EFFECTS OF BIOCHAR ON PRODUCT YIELDS DURING BIOMASS PYROLYSIS IN A BUBBLING BED REACTOR

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Flash Pyrolysis:
Conversion of Biomass into Bio-oil and Bio-char

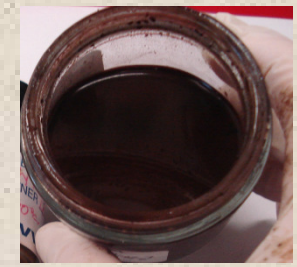
HEAT

Biomass
e.g. lignin, sawdust, cornstover

Bubbling Bed Pyrolyzer

Temperature: 300-600 °C

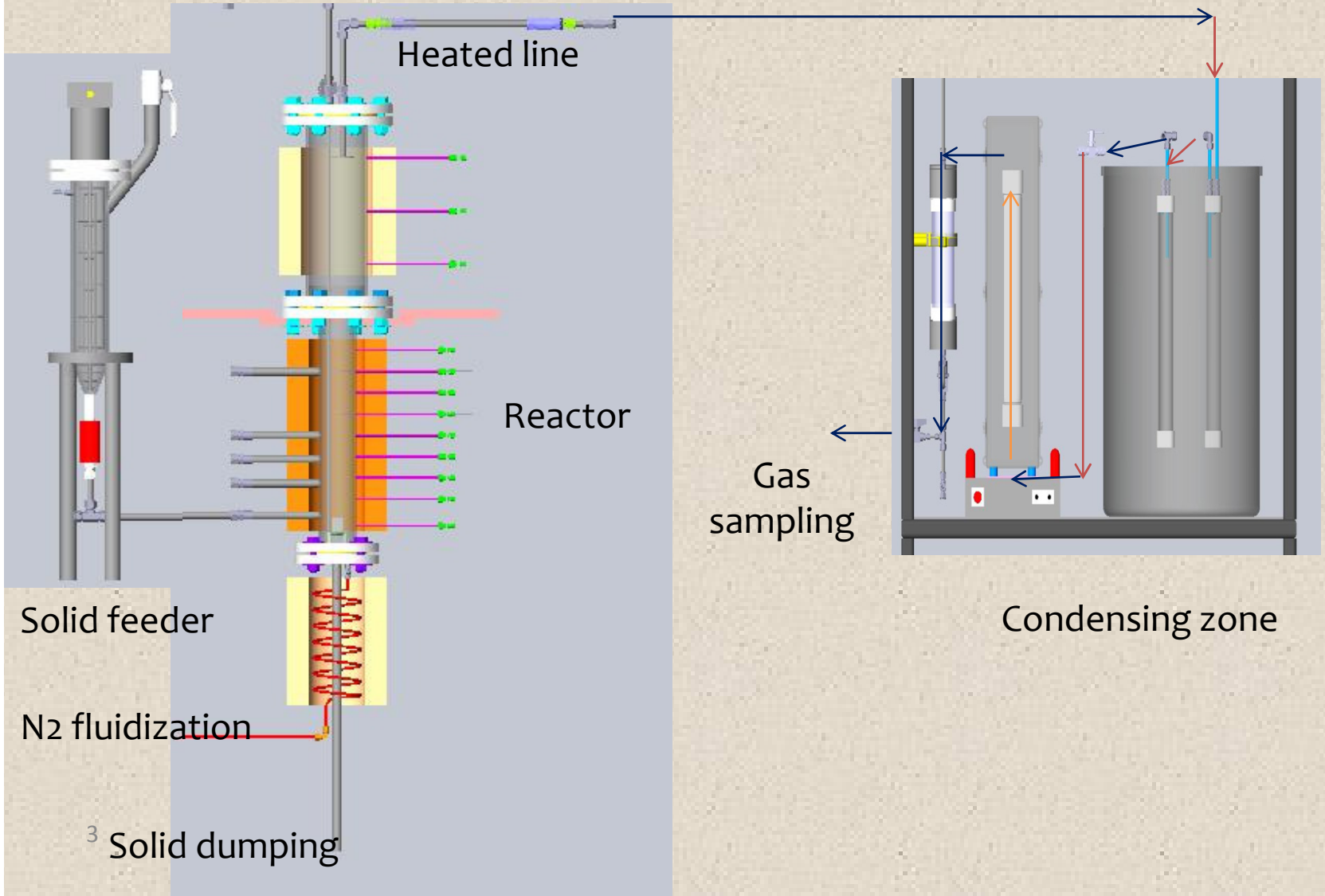
Gases 10-40%



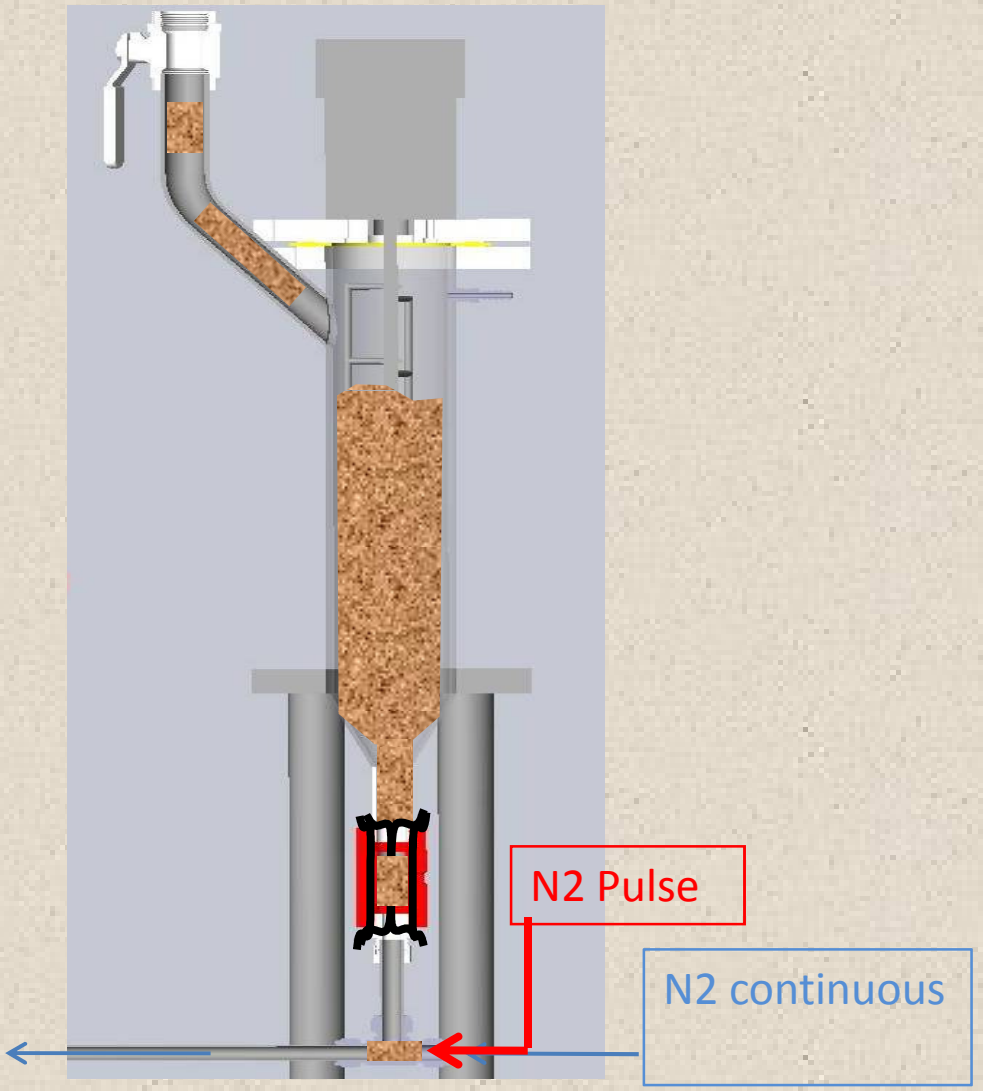
Liquid Bio-oil 20-80%

Solid Char 10-50%

Experimental Apparatus: Bubbling Bed Reactor



Experimental Apparatus: Continuous System Feeding



Pyrolysis Reactor and Operating Parameters in Continuous System

Vapour residence time = 2 s

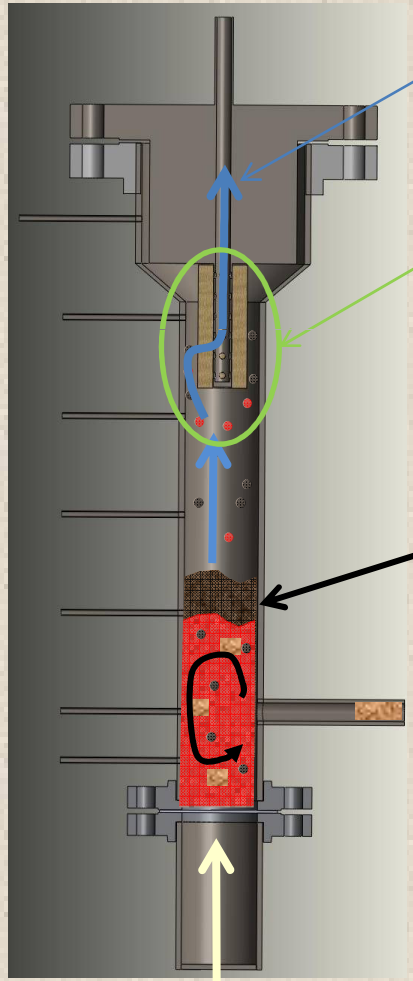
Reactor section = 7.5 cm

Reactor volume = 2.8 liters

Sand weight = 1.5 kg

Sand d_{psm} = 180 μm

Biomass injection rate = 1 kg/hr



Bio-oil vapours and gases

Hot filter traps fine char particles

The char stays in the bed

Biomass injection

N_2 or Recycled pyrolysis permanent gases

Bio-Oil and Bio-Char characterization

- **Water content** measured by Karl Fisher titration
- **LHV** by bomb calorimetric
- **Elemental analyses** by Thermo CNHS-O analyzer
- **Ash content** by furnace combustion
- **Biomass processed**: sawdust, cornstover, lignin

For each biomass the pyrolysis has been repeated in the bubbling bed without removing (or burning) the bio-char produced from the previous run. Respect to the initial sand load the bio-char concentration inside the bed increased pyrolysis by pyrolysis.

SET-UP Experiments: Sawdust (1st feedstock)

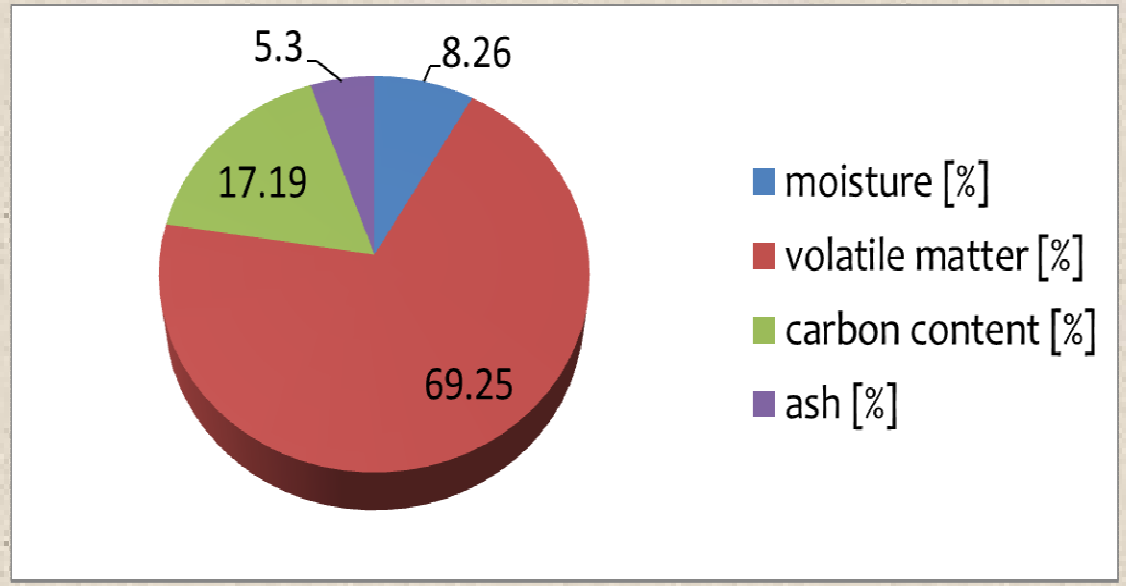
- Pyrolyzer: Bubbling Bed Reactor
- 1,5 kg of silica sand
- 200g biomass processed for each run
- 500°C temperature operation
- 2 seconds vapour residence time
- Horizontal Feeding line at the Bottom of the reactor
- 1kg/h Biomass feeding rate
- 4 runs in series (After each experiment the biochar remains inside the reactor mixed with the sand)

Experimental results

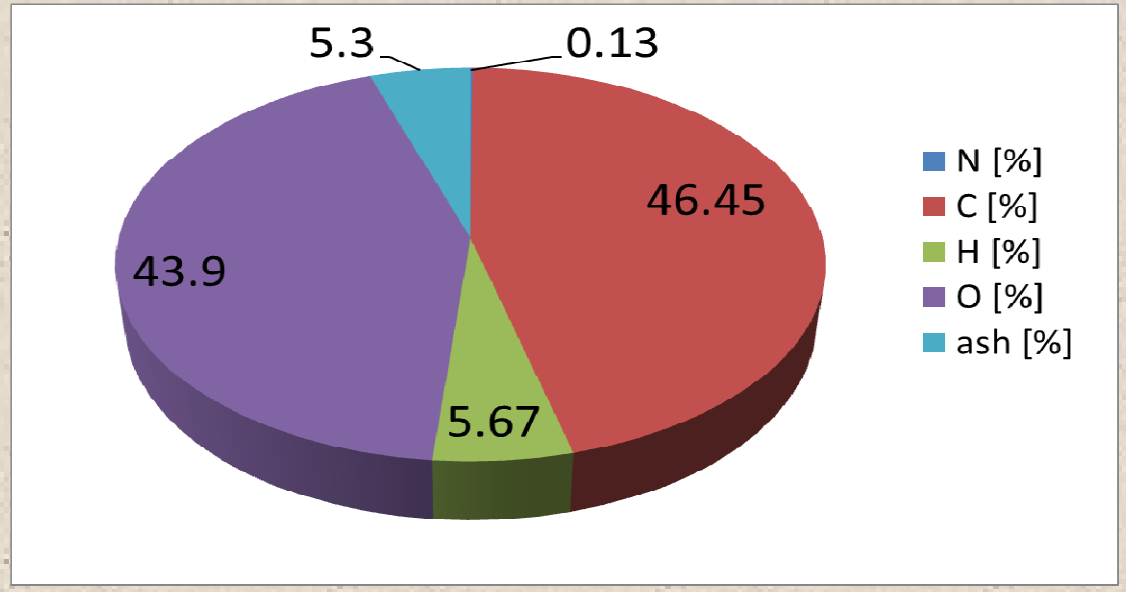
- Liquid, Solid and Gas yield
- Energy recoveries for each phase
- Fuel properties for the bio-oil
- Proximate analysis for the bio-char

Biomass characterization: **SAWDUST**

- **Proximate analysis**



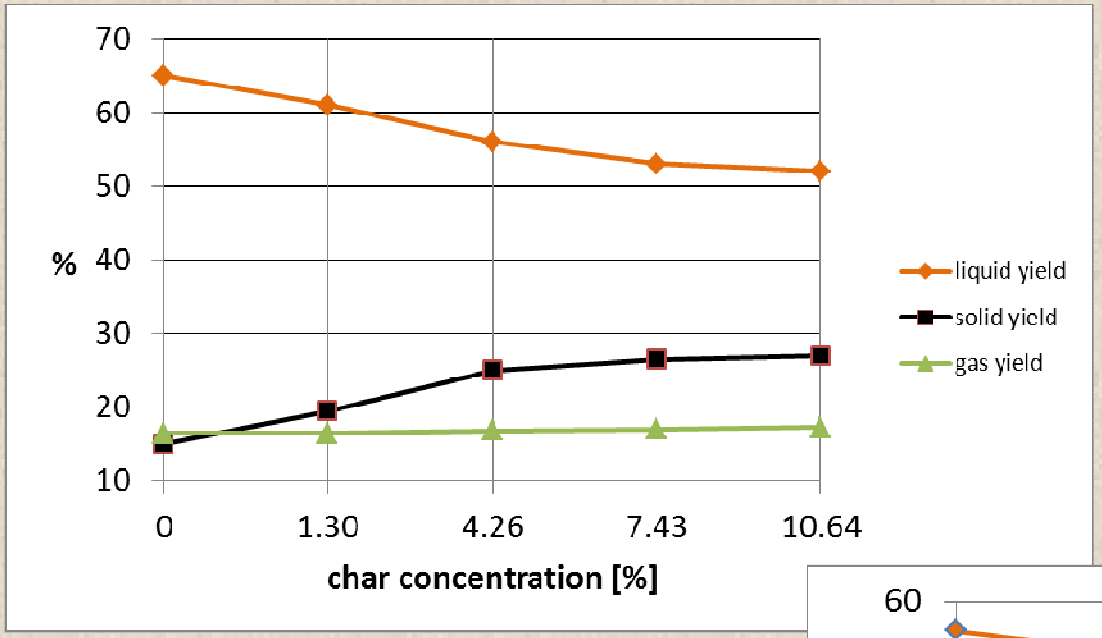
- **Ultimate analysis**



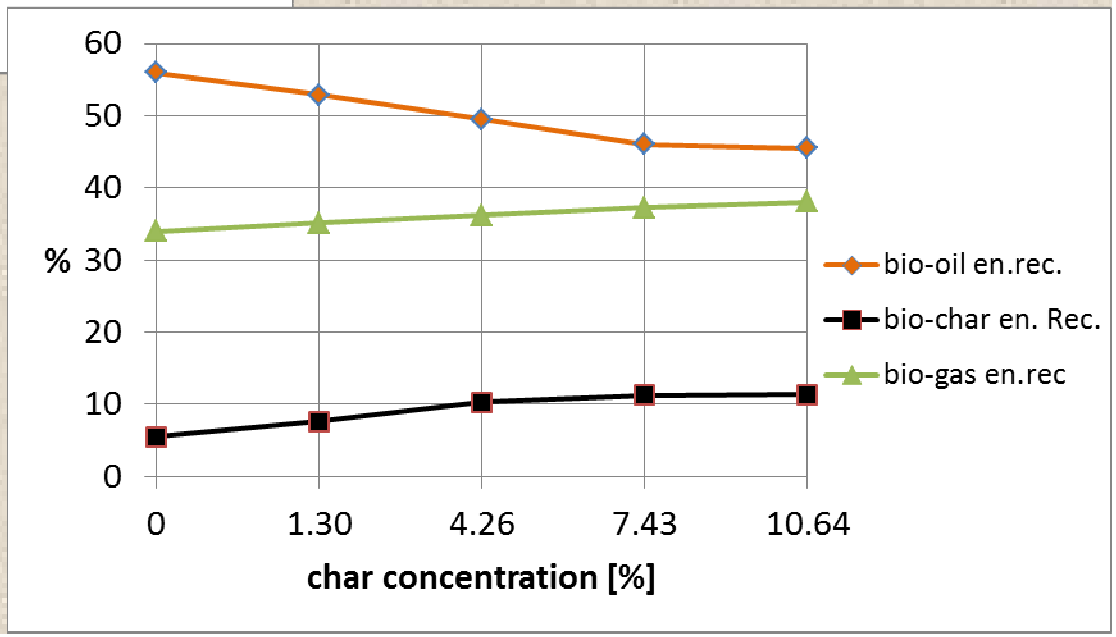
*The oxygen has been estimated as follow:
O%=100-C%-H%-N%-S%-Ashes%

Results: Yield with Energy Recovered

Yields



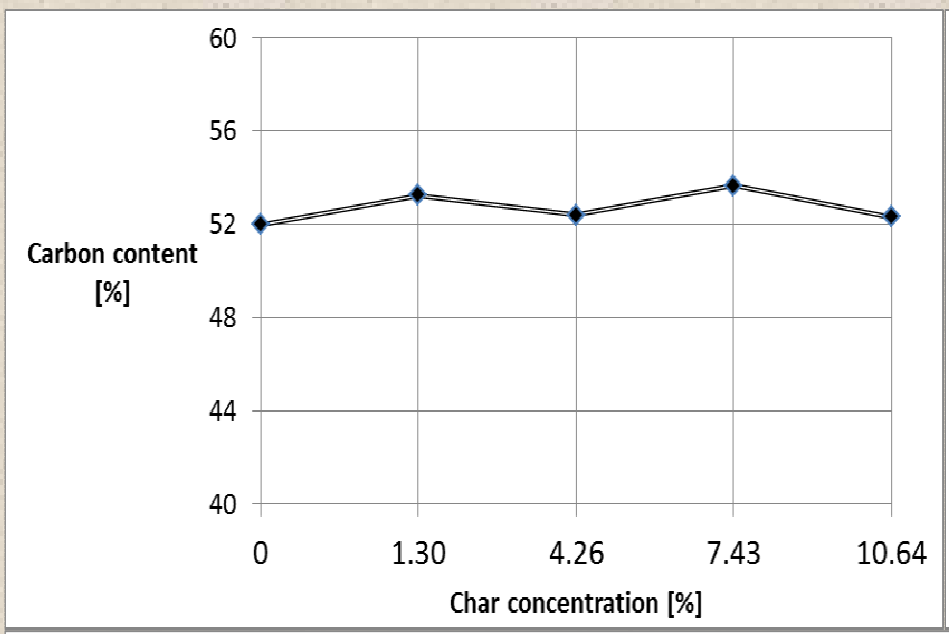
Energy Recovered

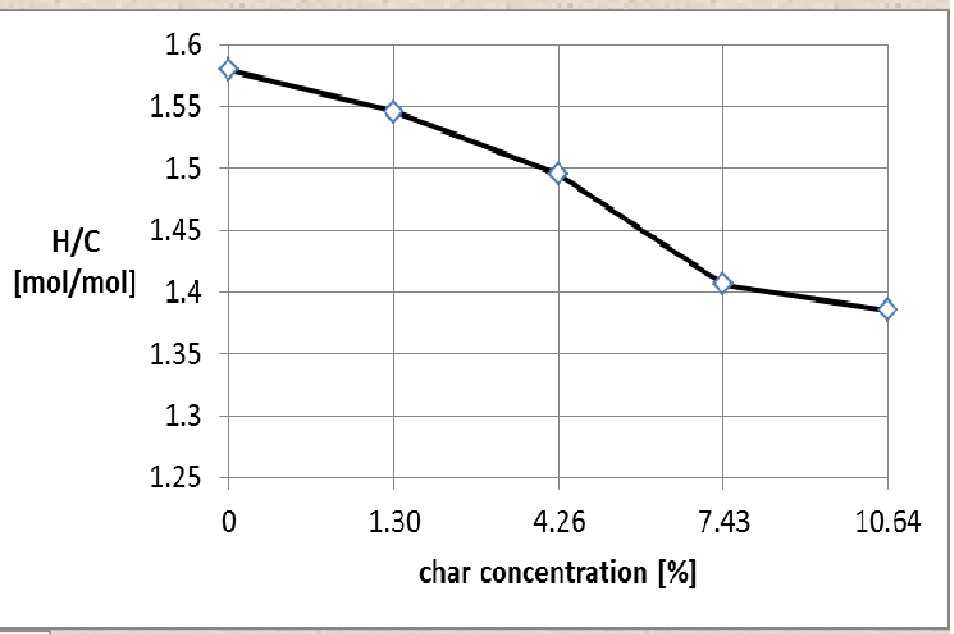


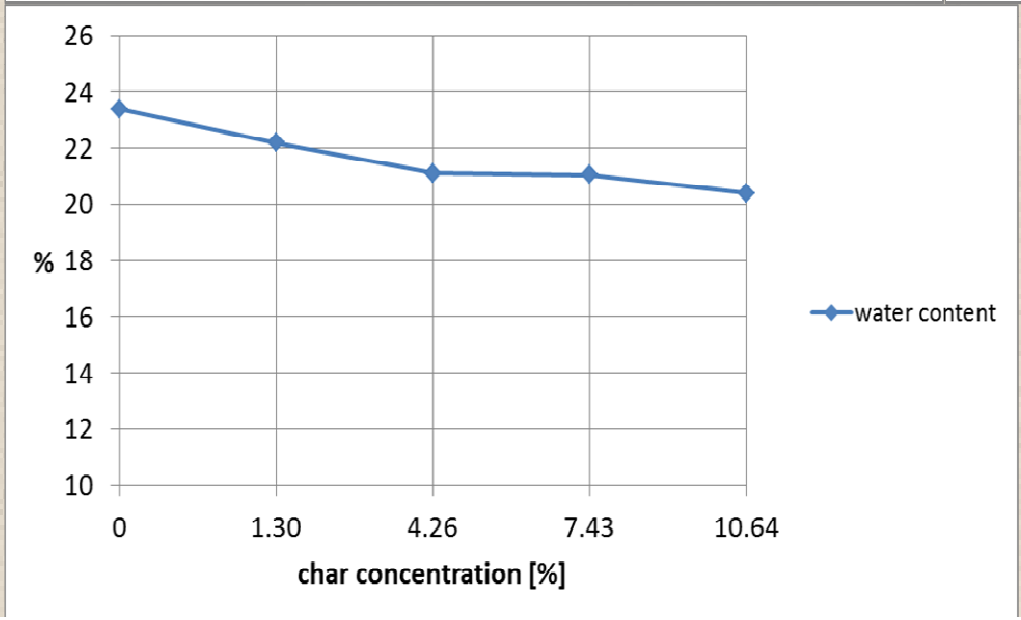
Energy in bio-oils / energy in biomass, energy in bio-char/energy in biomass, energy in bio-gas/energy in the biomass

LHV for sawdust: 17.5 KJ/g

Bio-oil: fuel properties and water content





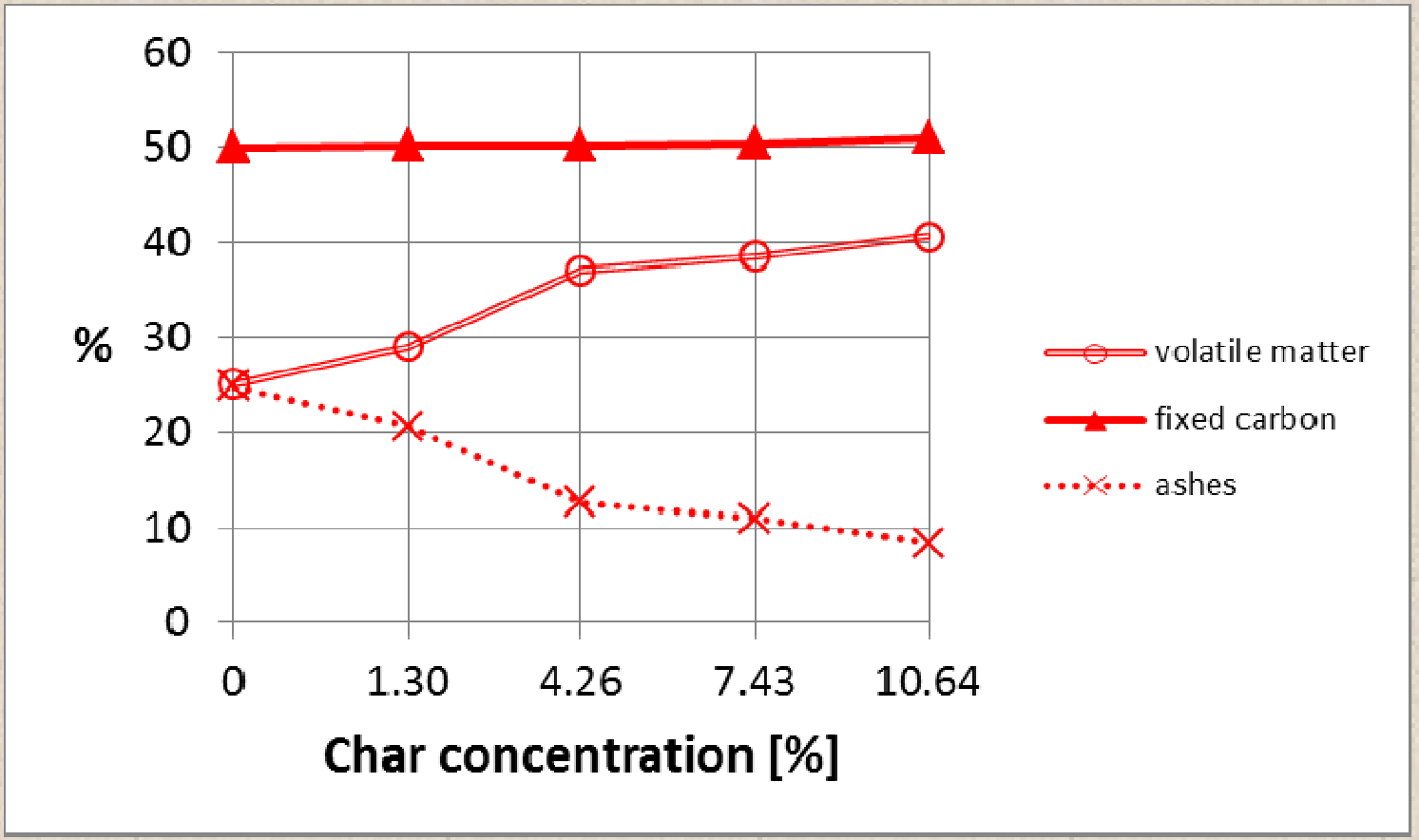


The decreasing energy content in the bio-oil (as shown in the Energy recovering graph) is strictly related to the H/C ratio . It decreases when the char concentration inside the bed (respect the sand load) increases .

Carbon content and could be considered almost constant.

The water content in the bio-oil decreases lightly, (the water content presence will increases as vapour in the incondensable gas fraction.

Sawdust Bio-char: proximate analysis



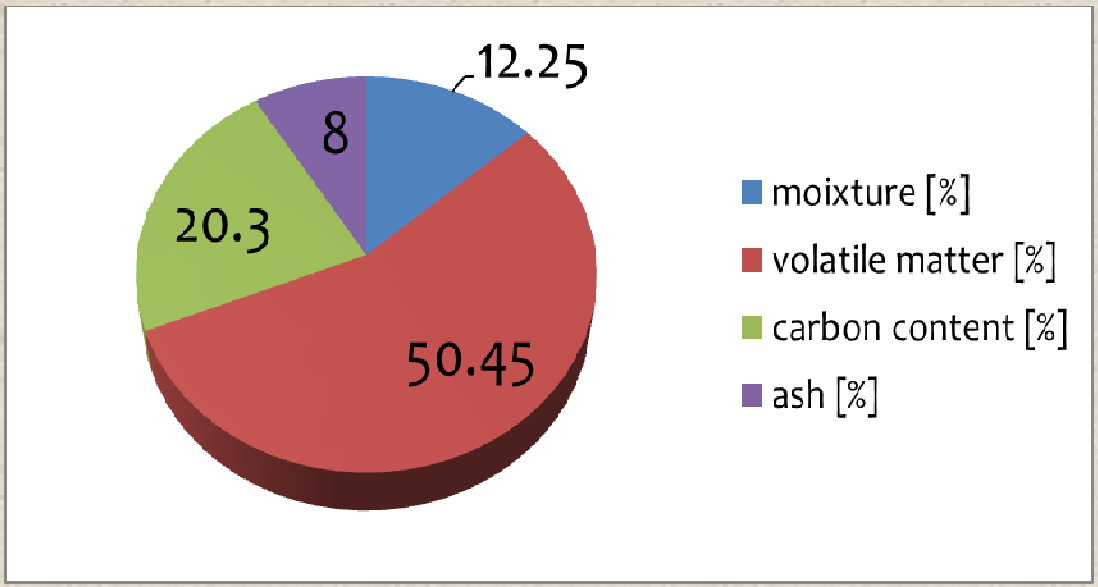
- The volatile matter presents in the biochar increases when the char concentration into the bed increases.
- The carbon content and the ash content remain almost constants
- The volatile matter increment determines the higher energy content in the biochar

SET-UP Experiments: CORNSTOVER (2nd feedstock)

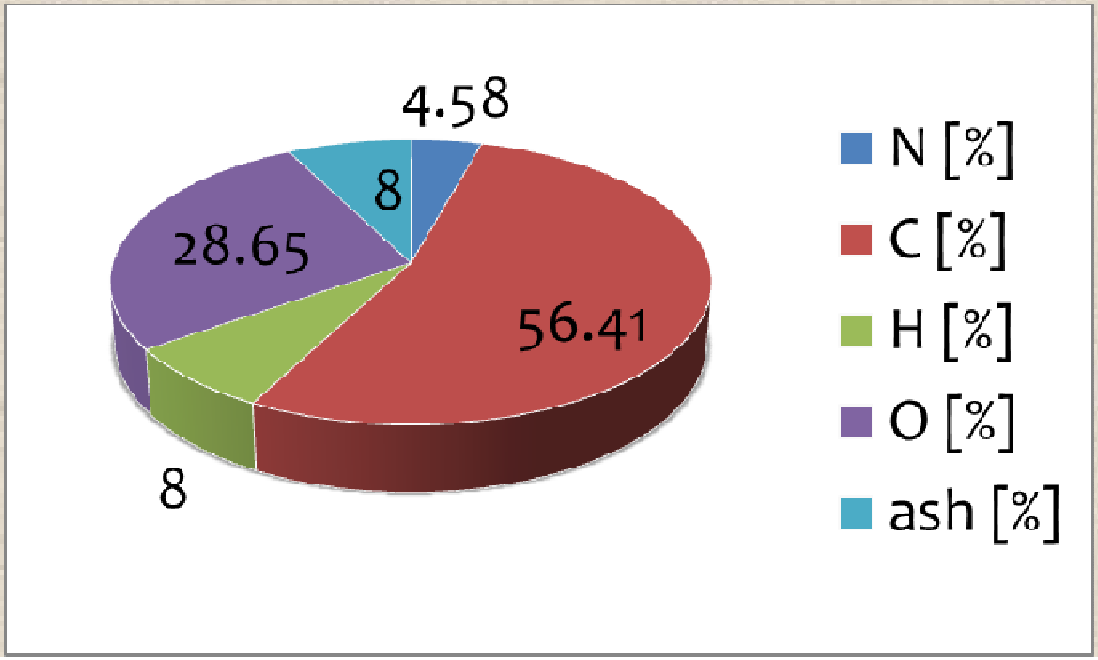
- Pyrolyzer: Bubbling Bed Reactor
- 1,5 kg of silica sand
- 200g biomass processed for each run
- 450°C temperature operation
- 2 seconds vapour residence time
- Horizontal Feeding line at the Bottom of the reactor
- 1kg/h biomass feed rate
- 4 runs in series (After each experiments the bio-char remains inside the reactor mixed with the sand)

Biomass characterization: **Cornstover**

- **Proximate analysis**

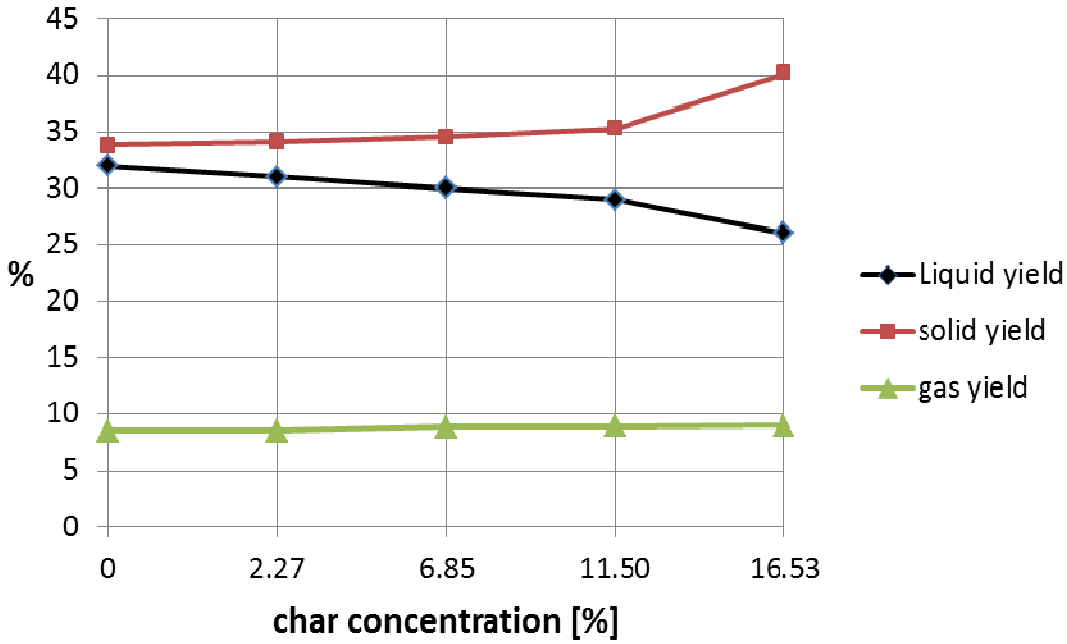


- **Ultimate analysis**

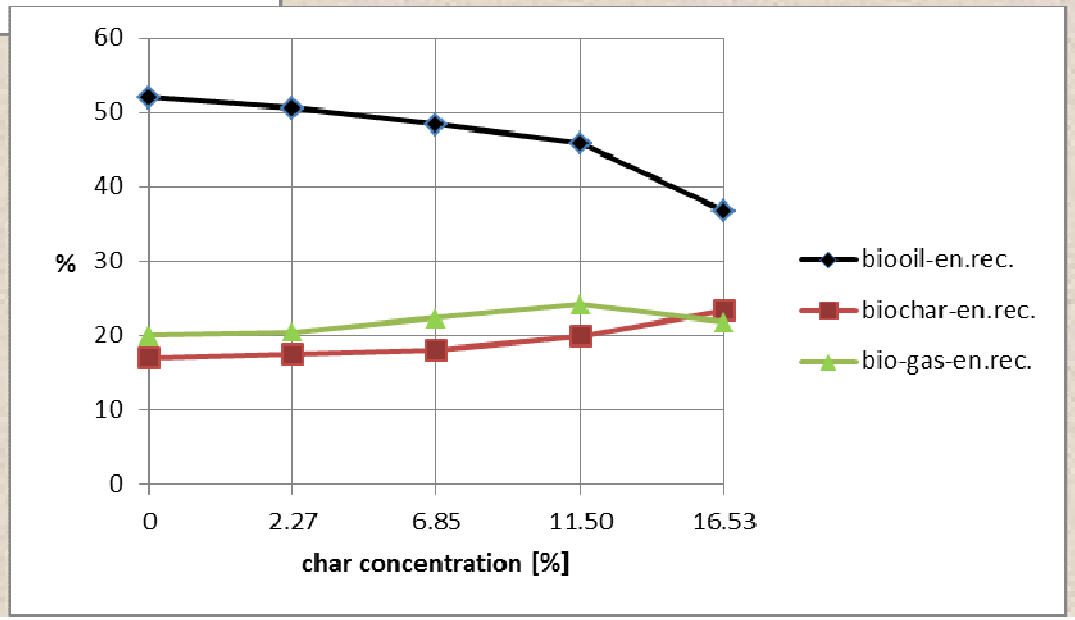


*The oxygen has been estimated as follow:
O%=100-C%-H%-N%-S%-Ashes%

Yields



Energy recovery

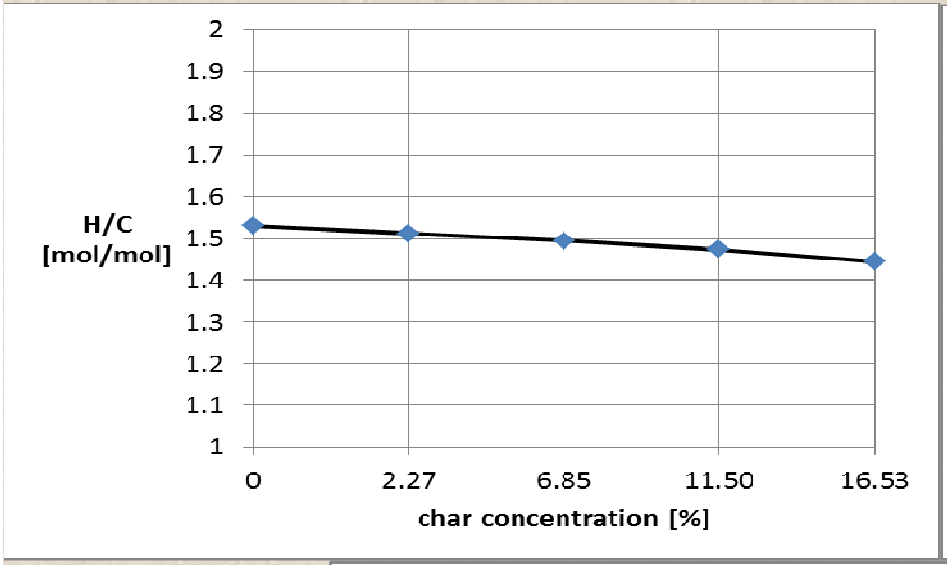


Energy in bio-oils / energy in biomass,
energy in bio-char/energy in biomass,
energy in bio-gas/energy in the biomass

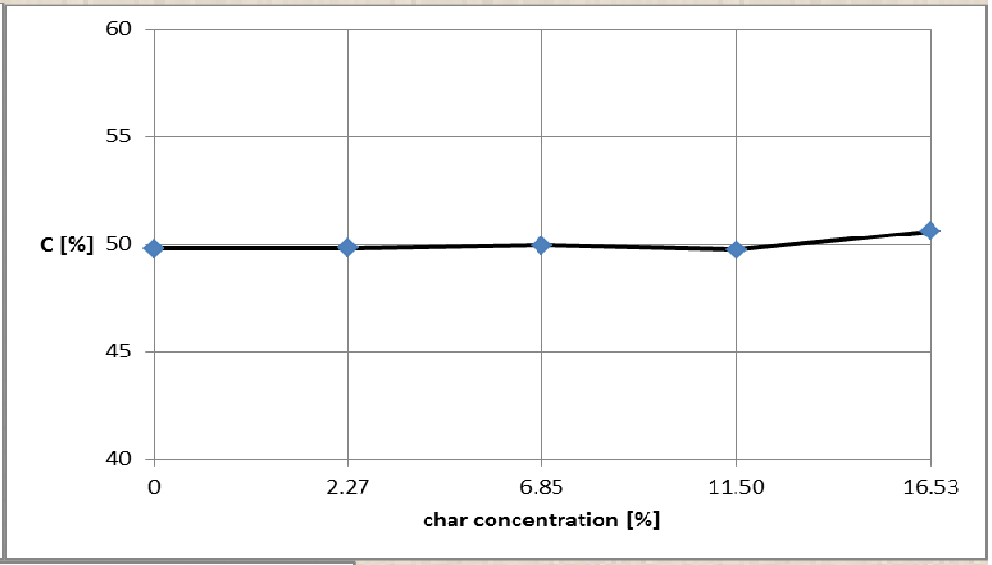
LHV for cornstover: 10.5 KJ/g

Bio-oil: fuel properties and water content

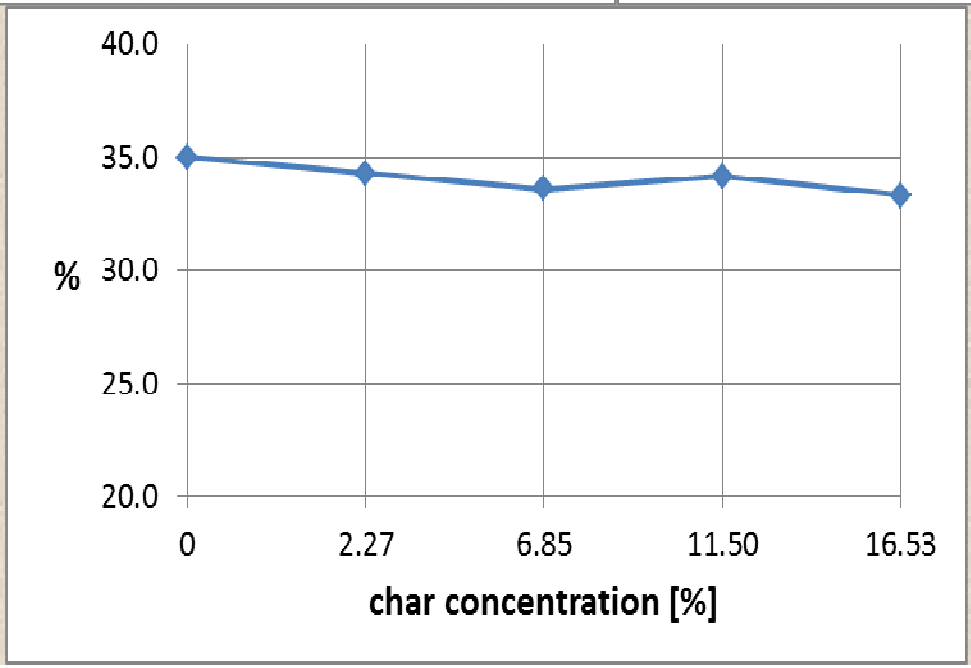
H/C molar ratio



Carbon content

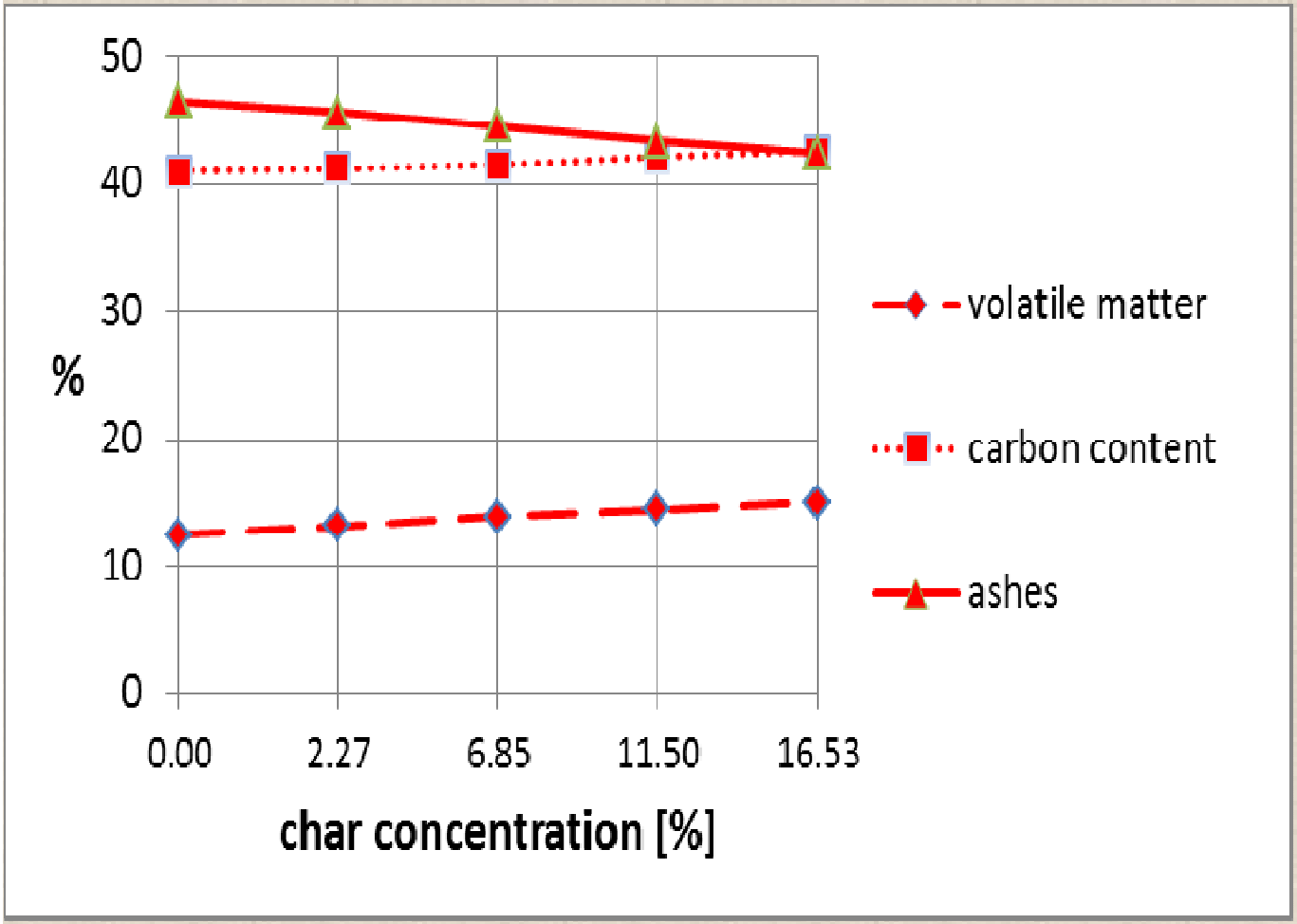


Water content



The carbon content, the H/C molar ratio and the water content in the bio-oils fractions follow the same behaviour seen for the sawdust.

Cornstover Bio-char: proximate analysis



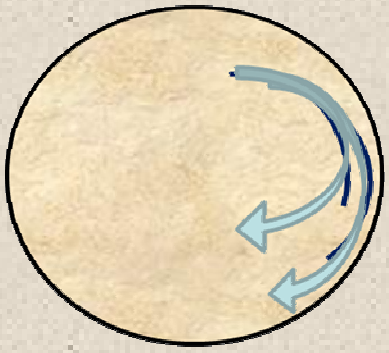
- Carbon content and the volatile matter for the biochar increase when the char concentration inside the bed (respect the sand load) increases.
- It can explain that the energy content of the biochar increases as well as shown in the energy recovery graph

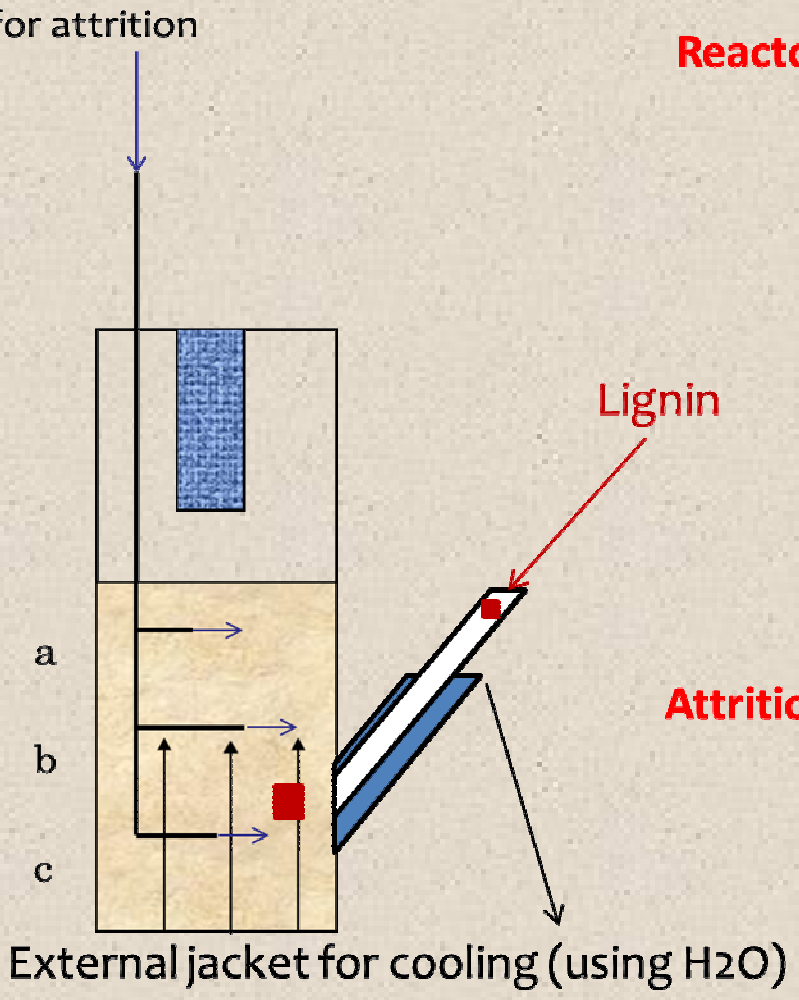
SET-UP Experiments: Lignin (3rd feedstock)

- Pyrolyzer: Bubbling Bed Reactor
- 1.5 kg of silica sand
- 100g biomass processed for each run
- 500˚C temperature operation
- 1 seconds vapour residence time
- Inclined and Cooled Feeding line at the Bottom of the reactor
- 1kg/h biomass feed rate
- Swirling attrition jet (internal) to enhance the contact between hot sand and lignin
- 3 runs in series (the biochar after each experiments remains in the bed)

Reactor set-up for Lignin (3rd feedstock)

Swirling attrition



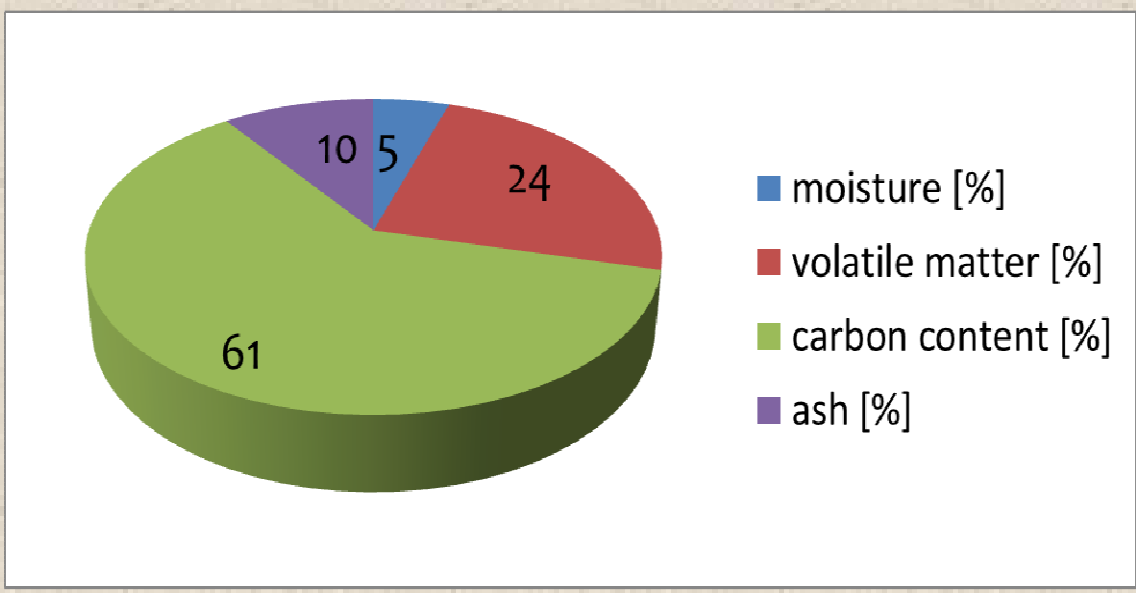


Reactor cap

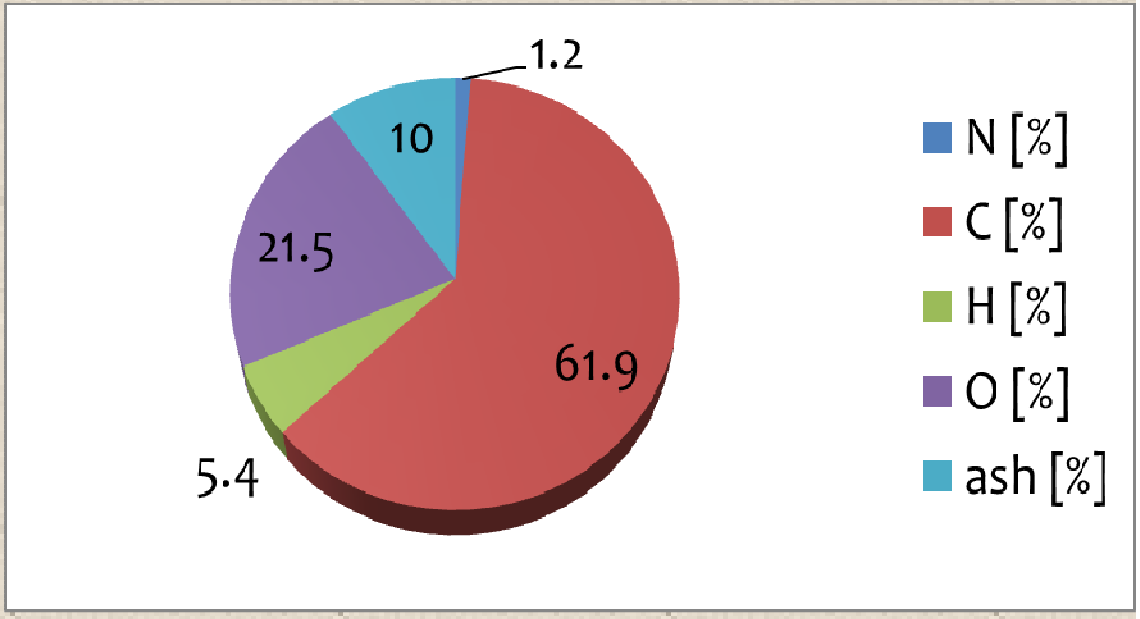
Attrition jets

Biomass characterization: **Lignin**

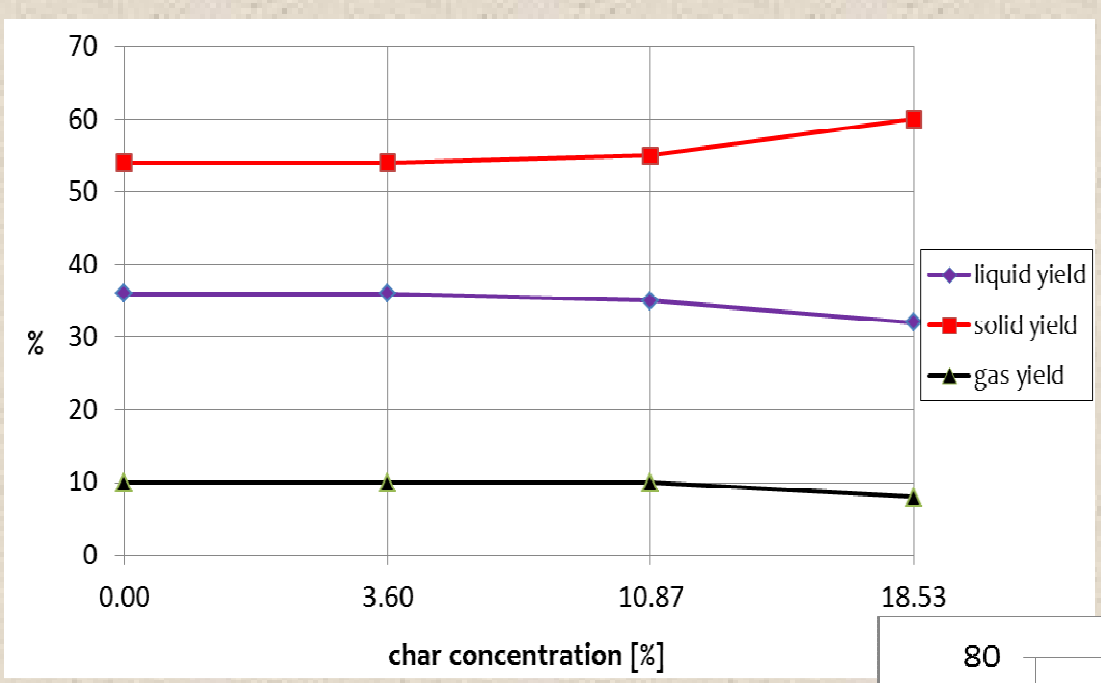
- **Proximate analysis**



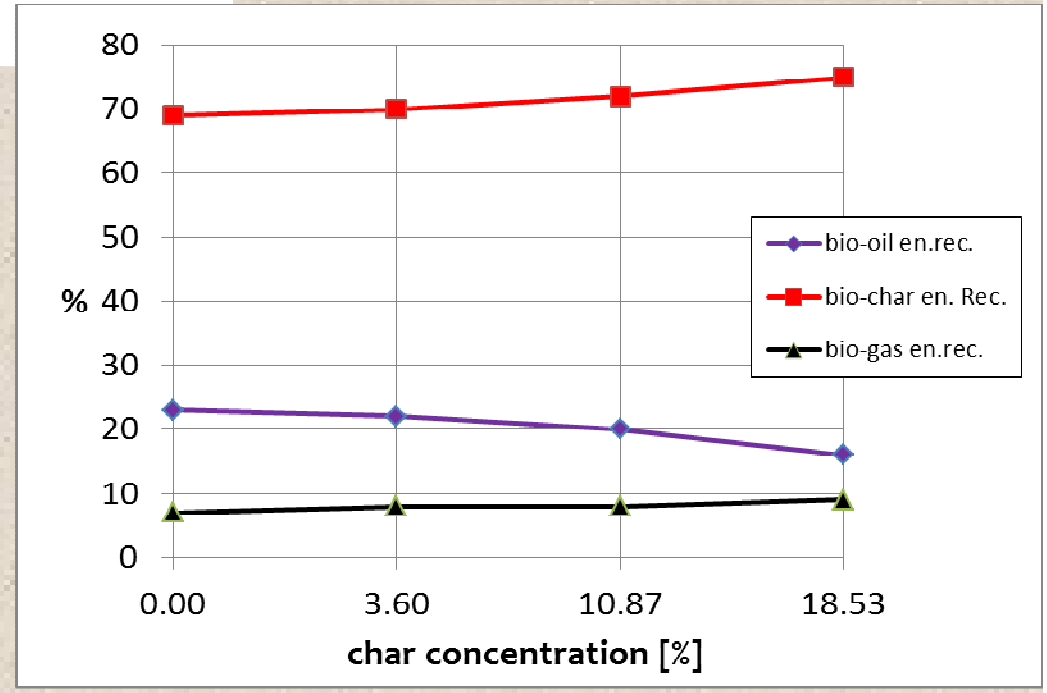
- **Ultimate analysis**



Yields



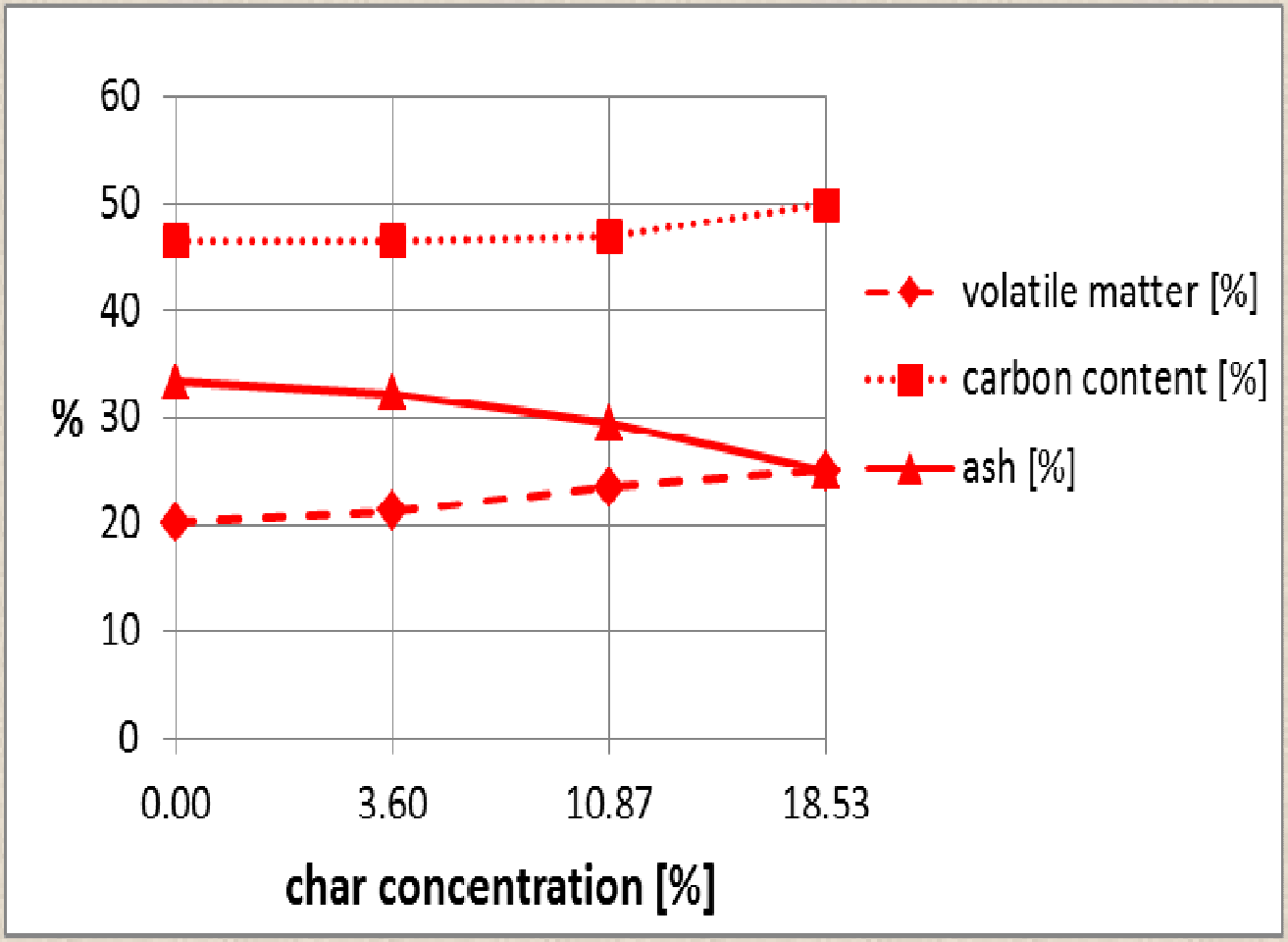
Energy recovery



Energy in bio-oils / energy in biomass,
energy in bio-char/energy in biomass,
energy in bio-gas/energy in the biomass

LHV for Lignin: 26 KJ/g

Lignin Bio-char: proximate analysis



- Even for the Lignin-biochar the Carbon content and the volatile matter increase when the char concentration inside the bed increases.
- It can explain that the energy content of the biochar increases as well as shown in the energy recovery graph

Conclusions:

Experiments conducted with different biomass feedstocks have shown that increasing the content of char inside the bubbling bed reactor (respect the sand load) -during a pyrolysis- seems to favour positively the solid yield, and negatively the liquid yield (the gas yields is almost constant).

Even the energy recovery for each product is affected following the same behaviour above explained. The proximate analysis and the elemental analysis (for biochar and bio-oil) have illustrated has the carbon content and especially the volatile matter increase in a certain measure for the biochar, when more char is presents in the bed.

The char makes char, and the fuel properties of the chars obtained with the higher char concentration inside the bed improve as well; simultaneously the liquid production decreases in terms of amount and quality.