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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)

\[ T_m = 167^\circ C \quad \Delta H_m = 2.9 \text{ kJ/mol} \quad \alpha = 33\% \]
Thermal Analysis

DSC

2 – decomposition (in air or inert)

Degradation of coffee $T > 250 \, ^\circ C$

Degradation of PP $T > 360 \, ^\circ C$
Pyrolysis Reactor
upflow fixed bed

from mg to tens of g  (ID = 38mm)  products condensation @ 65, 25,-20 °C
Heating policy

'isothermal'

\[ HR = 5^\circ C/min \]

3h at max \( T \) (360, 380, 400, 420°C)
Experimental design

% and T effect

<table>
<thead>
<tr>
<th># test</th>
<th>Composition [% vol]</th>
<th>T [°C]</th>
<th>WL [%]</th>
<th>liquid yield [% wt]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PP</td>
<td>coffee</td>
<td></td>
<td></td>
</tr>
<tr>
<td>set 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>90</td>
<td>360</td>
<td>54.3</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>80</td>
<td>360</td>
<td>56.7</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>70</td>
<td>360</td>
<td>42.9</td>
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<tr>
<td>4</td>
<td>40</td>
<td>60</td>
<td>360</td>
<td>38.1</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>50</td>
<td>360</td>
<td>34.0</td>
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<tr>
<td>set 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>50</td>
<td>360</td>
<td>34.2</td>
</tr>
<tr>
<td>7</td>
<td>50</td>
<td>50</td>
<td>380</td>
<td>74.2</td>
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<tr>
<td>8</td>
<td>50</td>
<td>50</td>
<td>400</td>
<td>83.8</td>
</tr>
<tr>
<td>9</td>
<td>50</td>
<td>50</td>
<td>420</td>
<td>93.1</td>
</tr>
</tbody>
</table>

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 condensible prod.

- Linear HCs
- Low MW aromatics and euterocycles
- Linear alcools $C_{12}-C_{13}$ and groups of isomers
- Water <4% (coffee dependent)
# Products clustering of products

<table>
<thead>
<tr>
<th>C atoms</th>
<th>Elution time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Light</strong></td>
<td>$&lt; C_6$</td>
</tr>
<tr>
<td><strong>Medium</strong></td>
<td>$C_6$ and $C_{16}$</td>
</tr>
<tr>
<td><strong>Heavy</strong></td>
<td>$&gt; C_{16}$</td>
</tr>
</tbody>
</table>

**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 $\rightarrow$ lower MW of the products, larger conversion

3. $T > 360^\circ C$ 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, $C_{14} - C_{30}$
   different: oxigenated 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