Fast Pyrolysis of Biomass Under Gasification Conditions:

Influence of Particle Size, Reactor Temperature and Gas Phase Reactions

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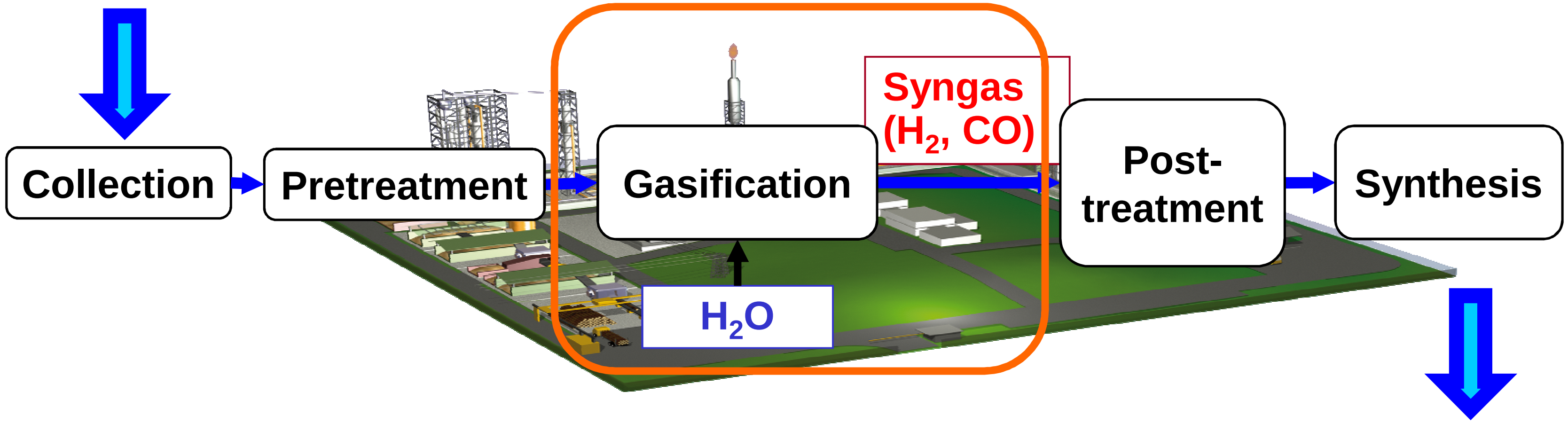
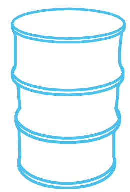
BtL Process: Biomass (lignocellulosic) → Liquid

Biomass (wood, straw…)

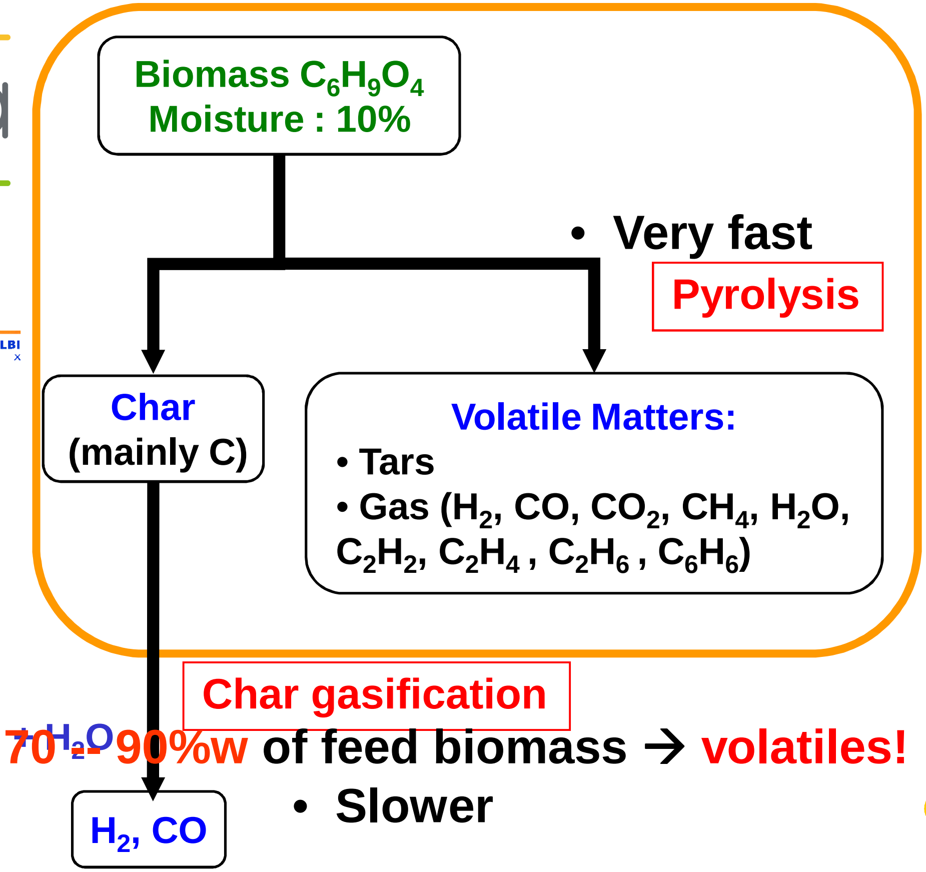




Fischer-Tropsch Diesel

One key step: Gasification

The gasification



Fast pyrolysis of biomass

- Chemical Reactions
- Heat/Mass transfer phenomena

Under FB gasification conditions
(800 – 950 °C)

Controlled by chemical reactions
(Particles < 100 µm)

???

Thermal regime
(Particles > 10 mm)

Research on fast pyrolysis

Objectives:

To better understand at **particle scale** the **pyrolysis behaviour** of **biomass (100 µm – 10 mm)** under the typical heating conditions in **industrial Fluidised Bed gasifiers:**

- **1 bar**
- **High temperature (800°C < T < 1000°C)**
- **High heat flux (> 10^5 W.m^{-2})**

Plan of experiments (laboratory scale)

Drop Tube Reactor (DTR)
(Sample # 350 µm – 800 µm)

Horizontal Tubular Reactor (HTR)
(Sample # 800 µm – 6 mm)

↓

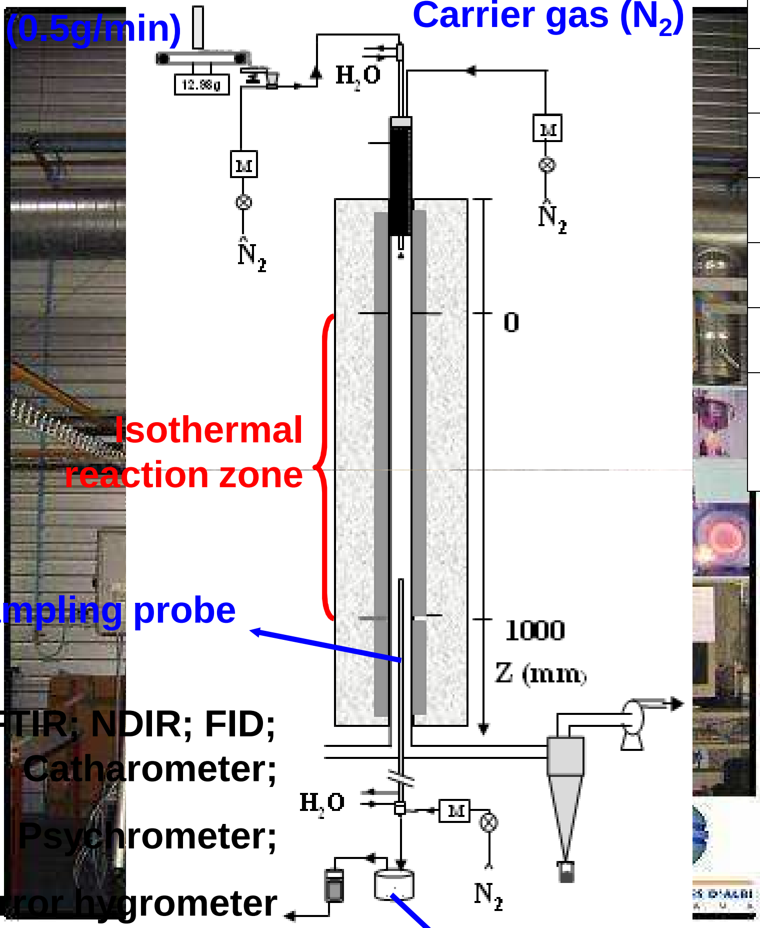
Comparison **DTR/HTR**
Sample # **800 µm**

ECOLE DES MINES D'ALBI
C A R M A U X

Drop Tube Reactor

(350 µm – 800 µm)

Facility description



Biomass	Beechwood $C_6H_{8.8}O_4$ (moisture 7 wt.%)
N_2 velocity (m/s)	0.35
Particle size (µm)	350, 500, 700, 800
Temperature (℃)	800; 950
Pressure (bar)	1
Reaction zone length (m)	0.3, 0.5, 0.7, 0.9
Estimated solid residence time (s)	~ 0.6 – 2 # 350 µm ~ 0.3 – 1 # 800 µm

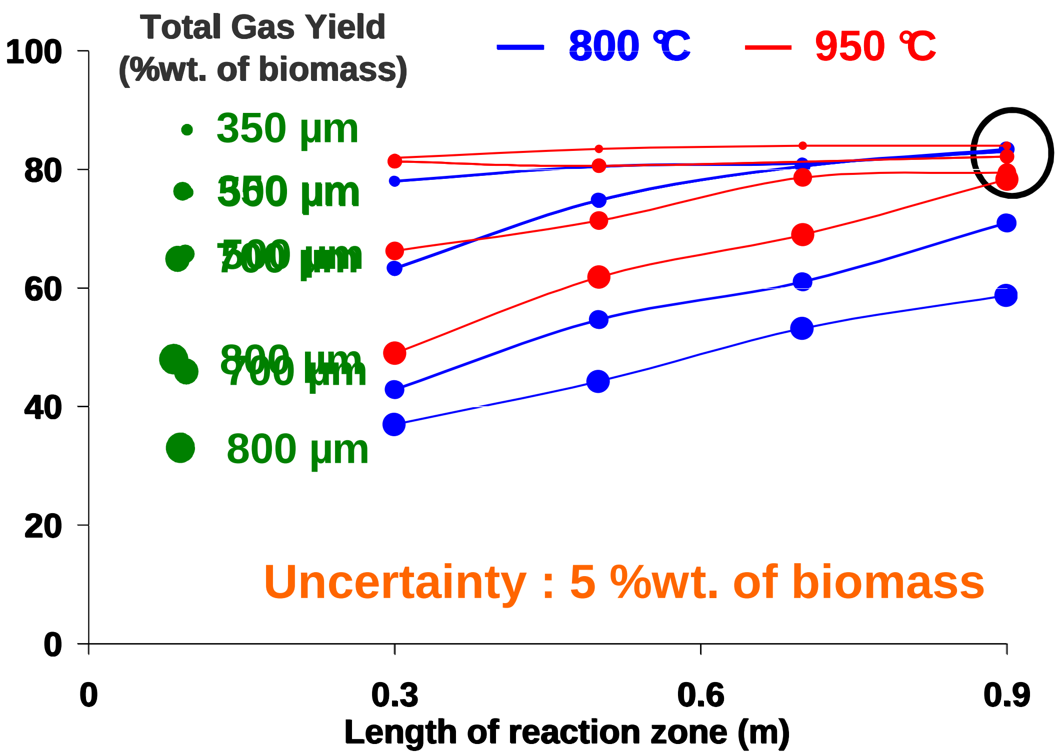
Solid analysis

Ash content → Tracer method

Gas analysis

H_2, CH_4, CO, CO_2, C_2H_2, C_2H_4, C_2H_6, C_3H_8, C_6H_6, H_2O

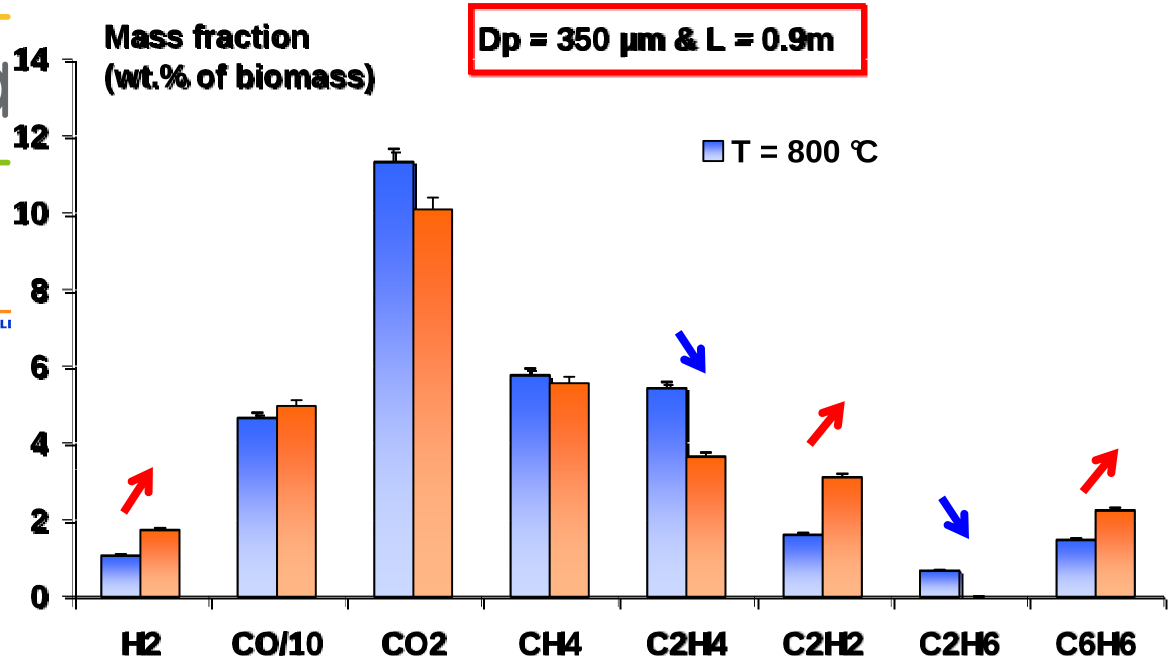
Total gas evolution



- **Final gas yields:** **~ 80 wt.%** of biomass
- **Final char yields:** **< 10 wt.%** of biomass

- **Dp ↗ → solid devolatilization rate ↘**
- **T ↗ → solid devolatilization rate ↗**
- **T = 950°C & Dp = 800 µm , devolatilization finished at L = 0.9 m (τ_{solid} ~ 1 s).**

Influence of T on the gas components yields

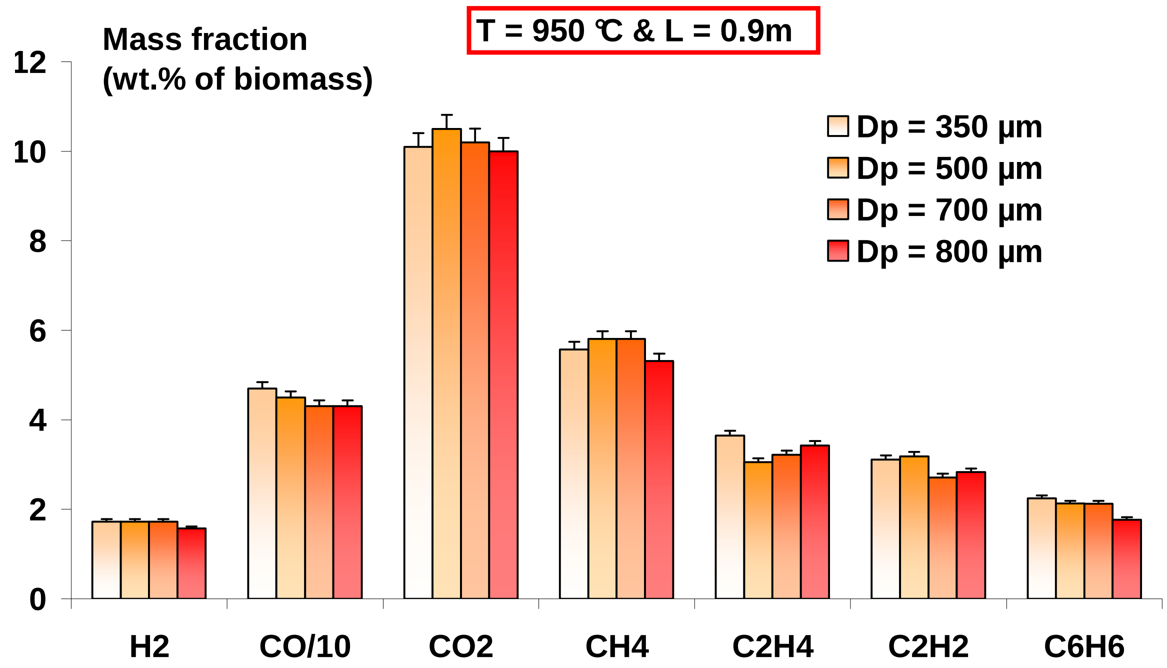


When T ↗ (800 → 950 ℃),

- ↗ H_2 (1 → 1.7 wt.%)
  C_2H_2 (1.6 → 3.1 wt.%)
  C_6H_6 (1.5 → 2.2 wt.%)
- ↘ C_2H_4 (5.4 → 3.6 wt.%)
  C_2H_6 (0.7 → 0 wt.%)
- → CO (48 wt.%)
  CO_2 (11 wt.%)
  CH_4 (5.5 wt.%)

The increase of temperature (800 → 950 ℃) seems to change mainly the yields of H_2, C_2 species, and C_6H_6 by enhancing the cracking reactions.

Influence of Dp on the gas components yields



Under operating conditions in DTR

Negligible influence of particle size (350 µm → 800 µm) on the final gas components yields

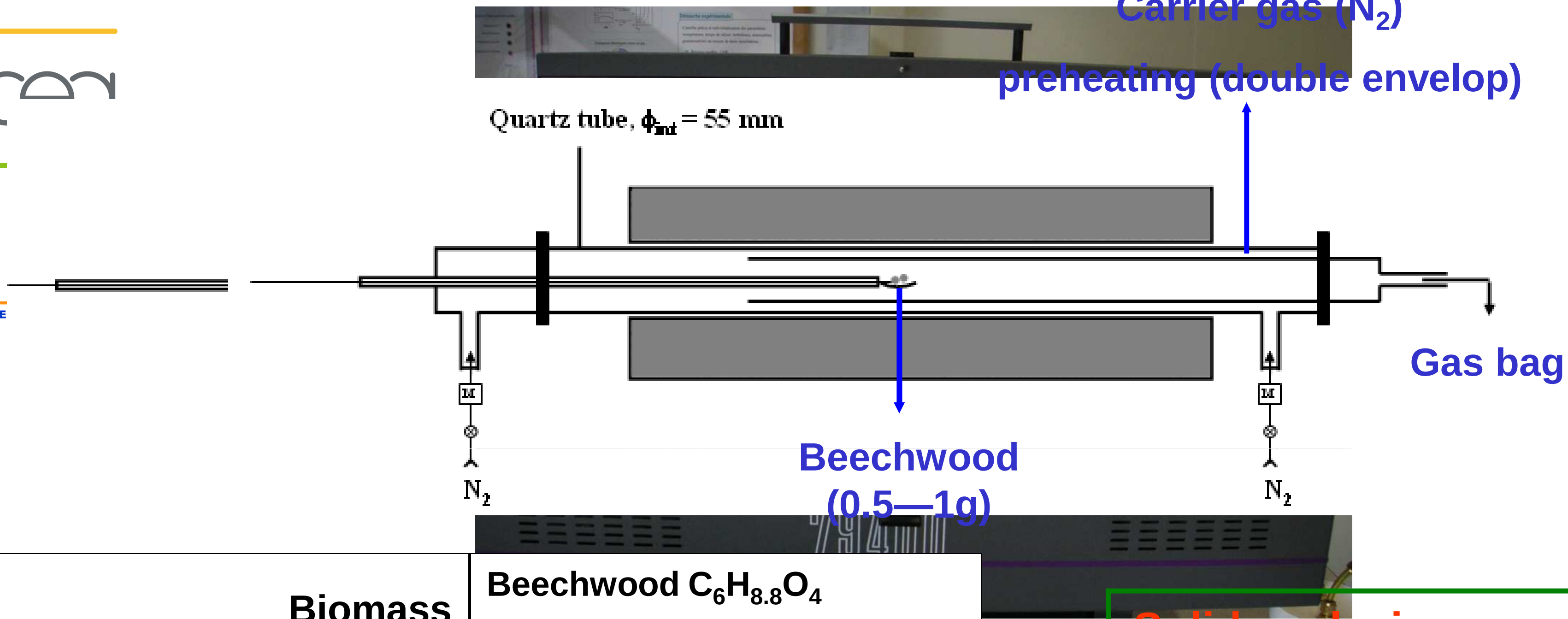
Drop Tube Reactor (350 µm – 800 µm)

(Limitation of solid residence time by the reactor configuration)

larger particles

Horizontal Tubular Reactor (800 µm – 6 mm)

Facility description



Biomass	**Beechwood $C_6H_{8.8}O_4$ (Oven Dried)**
Sample mass (g)	**0.5 – 1**
Particle size	**800 µm, 2 mm, 6 mm**
Temperature (℃)	**800, 950**
Gas residence time (s)	**1, 3.5, 10**
Solid residence time (s)	**180**

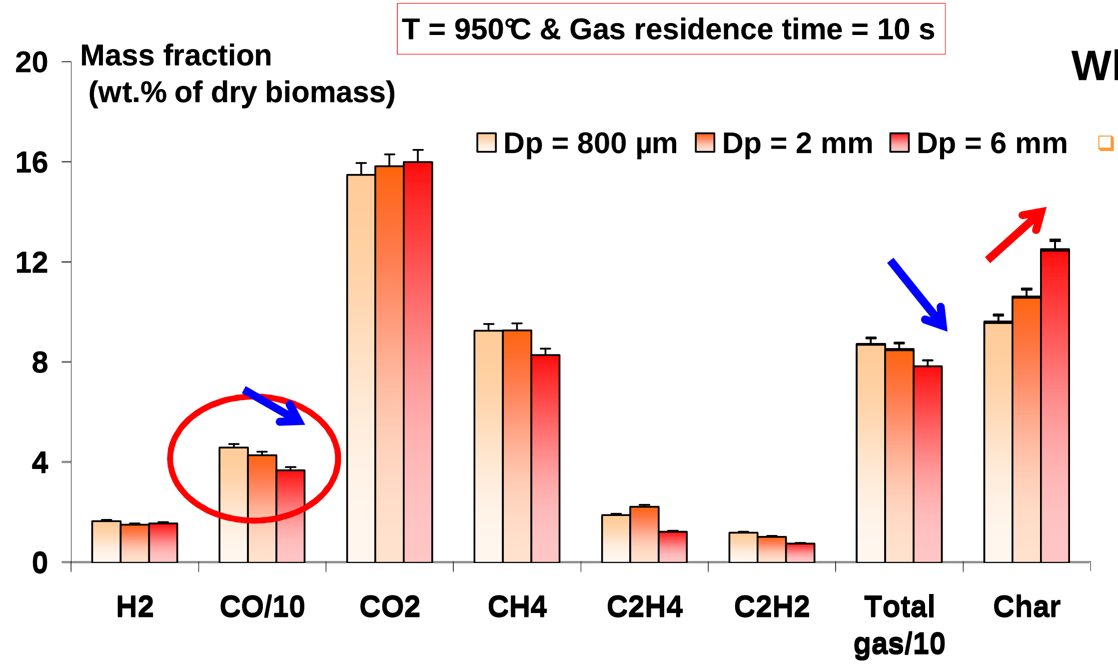
Solid analysis

Mass measurement

Gas analysis

H_2, CH_4, CO, CO_2, C_2H_2, C_2H_4, C_2H_6, H_2O

Influence of Dp on the gas components yields



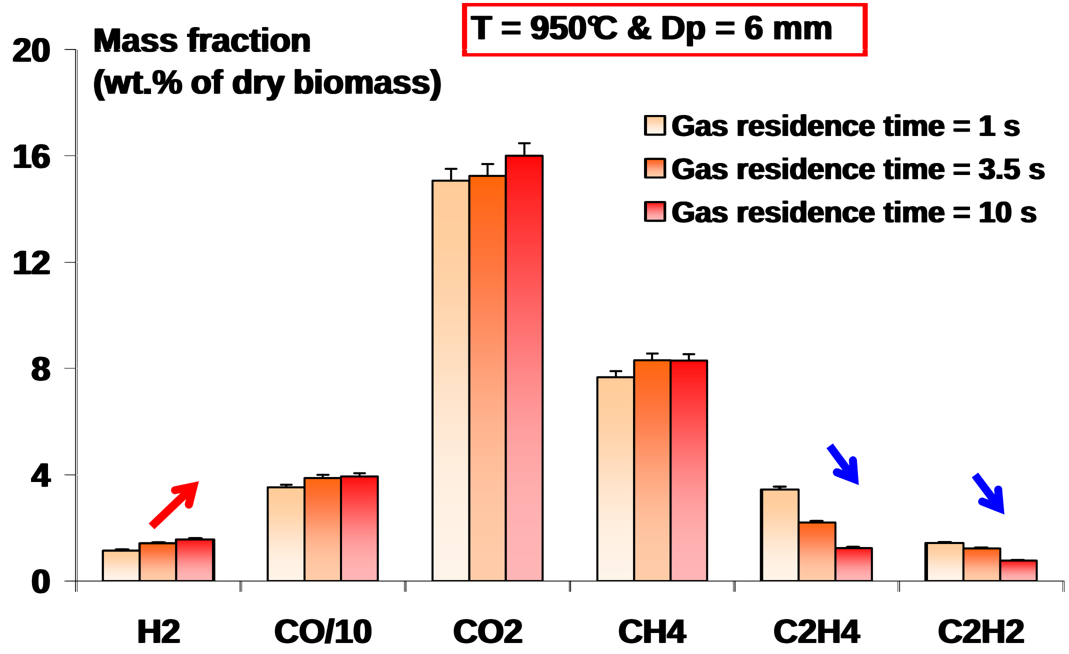
When Dp ↗ (800 µm → 6 mm),

- Total gas yield ↘ (10 wt.%)
  Char yield ↗ (3 wt.%)

  → CO ↘ (~ 8 wt.%)

Under operating conditions in HTR
Slight influence of particle size (800 µm → 6 mm) on the final products yields.

Influence of gas phase reactions



When τ_{gas} ↑ (1 → 10 s),

- H_2 ↑ (1.2 → 1.8 wt.%)
- C_2H_4 ↘ (3.5 → 1.2 wt.%)
  C_2H_2 ↘ (1.4 → 0.8 wt.%)
- CO, CO_2, CH_4 ➔
  (< 10% in relative)

Increasing gas residence time seems to change the yields of H_2 and C_2 species by favouring the cracking reactions of hydrocarbons.

Comparison DTR/HTR (Dp # 800 µm)

SAME T (950 °C), and gas residence time (~3.5 s)

ATTENTION: different reactor configuration and solid residence time

Mass yield (wt.% of dry biomass)	DTR	HTR
H_2	1.7	1.4
CO	48.4	45.5
CO_2	10.1	14.8
CH_4	5.7	9.1
C_2H_4	3.7	2.7
C_2H_2	3.1	1.0
C_2H_6	0	0.0
Total dry gas	73	75

Results obtained in 2 reactors are comparable.

Conclusions

- **Beech wood → char (~ 10 wt.%) + gas (~ 80 wt.%) + tar**
  (CO, H_2, CO_2, CH_4, C_2H_2, C_2H_4, C_2H_6, C_6H_6)
- **Particle size (350µm – 6 mm) changes the solid devolatilization rate, but has no/slight influence on the final product yields.**
- **Increasing temperature increases solid devolatilization rate and favours gas phase cracking reactions.**
- **Gas phase reactions change mainly the yields of H_2 and C_2 species.**

Obrigada

Thank you

Merci

谢谢

If you have any questions, please contact:

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