Slow Pyrolysis of Low-Density Polyethylene Coated Coffee Cups into Value-Added Products

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icfar

Context

95% Paper
+
5% LDPE

- **Single-use**
- **Globally, 2.3 billion cup waste every day**
- **Heterogeneous composition**
- **Incinerated Landfills**

Context

- Pyrolysis can convert biomass into value-added products in the forms of solid, liquid, and gas.
- Char – solid residue of pyrolysis process – can be further activated for better pore structure and higher surface area.
- Activated char can adsorb pollutants such as dyes, pharmaceuticals, phenolics, etc.

Objectives

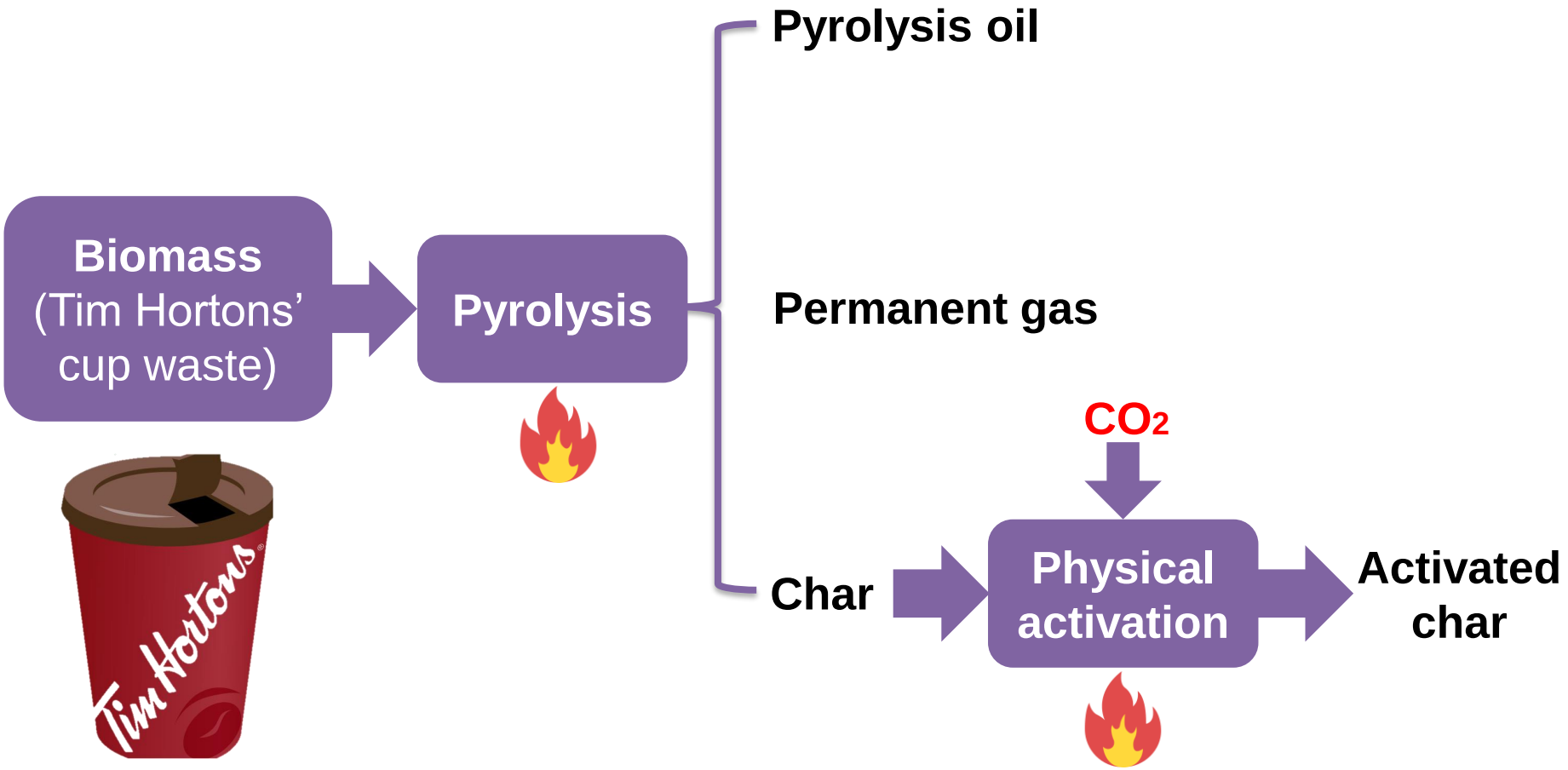
1. Pyrolytic conversion of coffee cup waste into value-added products

    a. Investigation of the conversion yields, characteristics of pyrolysis products, and their potential applications

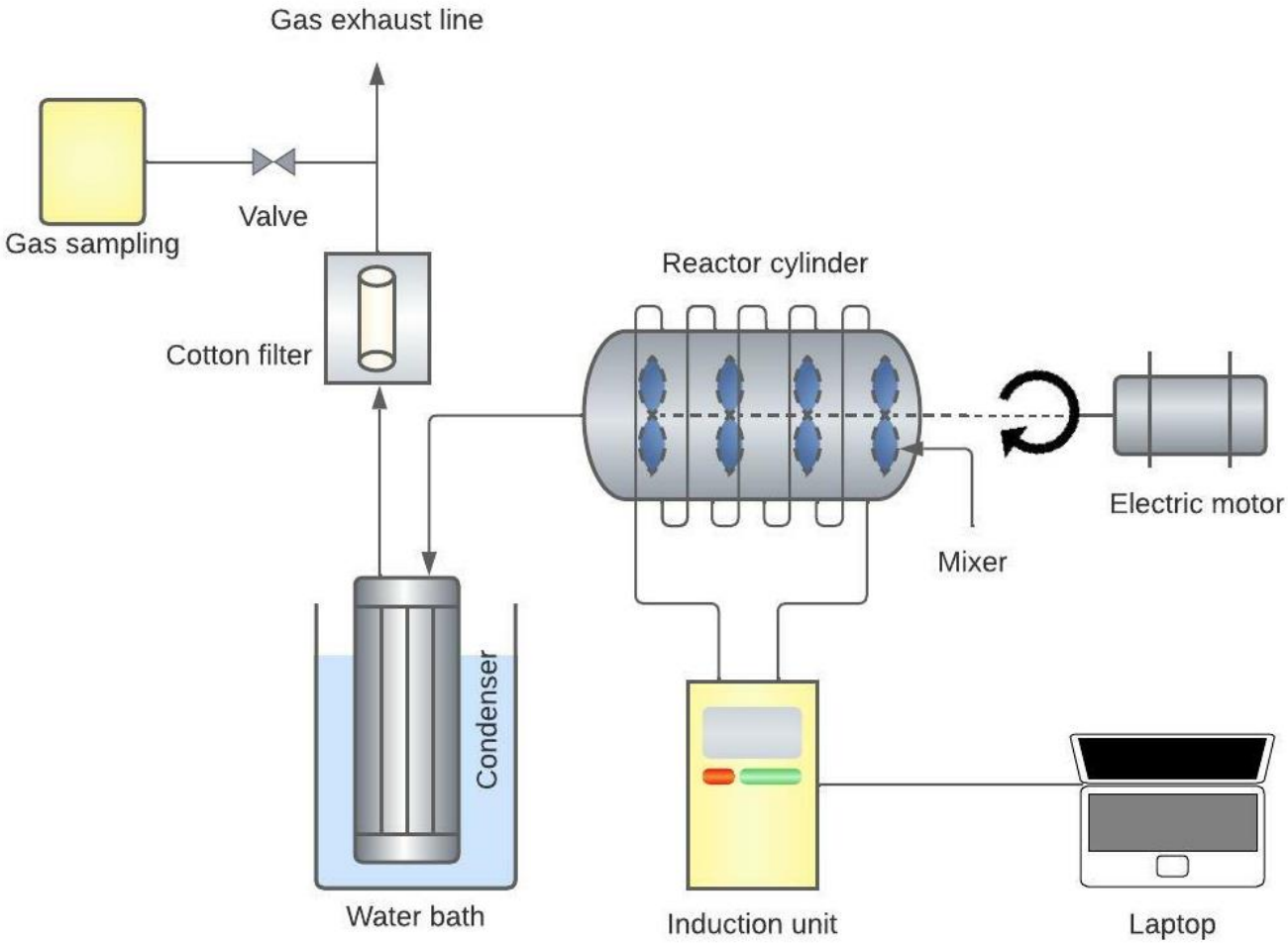
    b. Activation of char derived from slow pyrolysis of coffee cup waste

2. Adsorption of selected molecules using activated char produced from coffee cup waste

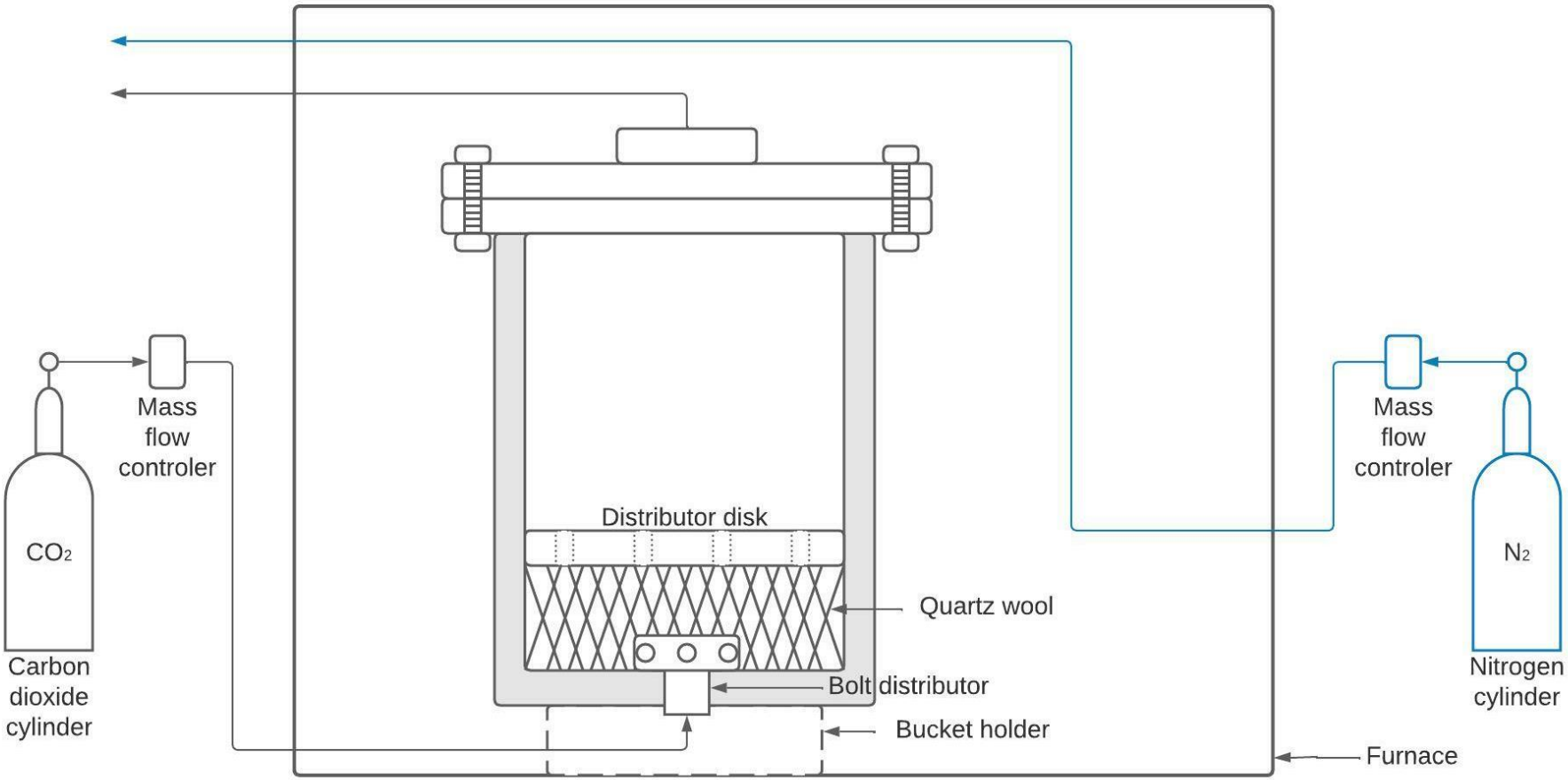
Methodology



Batch Horizontal Induction-Heated Reactor



Char Activation Unit



Experimental Methodology

- **Batch pyrolysis** under different operating conditions
- **Characterization** of liquid, gas, and char for their value-added applications

Pyrolysis oil	Permanent gas	Char
• pH • HHV • Water content • GC-MS • HPLC	• Micro-GC	• pH • Ultimate analysis • Proximate analysis

Experimental Methodology

- Comparison of different feedstocks:

250 g

95 wt.% Cellulose:
5wt.% LDPE

95 wt.% Paper :
5wt.% LDPE

95 wt.% Pulp :
5wt.% LDPE

500 °C

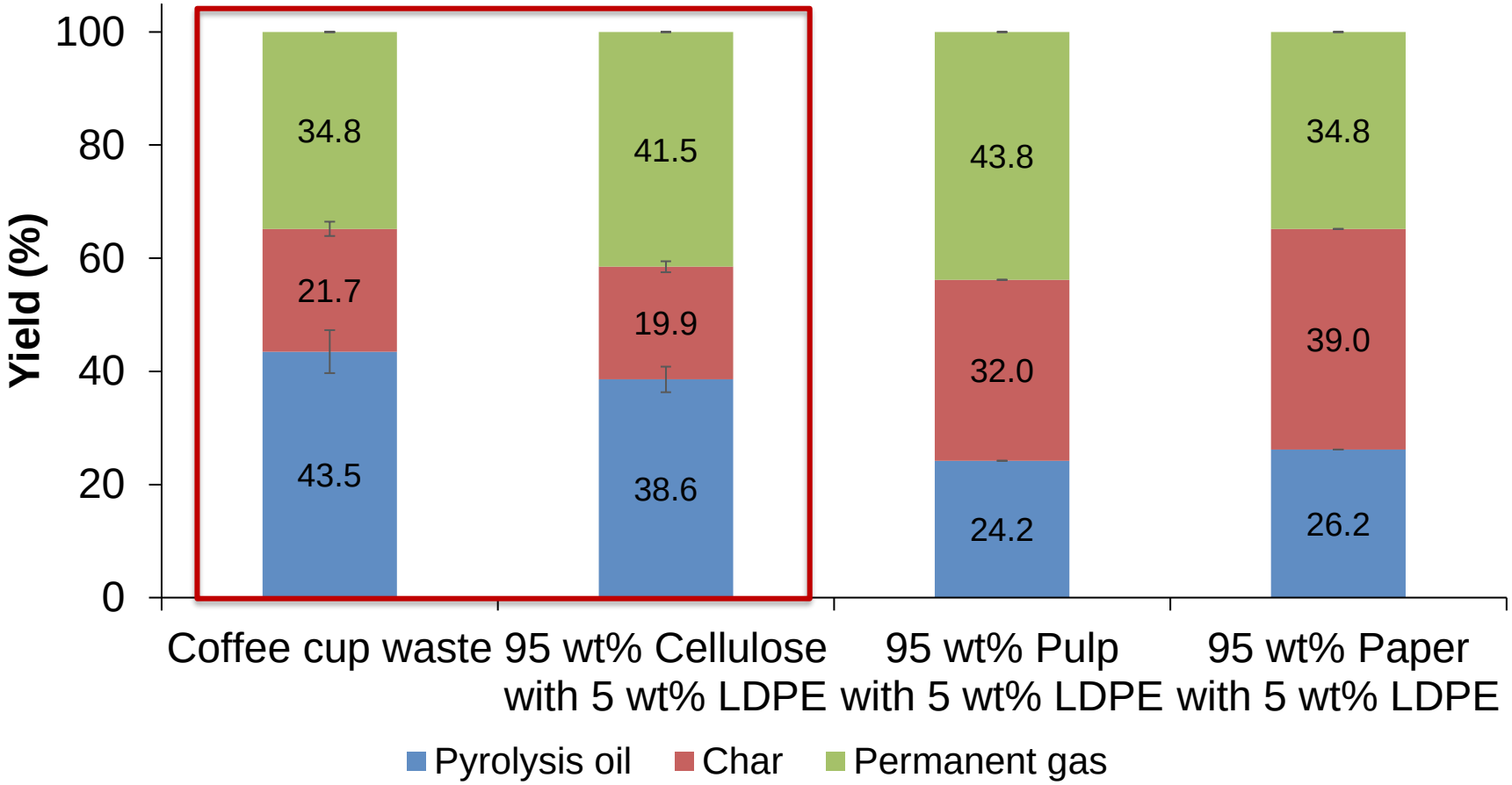
10 °C/min

30 min

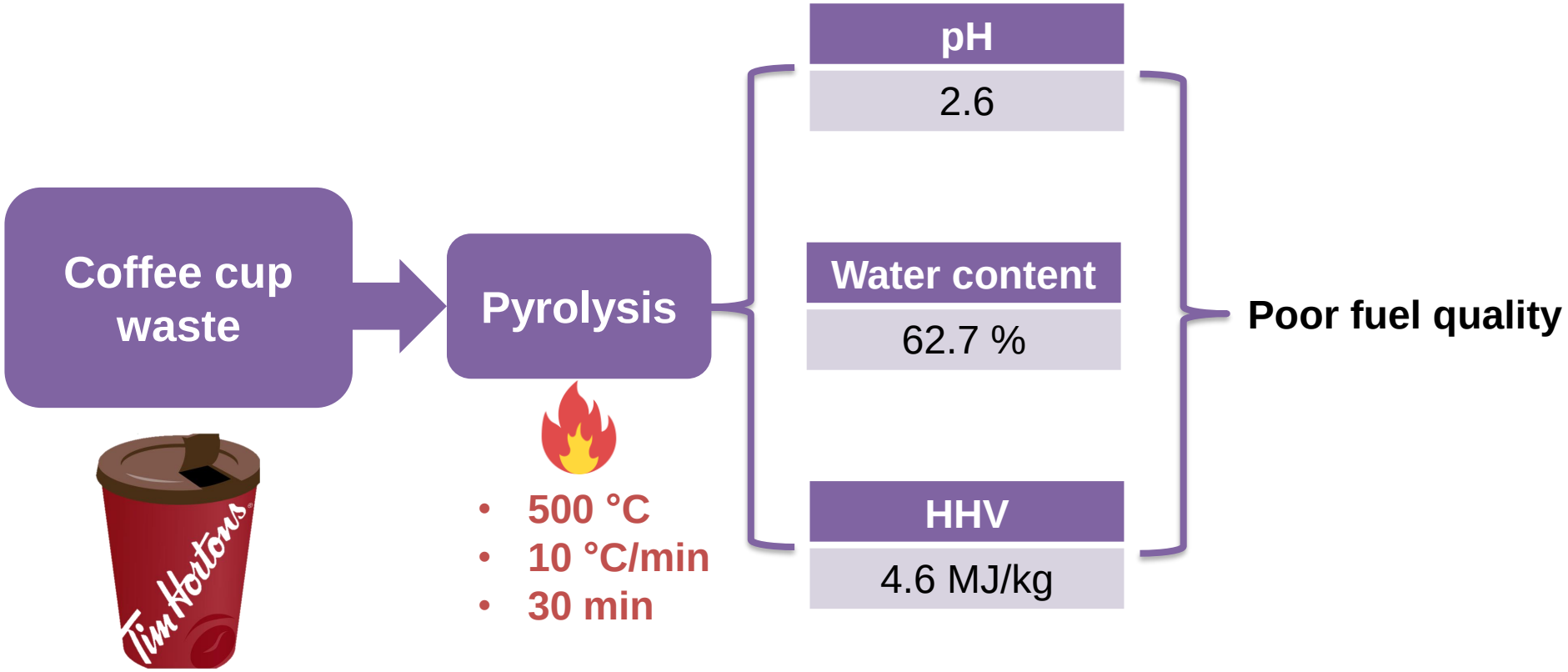
No sweeping gas

Pulp composition	
Cellulose	80%
Hemi-cellulose	15%
Lignin	5%

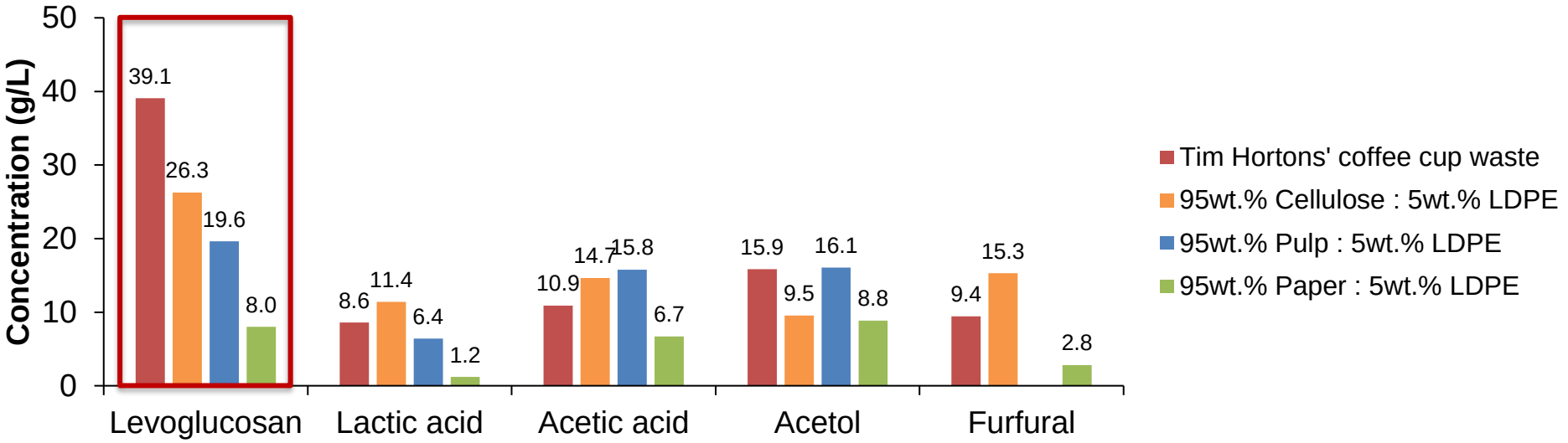
Yields(%): Comparison of different feedstocks



Pyrolysis Oil Characterization

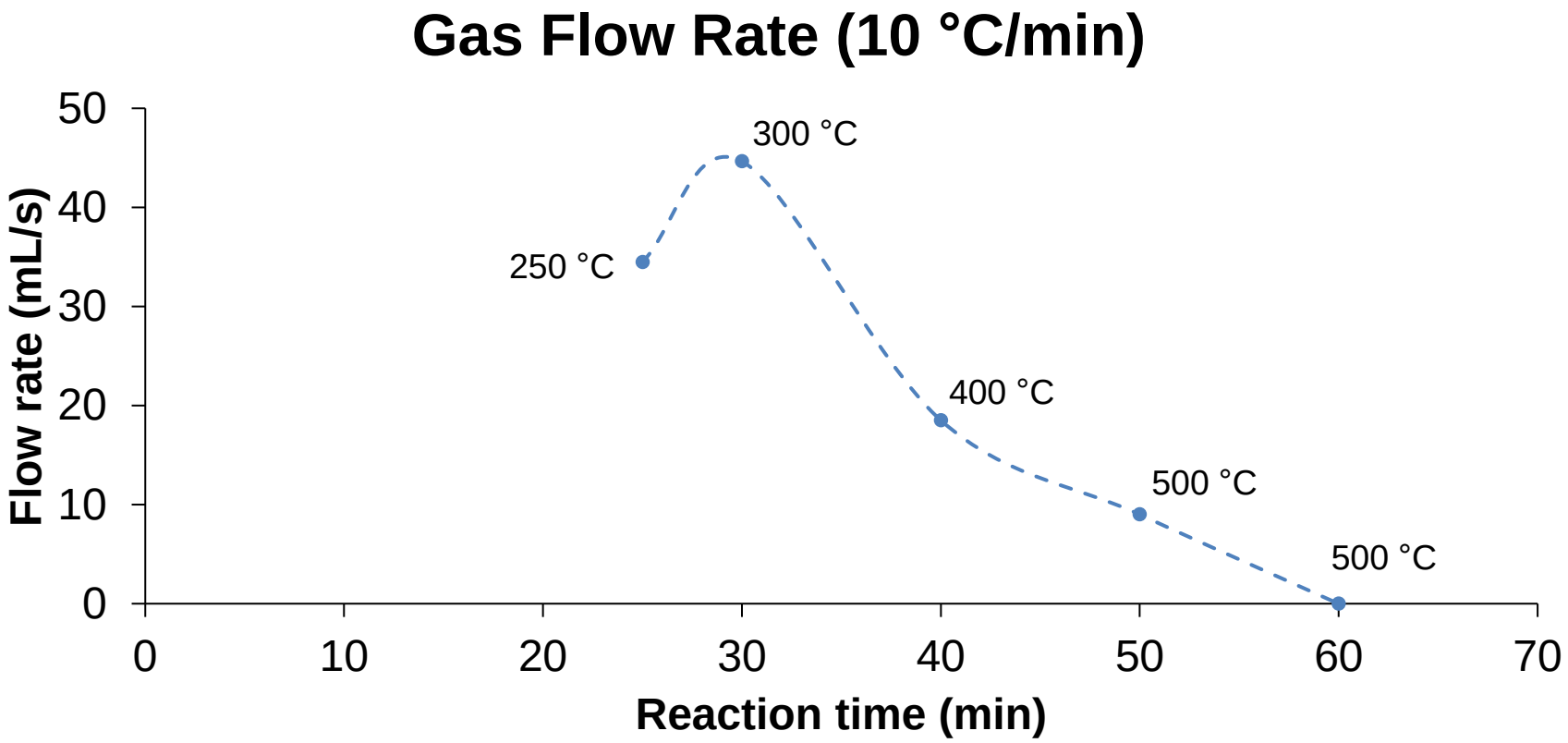


Pyrolysis Oil Characterization: HPLC

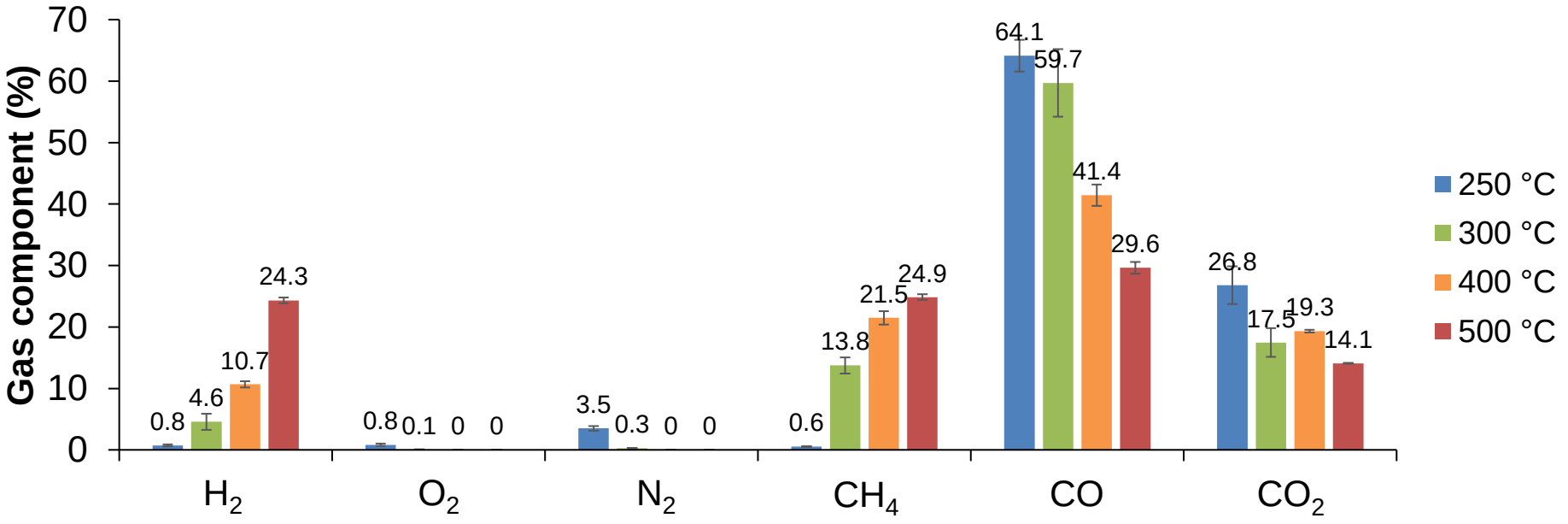


Levoglucosan	Lactic acid	Acetic acid	Acetol	Furfural
For synthesis of polymers and pharmaceuticals	For food preservative, curing, and flavoring agent	For production of paints, adhesives, and coatings	For production of compounds such as acetone	For making inks, plastics, and fertilizers

Gas Evolution with Time/Temperature



Gas Characterization: Micro-GC



Temperature (°C)	Flow rate (mL/s)	HHV (MJ/Nm^3)
250	34.5	11.0
300	44.6	16.3
400	28.5	19.6
500	9.0	21.6

Town gas

18 MJ/Nm^3

Activation of Coffee Cup Char

- Amount of char: 50 g
- Heating rate: 10 °C/min

Activation temperature (°C)	Holding time (h)	CO_2 flow rate (L/min)	Yield* (%)
900	1	0.5	43.9 ± 0.1
	2	0.5	29.9 ± 2.8
	3	0.5	19.0 ± 3.3
	3	1	8.8 ± 2.8
	3	2	6.5 ± 0.4

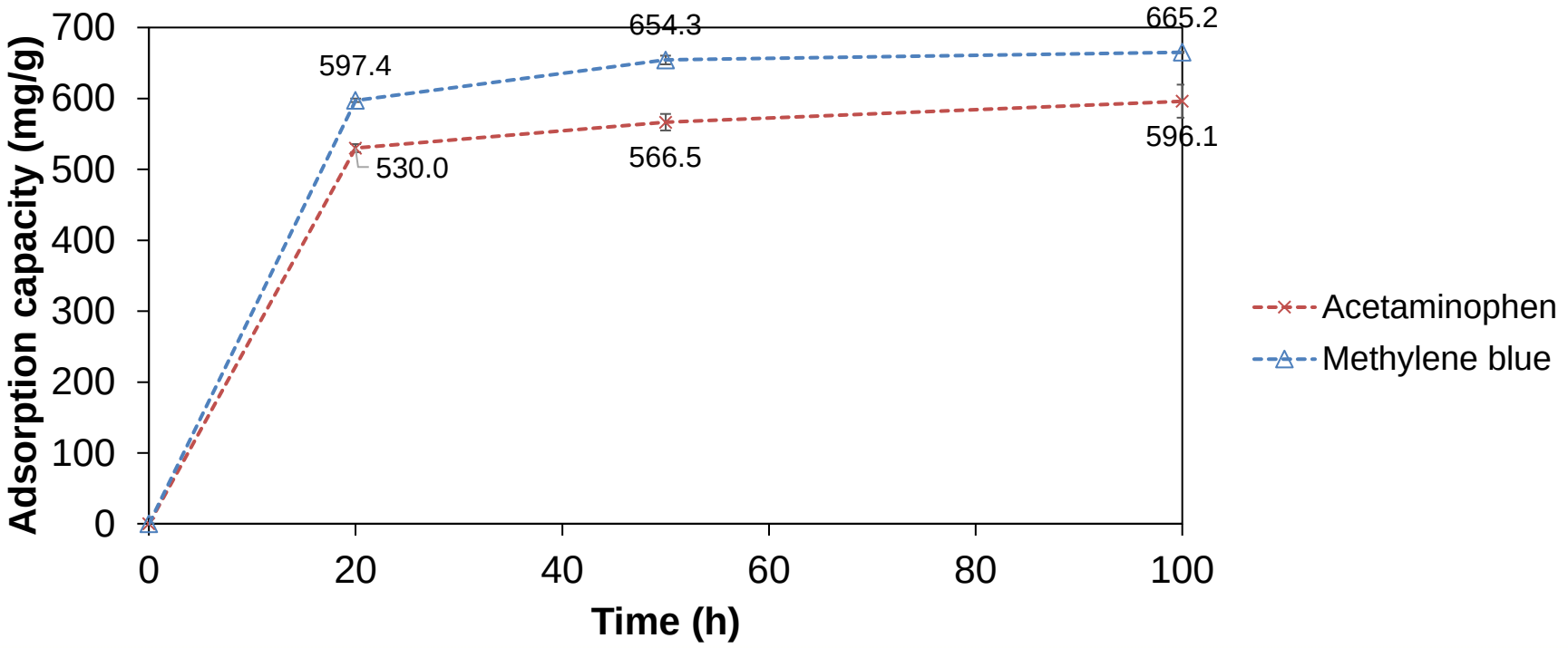
$$* \text{ Yield } (\%) = \frac{\text{Activated char}}{\text{Biochar}} \text{ X } 100\ (\%)$$

Adsorption Performance Testing

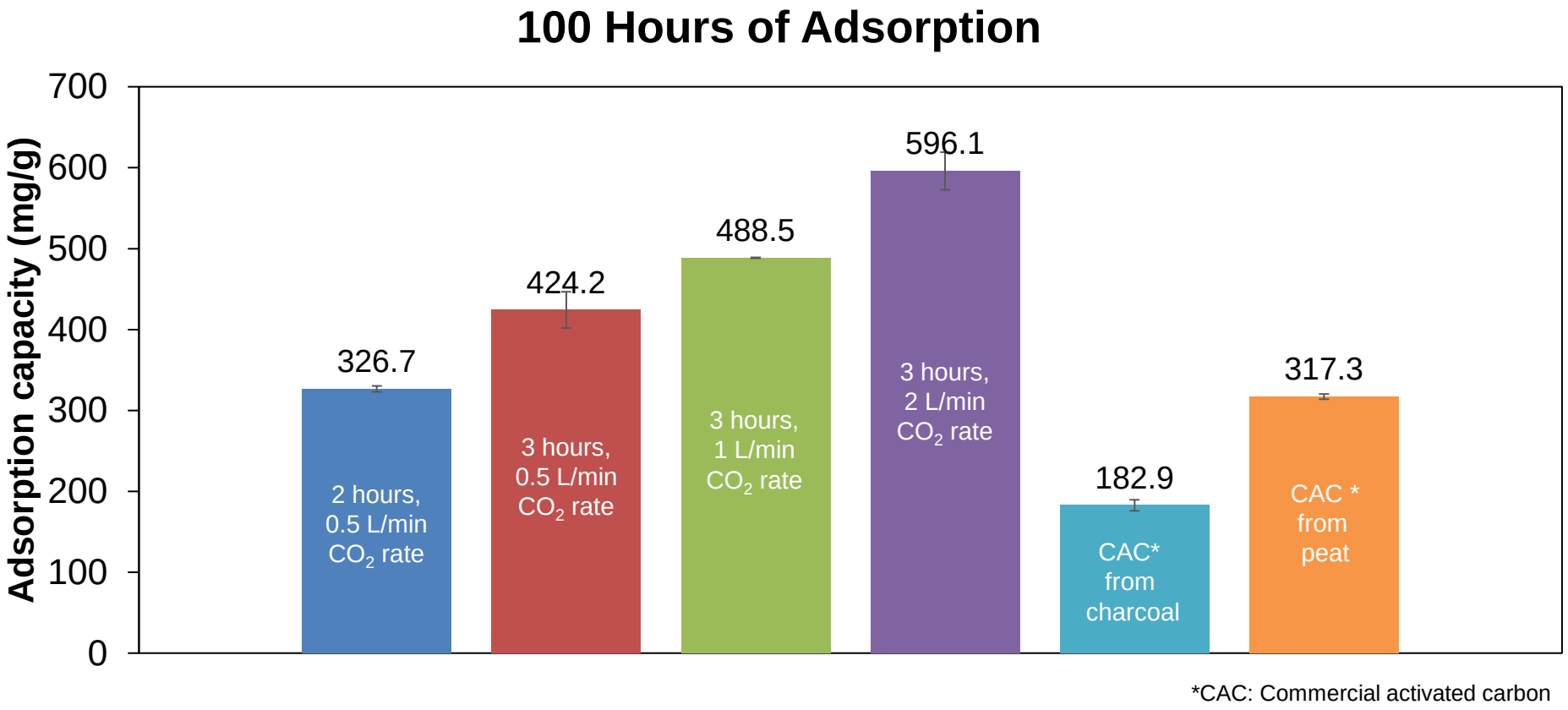
- Selected model compounds:
  - Methylene blue
  - Acetaminophen
- Concentration of standard solution: 3,000 mg/L
- 30 mL of standard solution + 100 mg of adsorbent in a stirred tank

Adsorption Performance

- Activation temperature: 900 °C
- Holding time: 3 hours
- CO_2 flow rate: 2 L/min

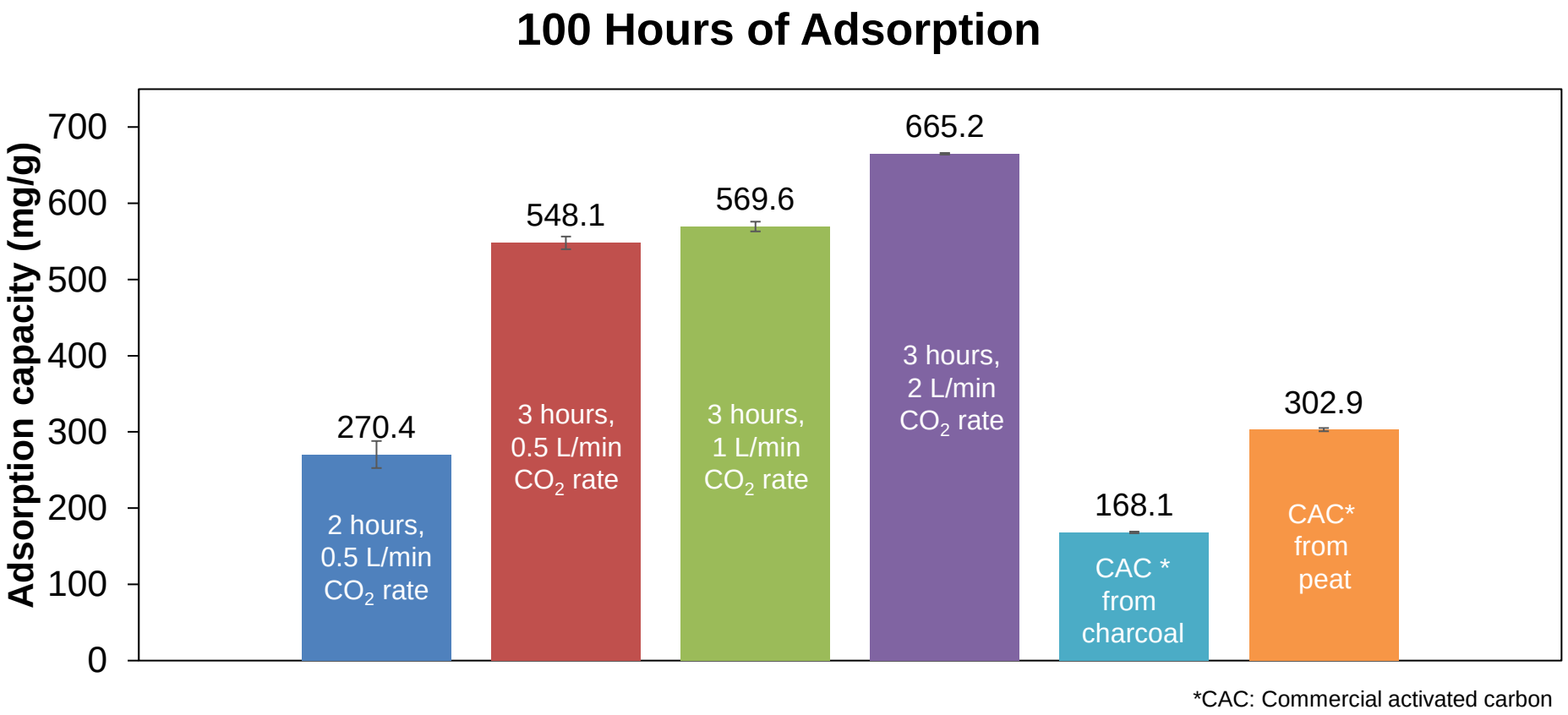


Adsorption of Acetaminophen (3,000 mg/L)



*CAC: Commercial activated carbon

Adsorption of Methylene Blue (3,000 mg/L)



*CAC: Commercial activated carbon

Major Findings

- Acetaminophen adsorption capacities

Adsorbent	Activation/treatment	Q_{max} (mg/g)	Reference
Coffee cup waste	**CO_2**	**596**	**This study**
Brazil nutshell	Zinc chloride	411	Lima et al., 2019
Brewer's spent grain	Potassium hydroxide	318	de Araújo et al., 2020
Cashew nut shell	Phosphoric acid	146	Geczo et al., 2021
Eucalyptus pruning residues	CO_2	98	Bursztyn Fuentes et al., 2020
Cotton textile waste	Phosphoric acid	62	Akkouche et al., 2021
Spent tea leaves	Phosphoric acid	59	Wong et al., 2018
Moringa oleifera Lam. seed husks	Phosphoric acid	17	Quesada et al., 2019

Major Findings

- Methylene blue adsorption capacities

Adsorbent	Activation/treatment	Q_{max} (mg/g)	Reference
Coffee cup waste	**CO_2**	**665**	**This study**
Yunnan pine	Potassium hydroxide	638	Zheng et al., 2021
Water hyacinth	Citric acid	395	Xu et al., 2016
Eucalyptus	Citric acid	179	Sun et al., 2015
Barley malt bagasse	CO_2	161	Franciski et al., 2018
Pine sawdust	CO_2	160	Liu et al., 2022
Lignocellulosic agriculture waste	Water vapor	149	El-Bery et al., 2022
Banana pseudostem	Phosphomolybdic acid	146	Liu et al., 2019
Lychee seed	Potassium hydroxide	125	Sahu et al., 2020

Conclusions

- Coffee cup waste can produce value-added products in the forms of solid, liquid, and gas via slow pyrolysis.

- A low-cost adsorbent with high efficiency properties can be produced through pyrolysis and activation of coffee cup waste.

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Thank you!