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# Low temperature co-pyrolysis of polypropylene and coffee wastes to fuels

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# Low temperature co-pyrolysis of polypropylene and coffee wastes to fuels

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# Motivation

## Coffee in capsules

- *espresso* with standard machines
- Optimal coffee flavor extraction and cream/foam production



- Large amount of poorly accepted waste → **valuable products?**

# Capsule concept



PP structure + Coffee (and a thin paper filter)



59% PP out of 16 g total, 37 mm high

# Experimental approach



## 1. Orientation by TA

DSC of single components and mixtures → **pyrolysis conditions**

## 2. Set-up and characterization of a pyro reactor (fixed bed)

## 3. Tests

- PP/coffee
- T

## 4. Liquids product analysis (GC-MS)

# Materials



Isotactic PP (virgin)



Coffee ground

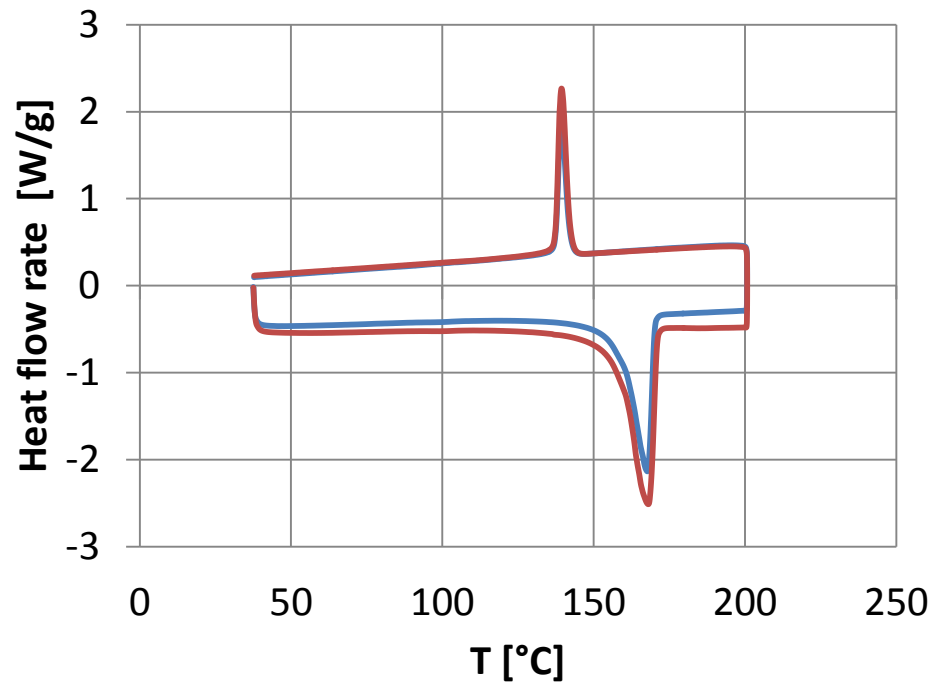
Singles components, to investigate composition

# Thermal Analysis

## DSC



1 - PP characterization (2°C/min)



$$T_m = 167^\circ\text{C}$$

$$\Delta H_m = 2.9 \text{ kJ/mol}$$

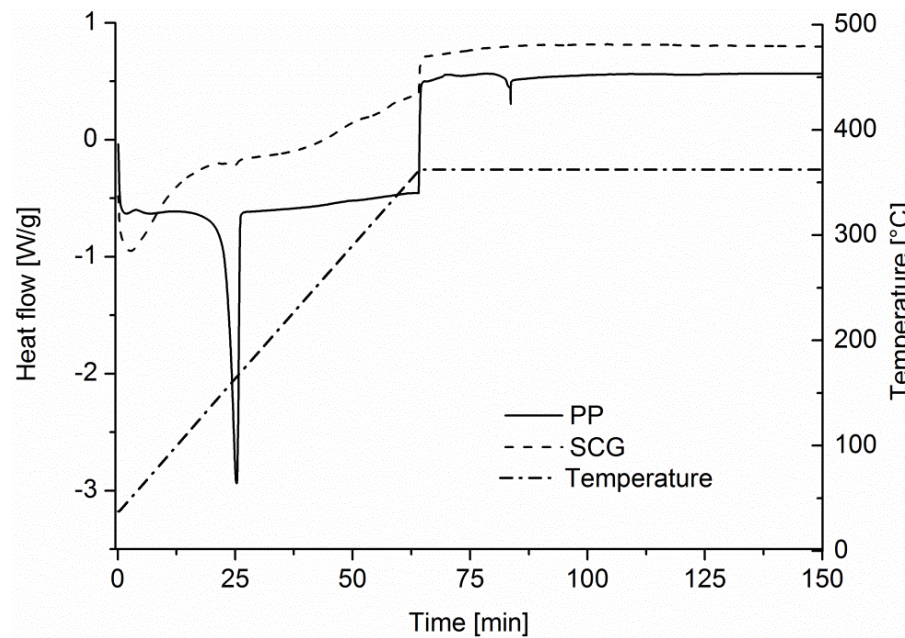
$$\alpha = 33\%$$

# Thermal Analysis

## DSC



### 2 – decomposition (in air or inert)



Degradation of **coffee**

$T > 250 \text{ } ^\circ\text{C}$

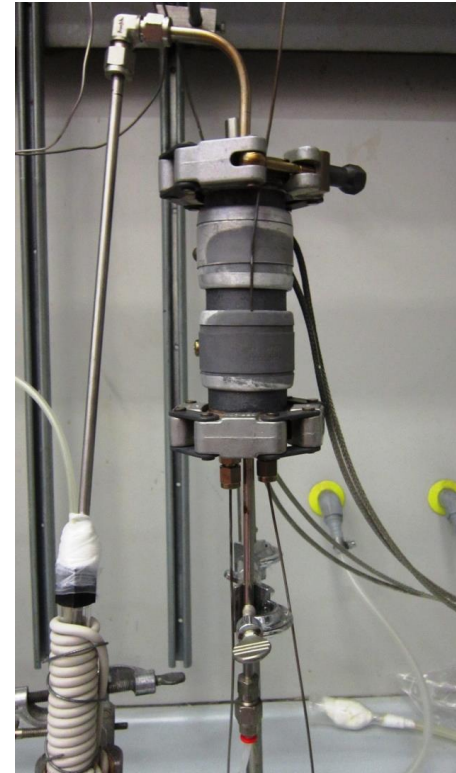
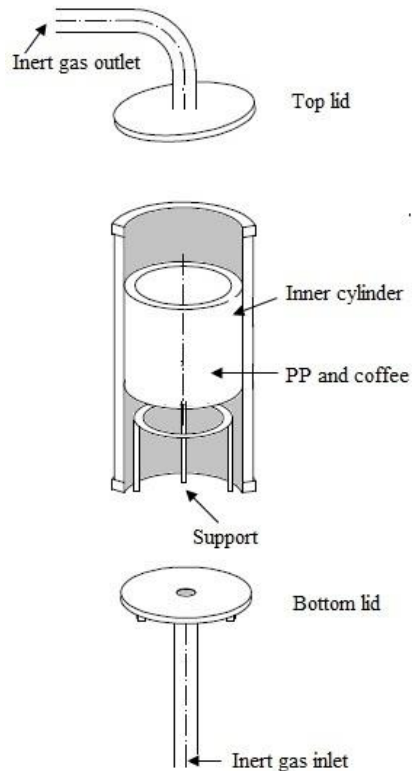
Degradation of **PP**

$T > 360 \text{ } ^\circ\text{C}$



# Pyrolysis Reactor

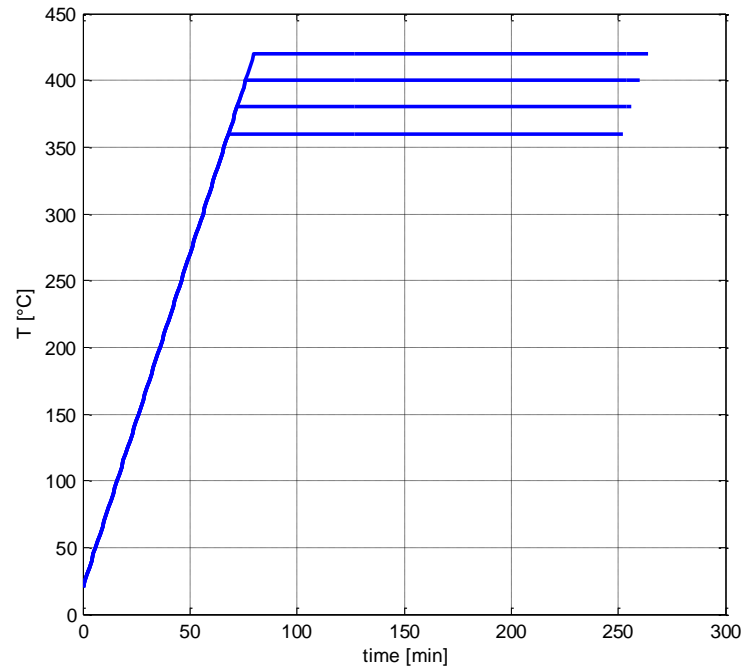
## upflow fixed bed



from mg to tens of g (ID = 38mm)

products condensation @ 65, 25,-20 °C

# Heating policy 'isothermal'



$HR = 5^{\circ}\text{C}/\text{min}$

3h at max  $T$  (360, 380, 400, 420°C)

# Experimental design

## % and T effect



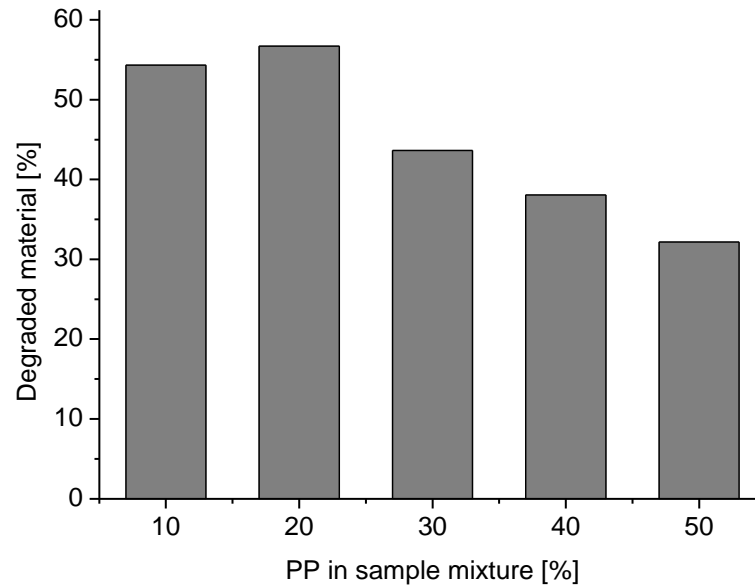
	# test	Composition [% vol]		T [°C]	WL [%]	liquid yield [% wt]
		<b>PP</b>	<b>coffee</b>			
set 1	1	10	90	360	54.3	34.9
	2	20	80	360	56.7	29.0
	3	30	70	360	42.9	27.6
	4	40	60	360	38.1	26.3
	5	50	50	360	34.0	25.6
set 2	6	50	50	360	34.2	25.6
	7	50	50	380	74.2	42.0
	8	50	50	400	83.8	63.7
	9	50	50	420	93.1	71.7

**Set 1:** PP from 10 → 50% @ 360°C

**Set 2:** T from 360 → 420°C @ 50% PP/coffee

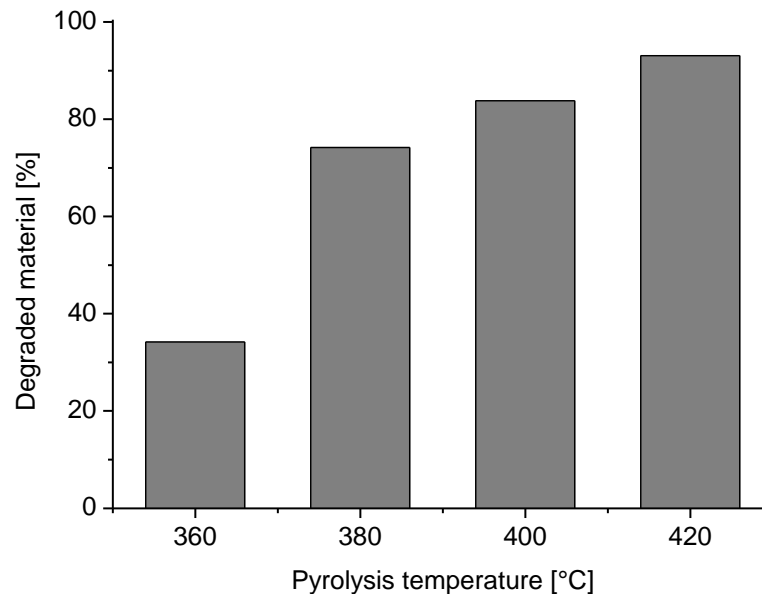
# Feed composition

## overall degradation



@ 360°C the fraction of PP severely limits degradation

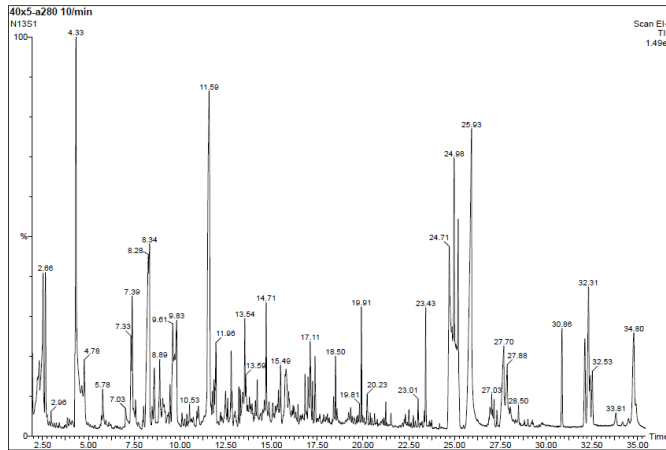
# Temperature overall degradation



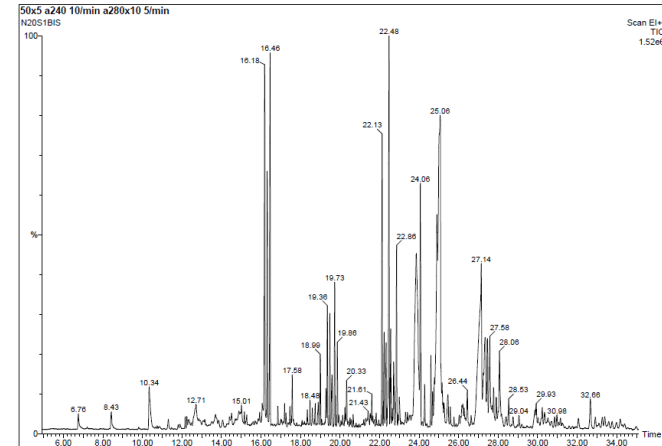
@ 50/50% the temperature dramatically supports degradation

# Products

## GCMS of condensable prod.



80% coffee



50% coffee

- Linear HCs
- Low MW aromatics and eterocycles
- linear alcohols  $C_{12}$ - $C_{13}$  and groups of isomers
- water <4% (coffee dependent)

# Products

## clustering of products

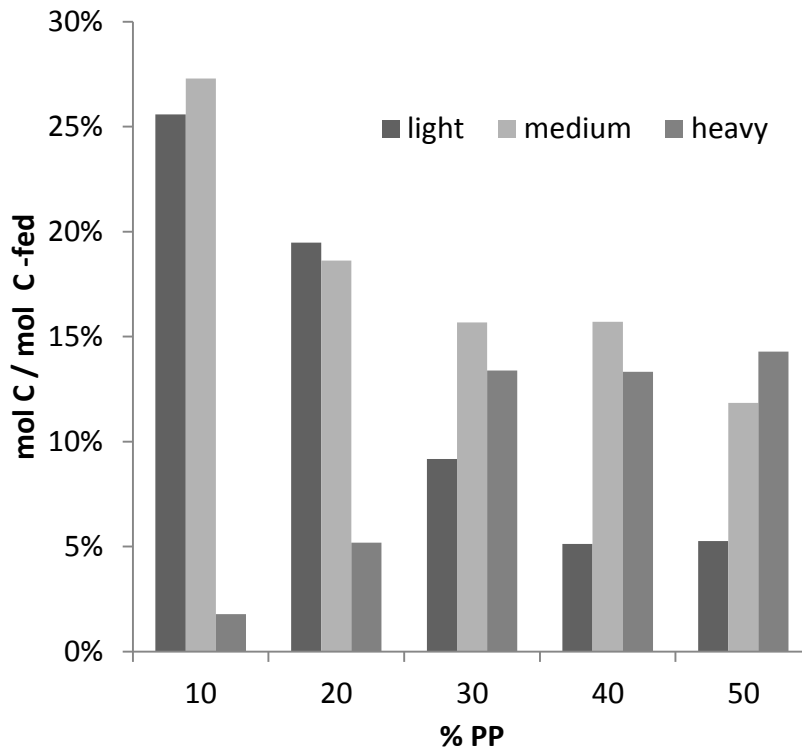


	C atoms	Elution time
Light	$< C_6$	$< 12$ min
Medium	$C_6$ and $C_{16}$	between 12 and 26 min
Heavy	$> C_{16}$	$> 26$ min

Common classification  
Rough but effective

# Feed composition

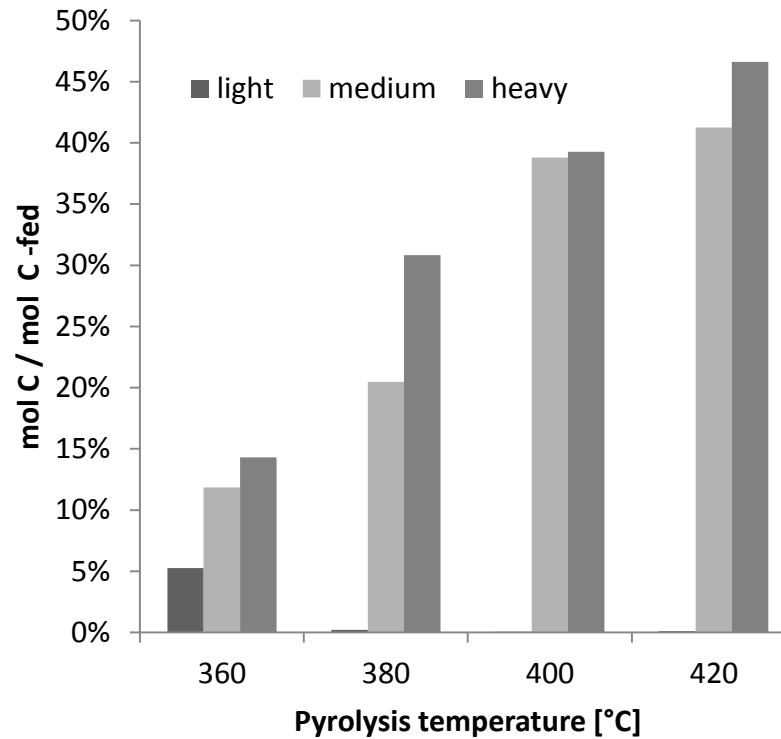
## yield by groups



more PP → products shift to higher MW  
@360°C PP yields mostly high MW products



# Temperature yield by groups



Light species degrade to gas  
(char might help)



# Conclusions

1. The degradation of coffee anticipates PP
2. Higher coffee/PP →  
lower MW of the products, larger conversion
3.  $T > 360^{\circ}\text{C}$  affects the PP degradation, while products of coffee degradation is believed to support its cracking
4. Products vs. fossil fuels:  
similar: Aliphatic HCs and aromatics,  $\text{C}_{14} - \text{C}_{30}$   
different: oxygenated and acids species



# Issues worth exploring

1. a 'fractional' pyrolysis of biomass/PP, at 2 T's
2. Effect of HR on the distribution of products  
Interactions of melt polymer and non-wettable biomass  
→ modelling
3. Characterization of gas, for energy balance



Thank you for the attention!

Keep drinking good coffee

