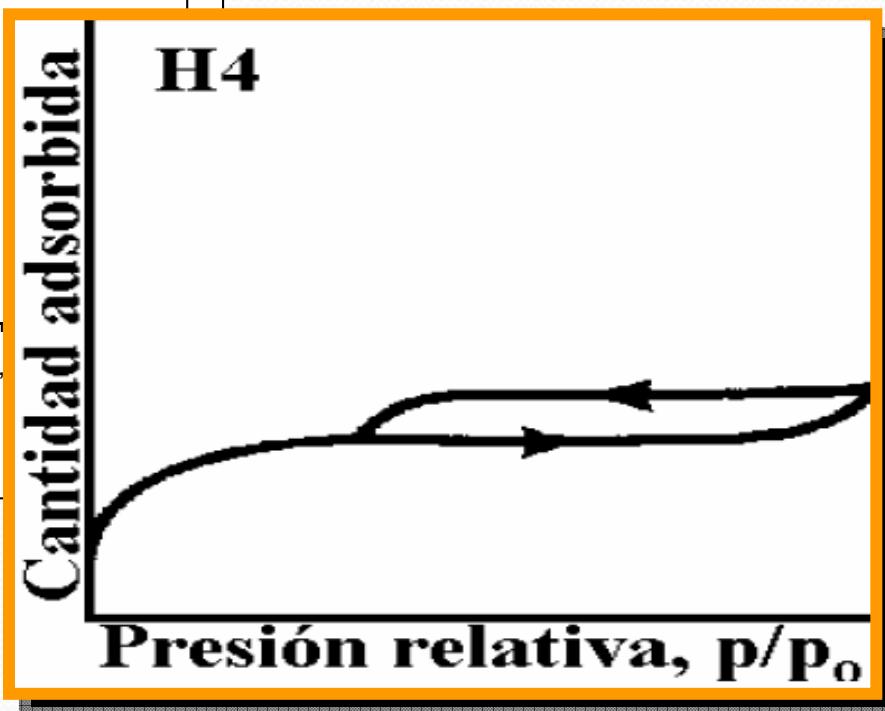


IUPAC: Microporous solid
(Equivalent diameter < 20 Å)

Biochar quality: hysteresis



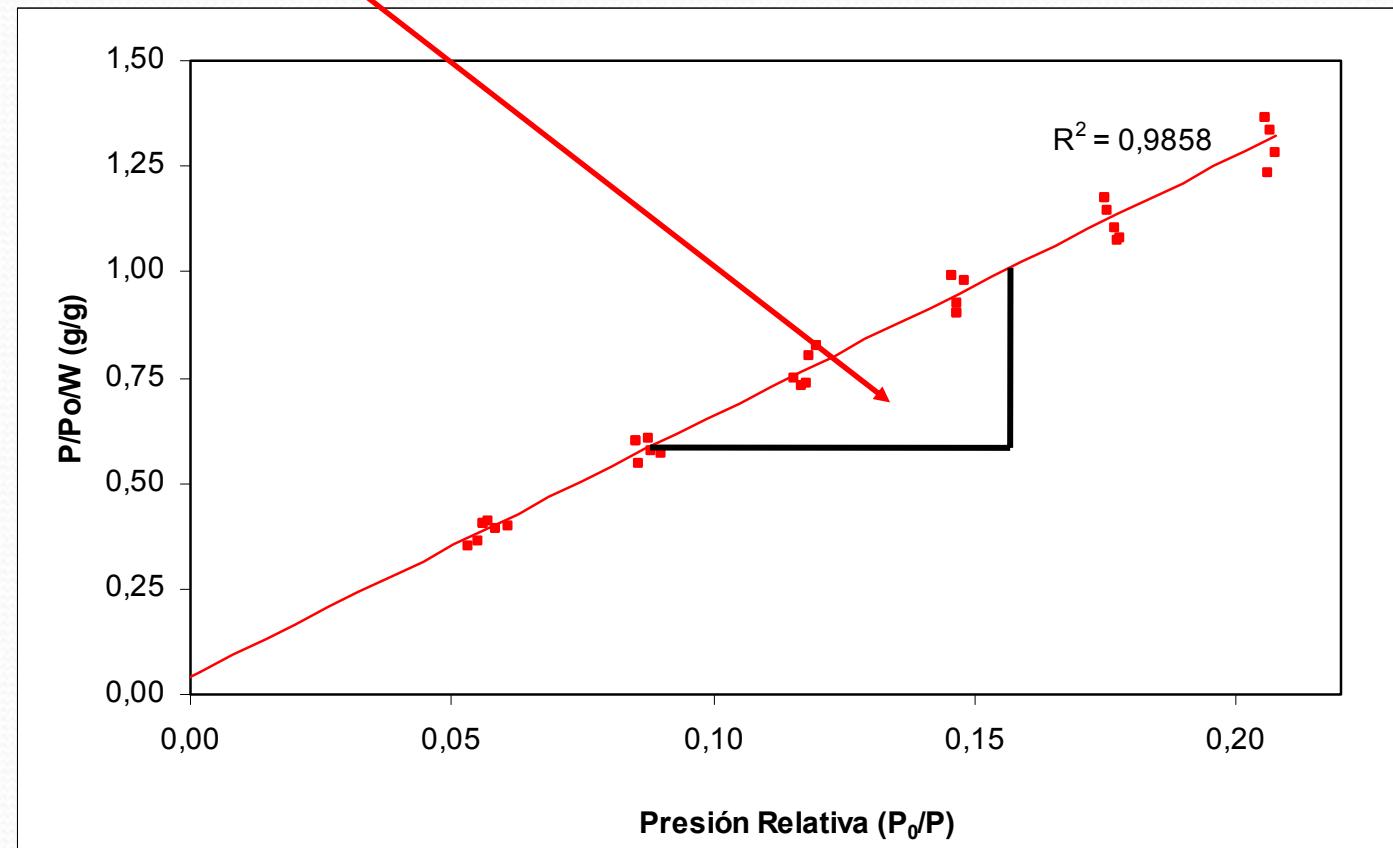
IUPAC: Typical from carbons



Biochar quality: Specific surface area

Langmuir model

$$\frac{P / P_0}{W} = \frac{1}{CW_m} + \frac{P / P_0}{W_m}$$



Biochar quality: Specific surface area

$$S_t = \frac{W_m N A_{cs}}{M}$$

W_m: adsorbate monolayer weight (N₂)

N: Avogadro number

A_{cs}: Cross sectional area of a N₂ molecule

M: Molecular mass of N₂

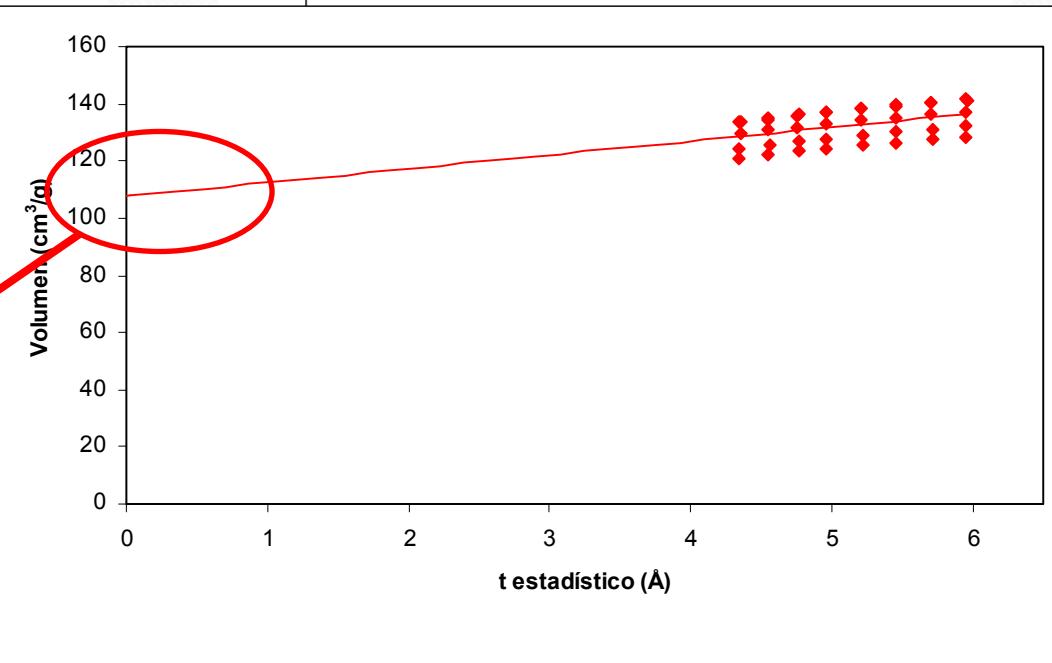
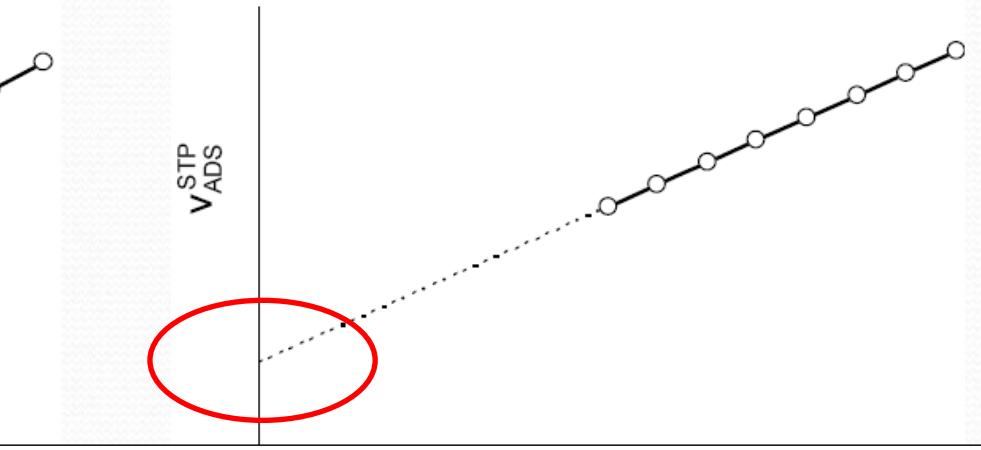
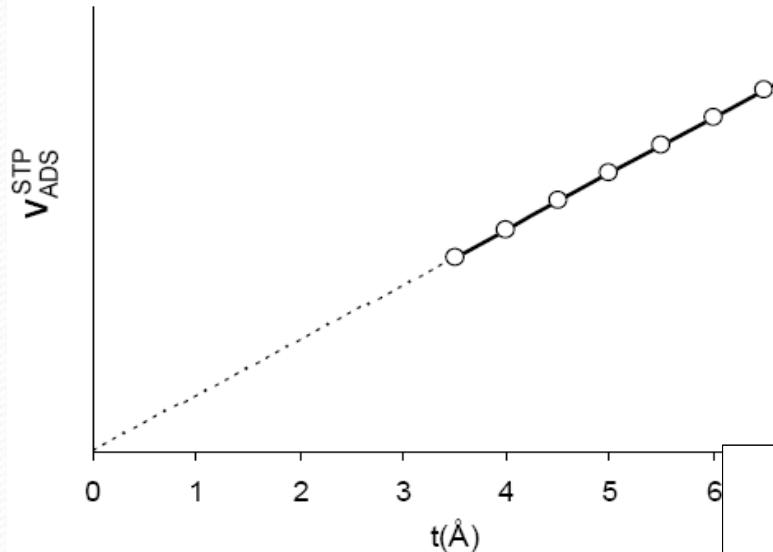
S_t: Total surface are of the sample

Specific surface area: 578 m²/g

Internal area: 503 m²/g

External area: 75 m²/g

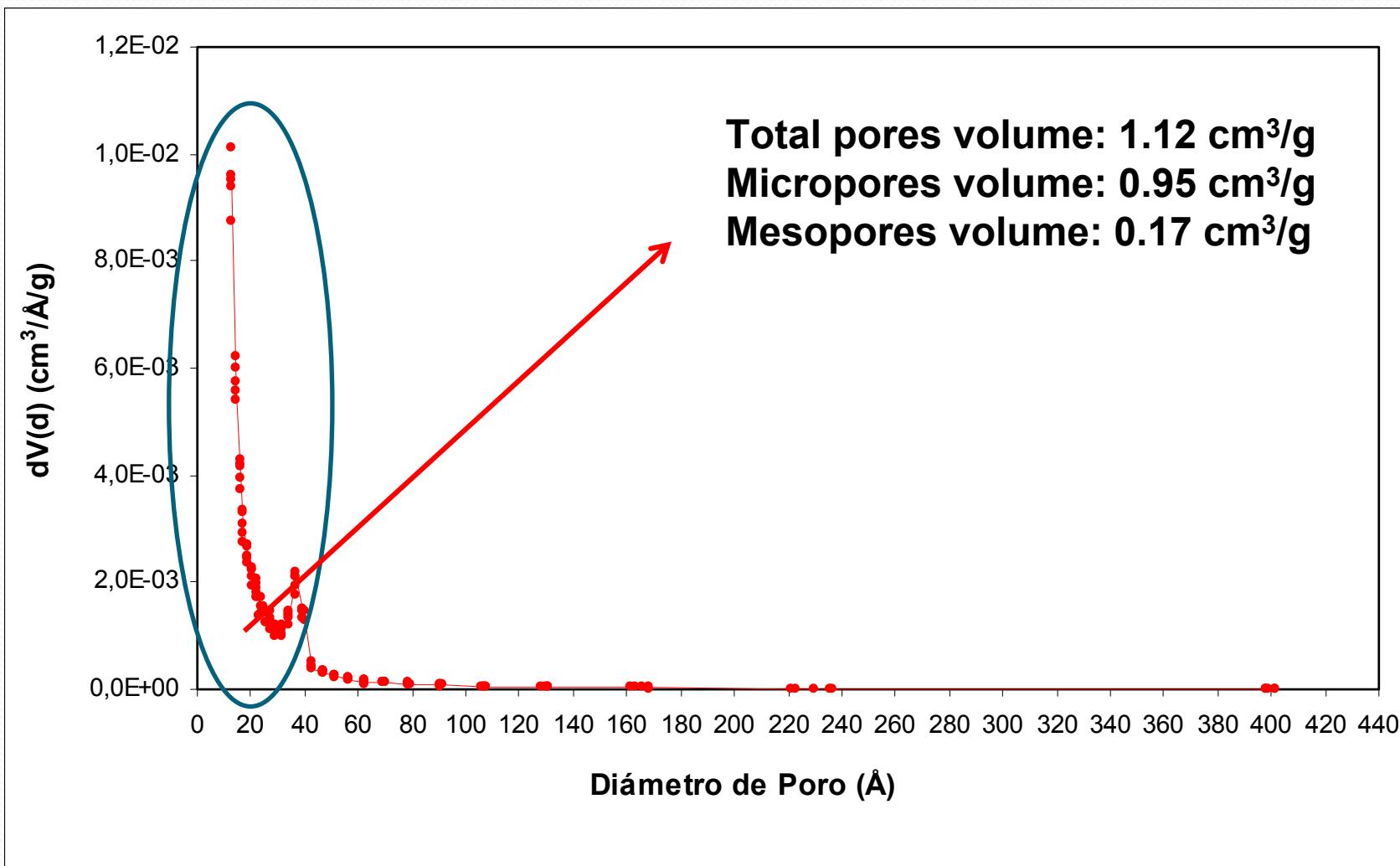
Biochar quality: Micropores volume (de Boer Method)



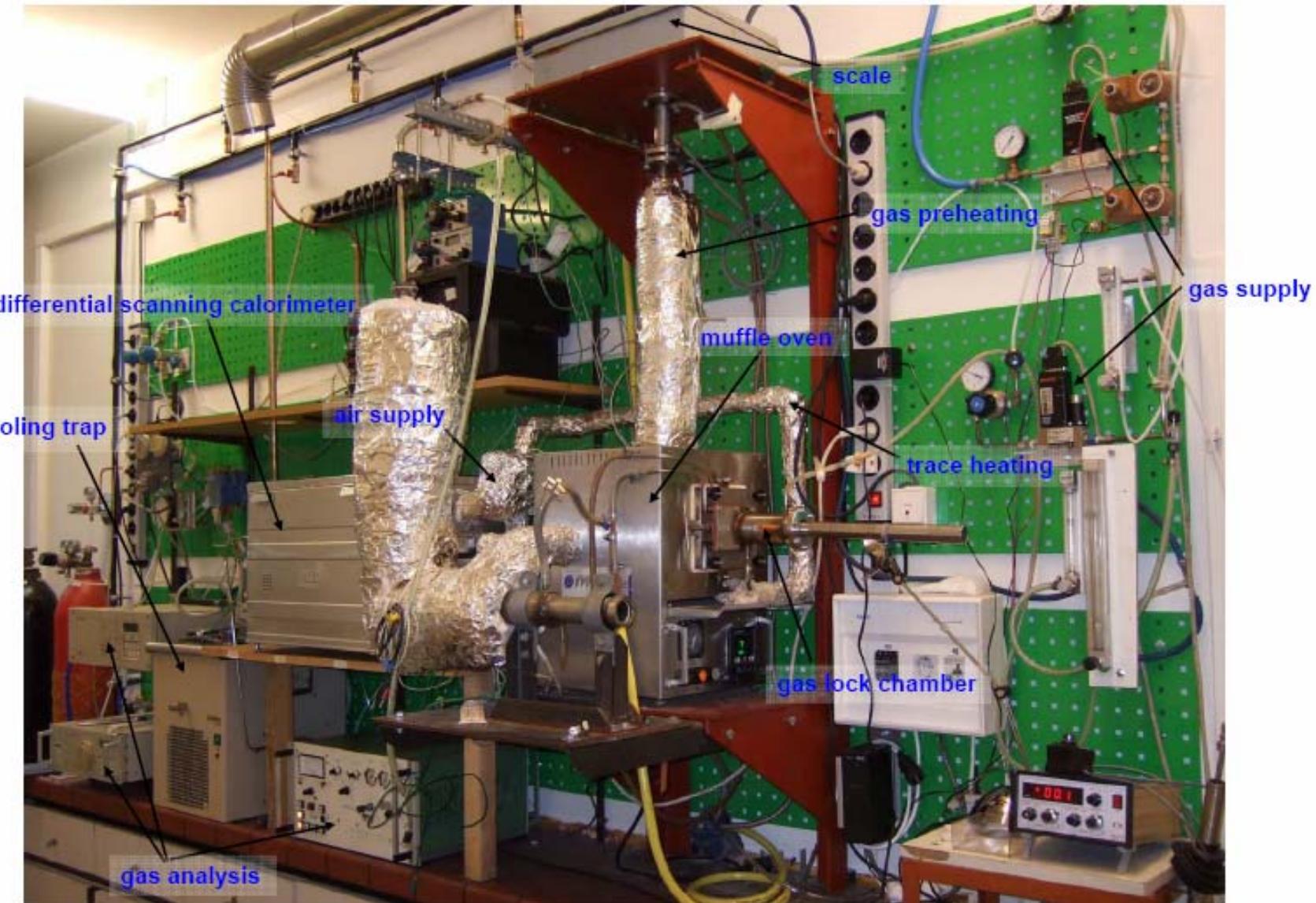
Micropores volume: $0.95 \text{ cm}^3/\text{g}$

Biochar quality: Total pore volume & pore size distribution

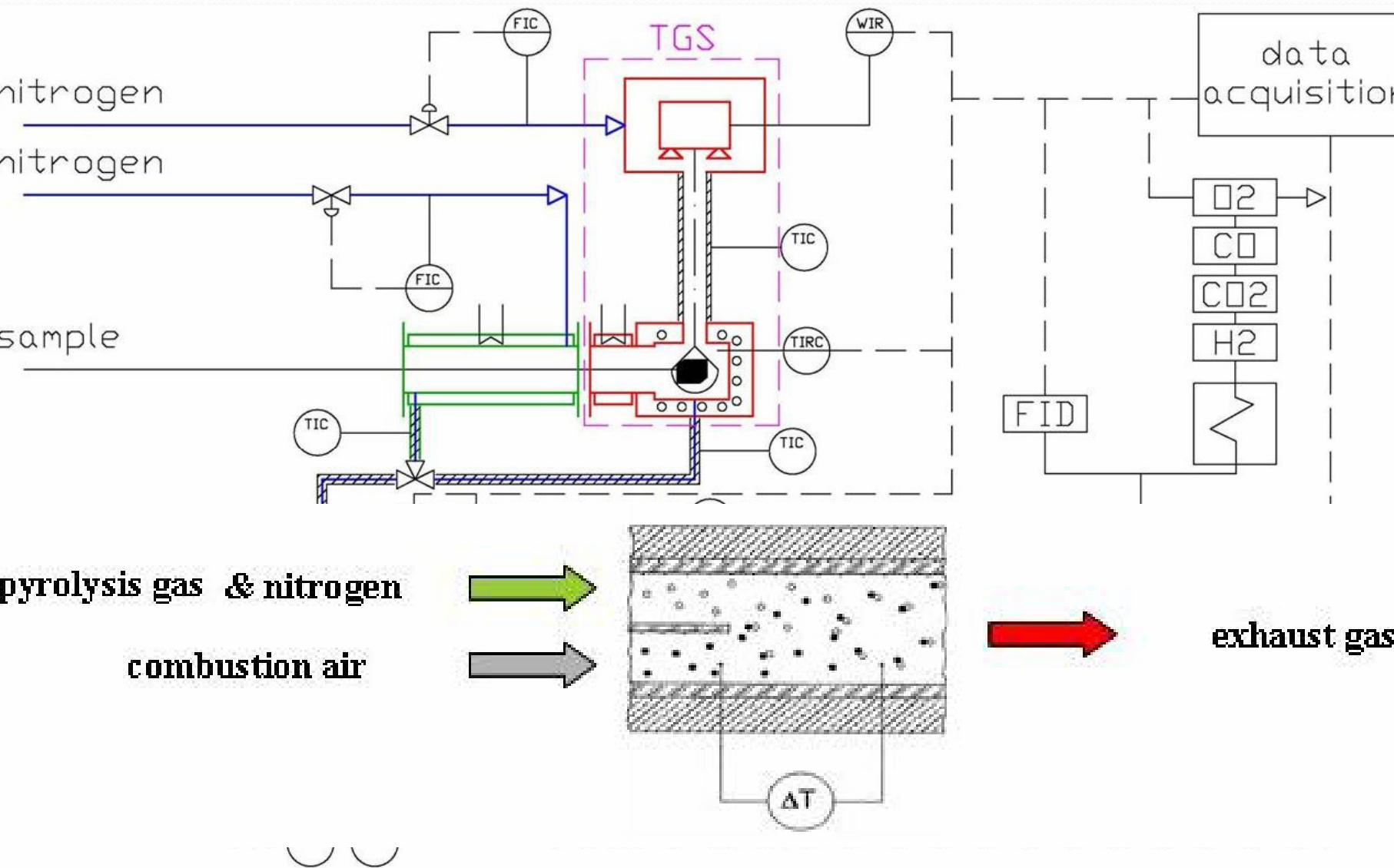
Barrett, Joyner & Halenda (BJH) Method



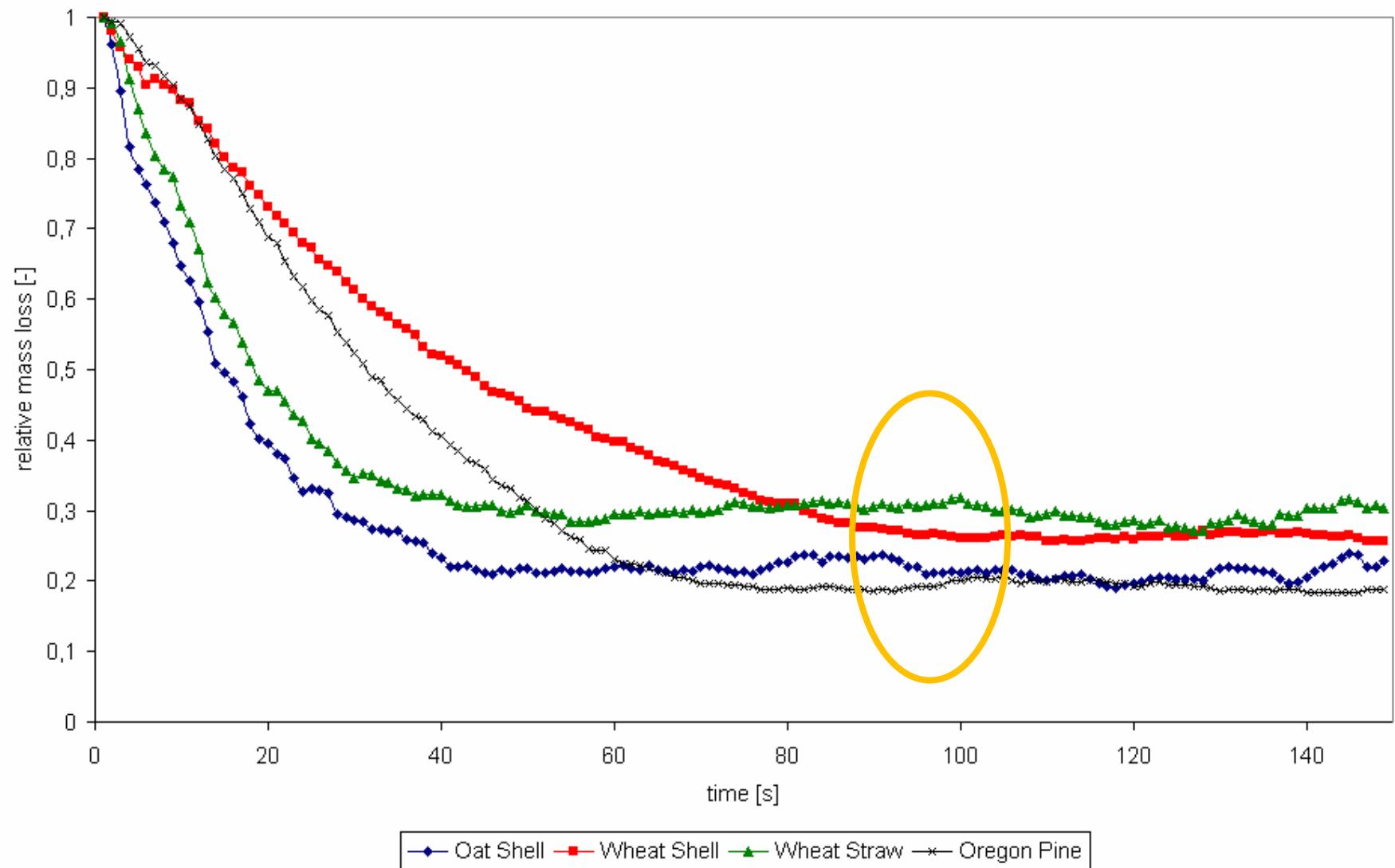
Syngas quality: Thermogravimetric scale (TGS) and differential scanning calorimeter (DSC)



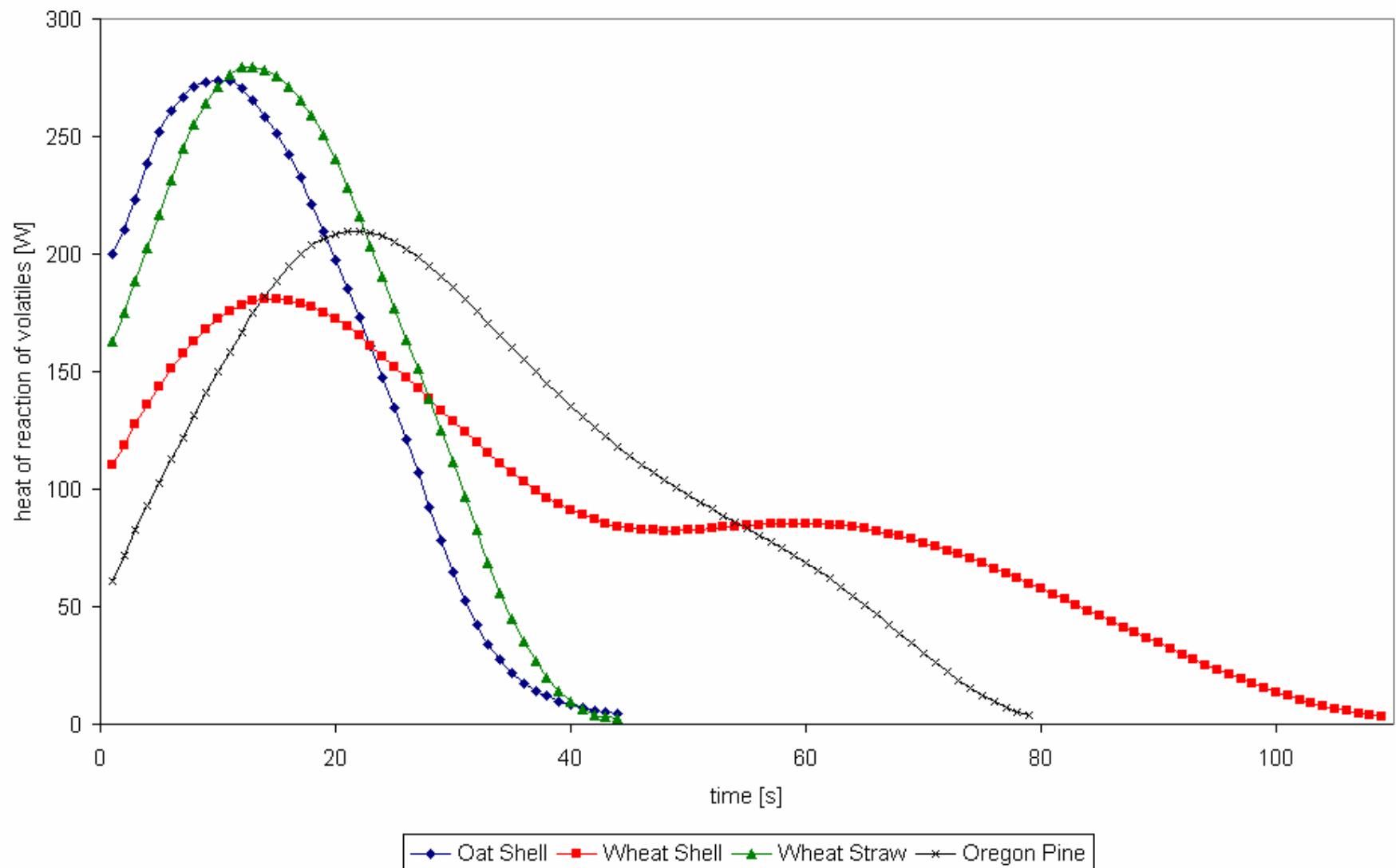
Syngas quality: Thermogravimetric scale (TGS) and differential scanning calorimeter (DSC)



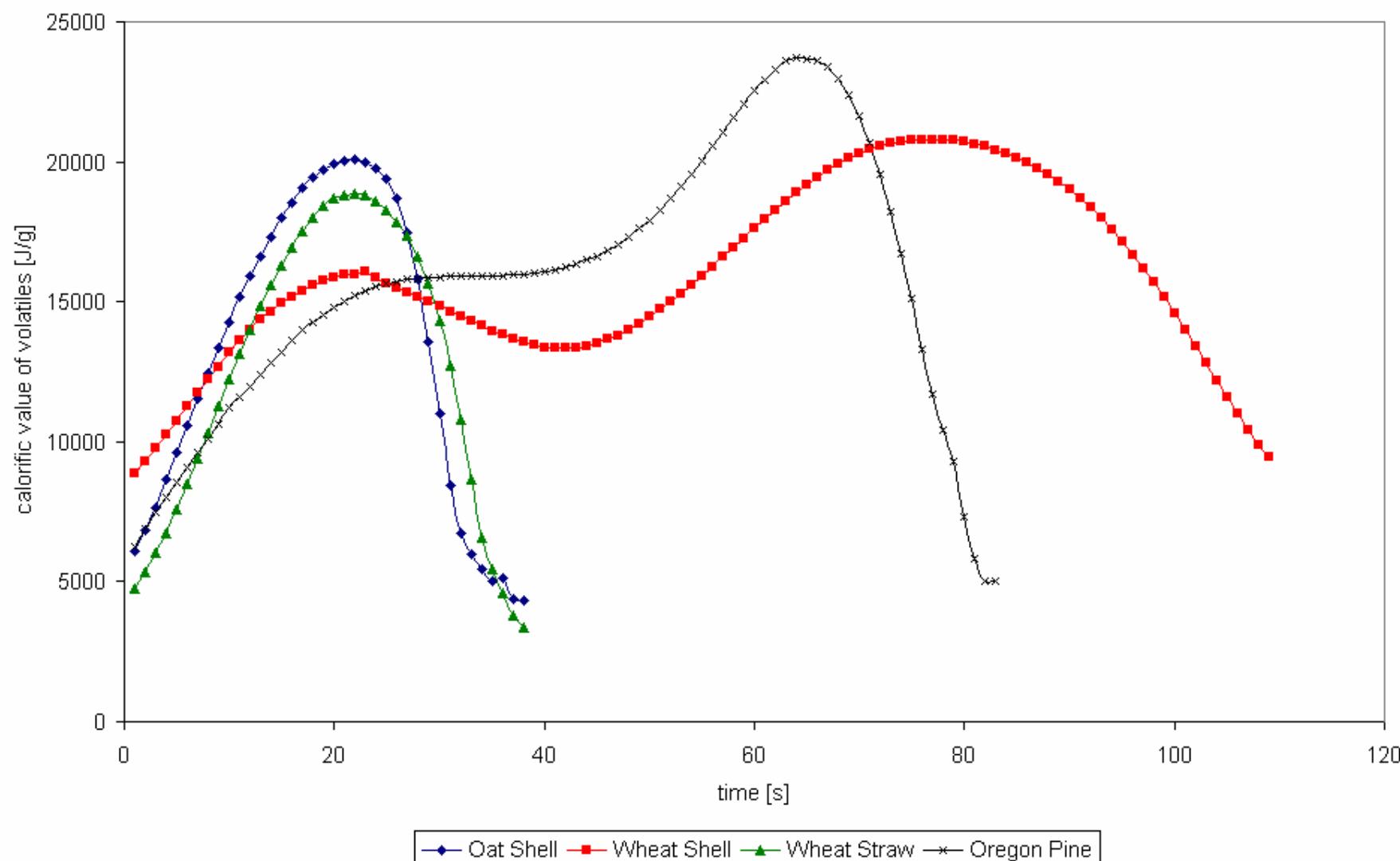
TGS-DSC technique: mass loss (all samples)



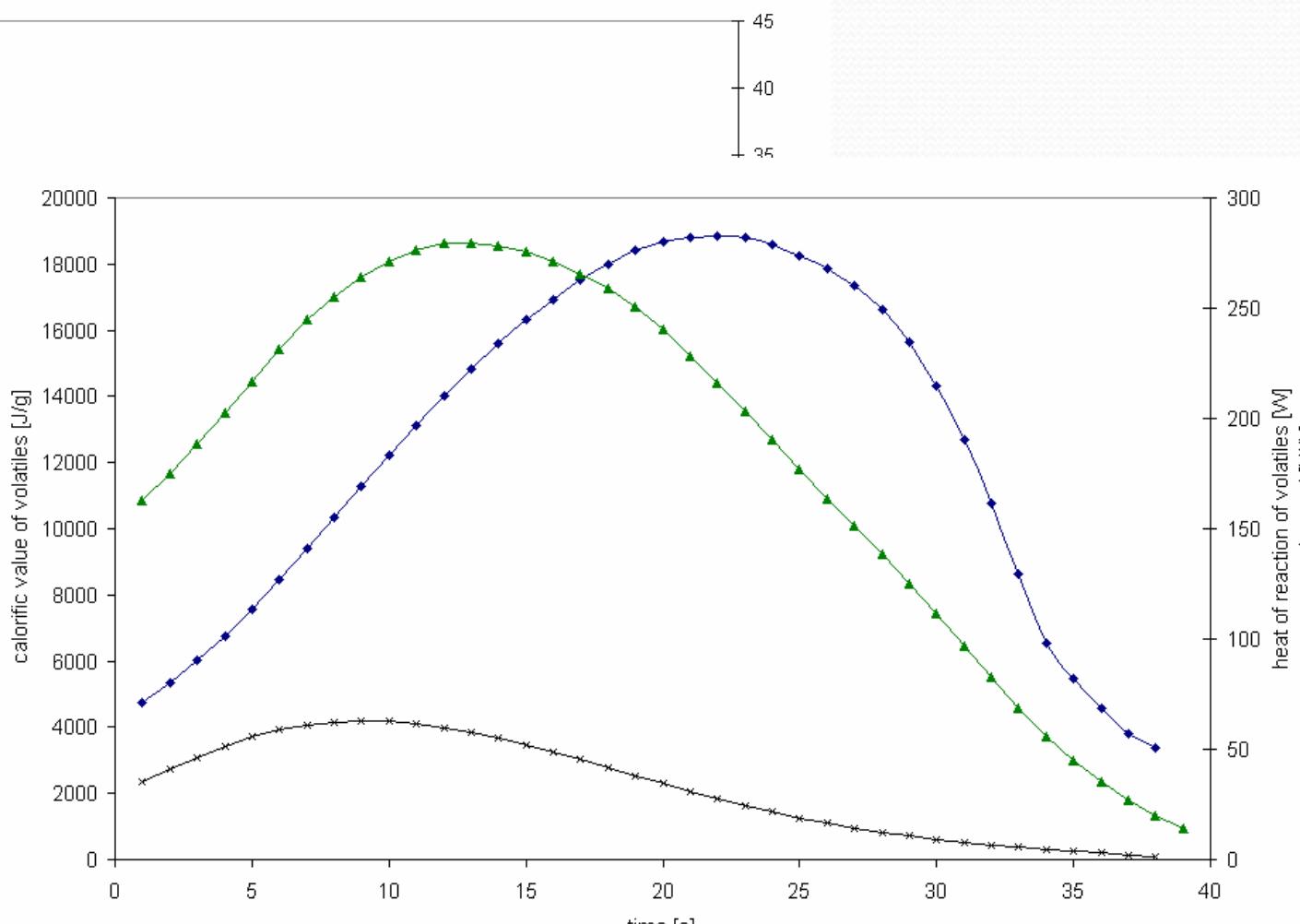
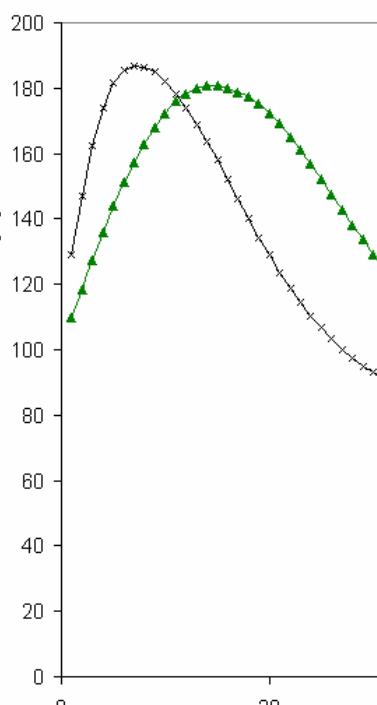
TGS-DSC technique: heat of reaction of volatiles (all samples)



TGS-DSC technique: calorific value of volatiles (all samples)



TGS-DSC technique: heat of reaction & oxygen demand



Wheat straw

Conclusions

Biochar conversion yield from the studied biomass samples is in the upper limit of 50%. This limit is considered as the best scenario compared to future trials in pilot plant scale.

Biochar is a micro-mesoporous material with a high specific surface area, suggesting not only energetic applications for this product but also agronomic ones.

Secondary crack reactions are occurring especially in case of wheat shells and Oregon pine pyrolysis. Only a lightly compression of the solid fuel is enough to obtain the effects of a formed ash and carbon framework, where the longer condensable hydrocarbons can crack into shorter non condensable compounds.

Wheat straw and oat shell secondary reactions could not be detected so great. The samples of these two solids are not as compact as the others. Furthermore the volatiles degas more quickly of such light samples, because there is no limitation of transportation.

Pyrolysis of residual biomass: Biochar conversion yield and synthesis gas quality

M. Poppenwimmer¹, H. Raupenstrauch¹, R. Muñoz² & R. Navia^{2,3}

¹*Chair of Thermal Processing Technology, University of Leoben, Austria*

²*Scientific & Technological Nucleus in Bioresources, University of La Frontera, Temuco, Chile*

³*Department of Chemical Engineering, University of La Frontera, Temuco, Chile*

