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FACULTY OF
BIOSCIENCE ENGINEERING

DEPARTMENT - GREEN CHEMISTRY AND TECHNOLOGY
RESEARCH GROUP - THERMOCHEMICAL CONVERSION OF BIOMASS

A LOW-COST ROUTE TO SUGAR-DERIVED PLATFORM CHEMICALS VIA FAST PYROLYSIS OF “VEGETABLE IVORY” RESIDUE

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WHY SHOULD WE BE INTERESTED?

→ SUSTAINABILITY AND NOVELTY

- To support a sustainable and circular economy, one should develop an instinct to get the most out of bioresources
- Three pillars
  1. Efficient processing technologies
  2. Bioresource recovery
  3. Valorization of various side streams
- We pioneered:
  - a simple and low-cost route to
  - valorize inevitable waste to
  - high-value platform molecules
- First comprehensive study with this “forgotten” feedstock

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WHAT IS VEGETABLE IVORY?

→ PALM SEED FROM AMAZON REGION

- Is neither a vegetable, nor ivory
- Is the white endosperm of a palm seed *Phytelephas*, according to Cooper (1844)
- Found in Colombia, Ecuador, Perú and Brazil
- Crafted into buttons, ornaments, etc.

XVII.—ON THE STRUCTURE OF THE NUT KNOWN AS VEGETABLE IVORY.*

By Daniel Cooper, A.L.S., Surgeon.

THE seed or nut of the Tagua-plant, a species of the genus *Phytelephas*, belonging to the order Pandaneæ of Brown, and Cyclanthaceæ of Lindley, of late much imported from South America as a substitute for the various uses to which ivory is applied in the arts and manufactures, as far

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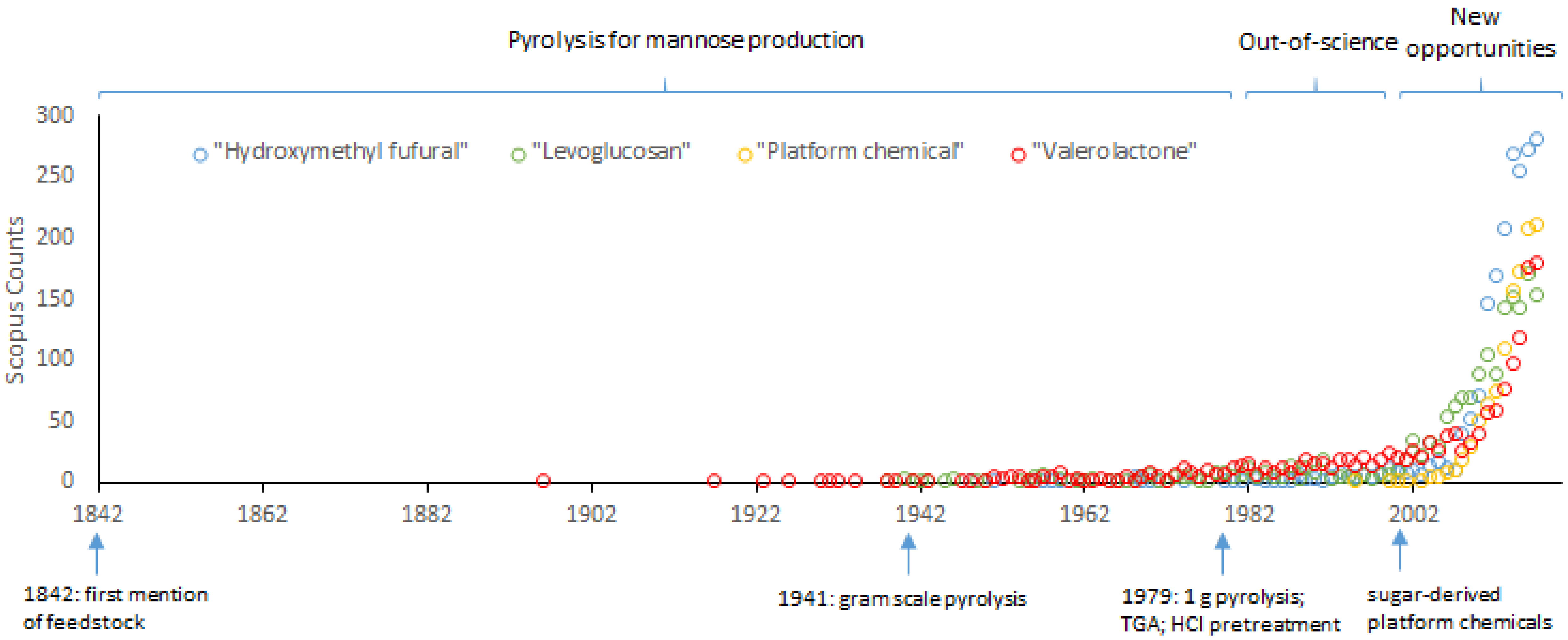
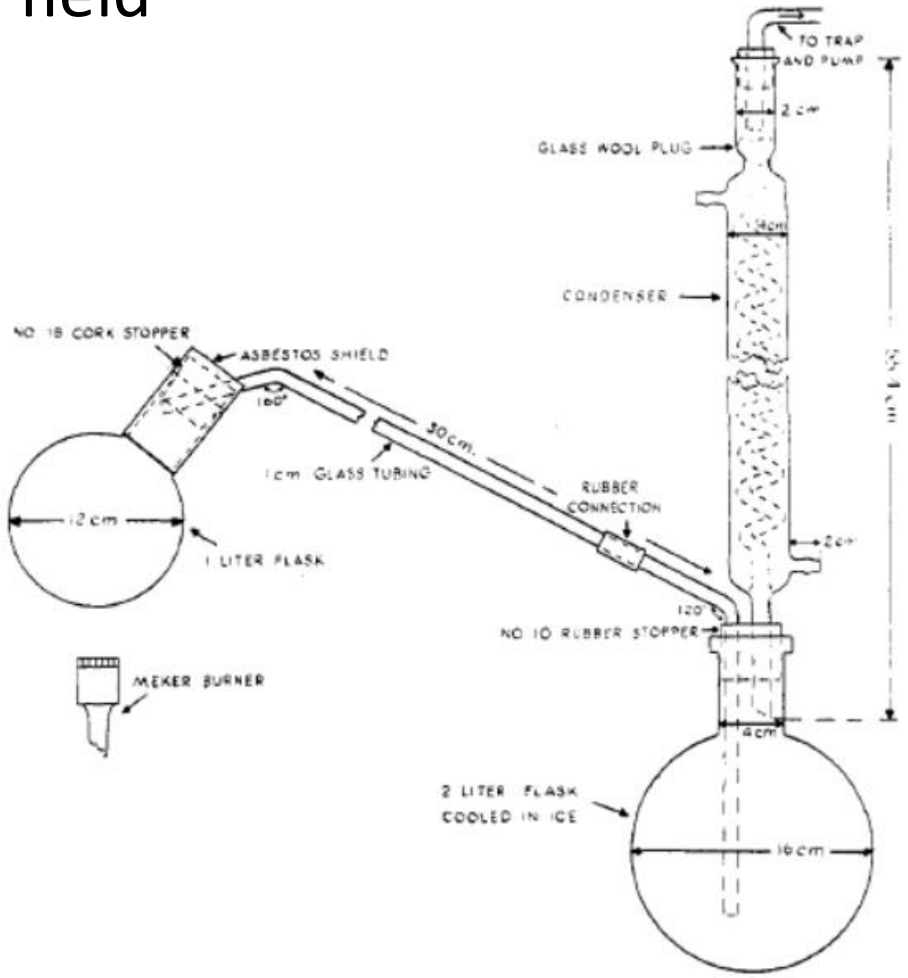
WHAT IS ITS RELEVANCE?

→ FORGOTTEN PRECURSOR FOR C6 PLATFORM CHEMICALS

- Produced residue in Ecuador: 1,200 – 4,800 metric tonnes/year, no end-use
- Composed of mannan (Oña, 2017), or cellulose (Timell, 1957) → C6-based carbohydrates, merely lignin
- Tested for mannose production, but became “forgotten”, within the scientific field





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WHAT IS ITS RELEVANCE?

→ VIRTUALLY PURE CARBOHYDRATE, WITHOUT FRACTIONATION

- **Hypothesis**: pyrolysis of vegetable ivory unlocks the low-cost route to:
  - Levo-sugars, levoglucosenone (cyrene^{TM} precursor), 5-HMF, etc.
  - Low-cost: second generation (lignocellulosic) biomass requires prior fractionation to obtain those platform chemicals

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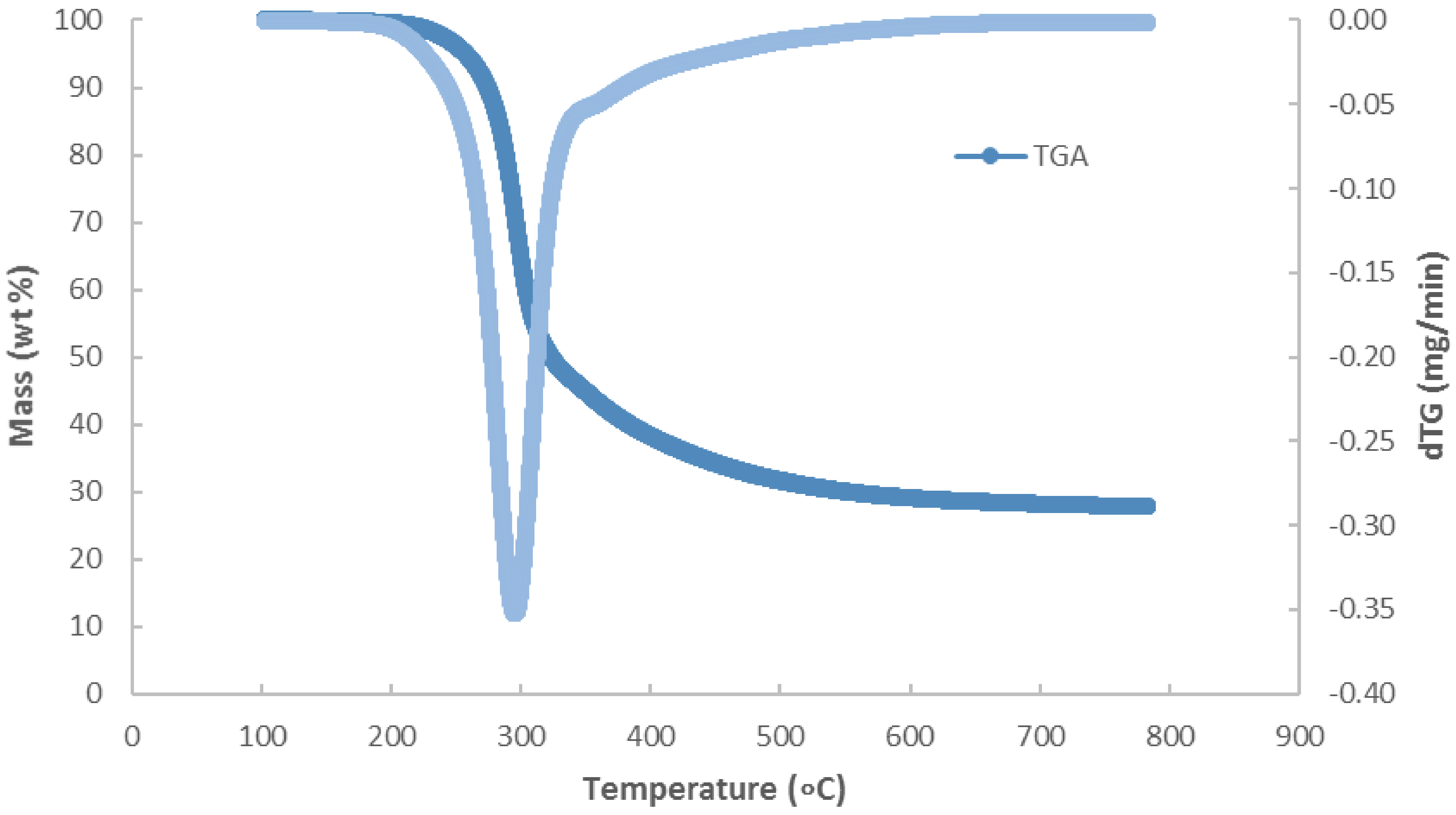
WHAT IS NEW ABOUT THIS STUDY?
→ VIRTUALLY EVERYTHING

1. Thorough analysis of the feedstock
2. Fast pyrolysis in a fully equipped, continuously operated lab-scale reactor:
   - Duplicate experiments, full mass balance closure
   - Applied two highest treatment temperature (HTT): 350°C and 500°C
3. Comprehensive characterization of the pyrolysis products

WHAT WAS DISCIVERED?

→ EXCELLENT FEEDSTOCK FOR FAST PYROLYSIS

- Feedstock characterization
  - $C_6H_{11}O_5N_{0.3}$; carbohydrate + protein
  - dTGA and end-weight; hemicellulose
  - Low in ash (0.95 wt%)
  - High in VM (82.39 wt%)



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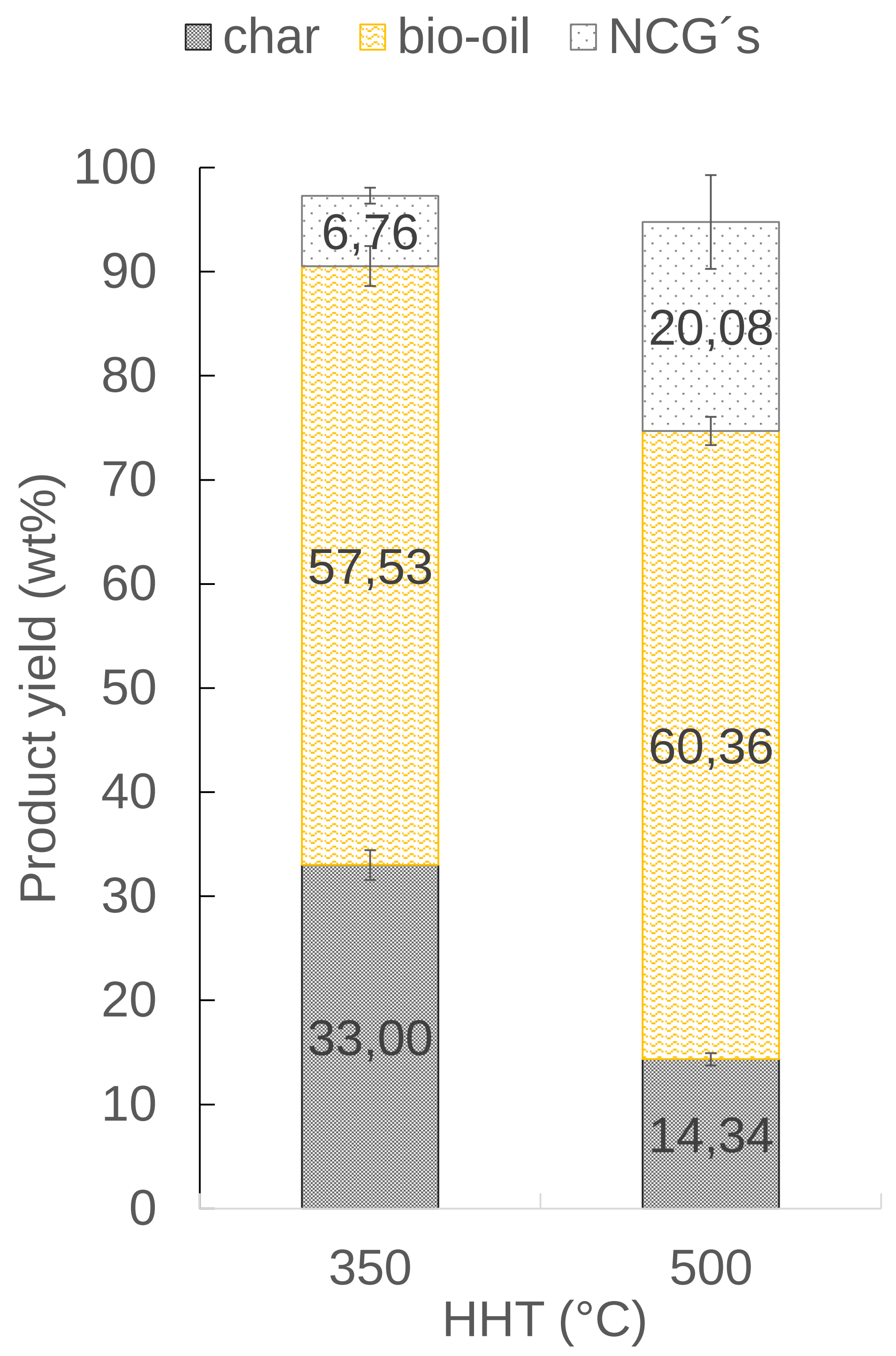
WHAT WAS DISCIVERED?

→ HIGH BIO-OIL YIELD, GOOD MASS BALANCE CLOSURES

- Pyrolysis products – **general**
  - Bio-oil:
    - Spontaneously separates in heavy and aqueous phase
    - 350°C → 96.45% aqueous; 500 °C → 86.47% aqueous
  - Biochar:
    - Decreased yield upon increase of HTT
    - Odorous biochar at 350 °C
  - Non-condensable gases:
    - Increased in tandem with HTT increase



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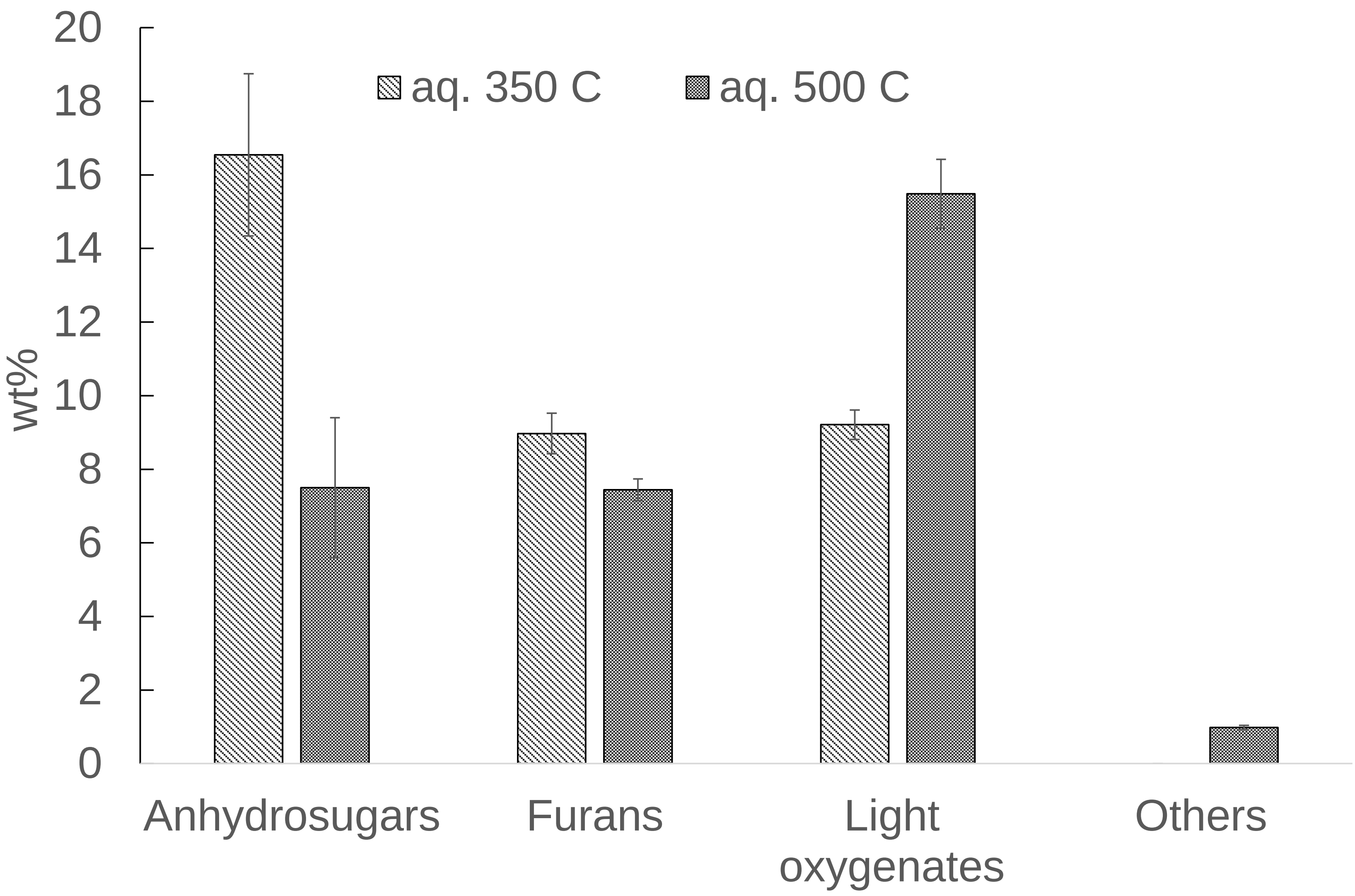
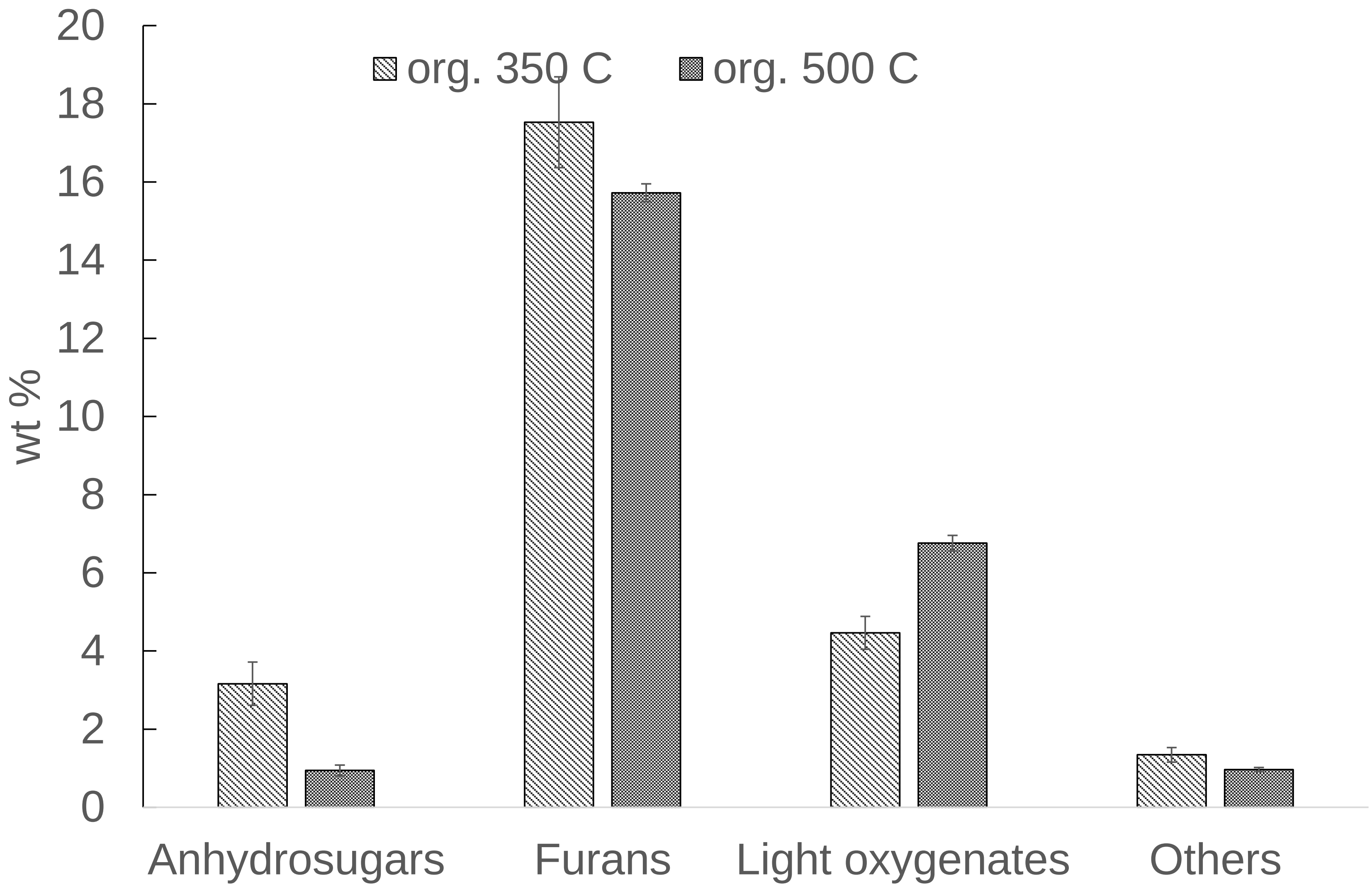
WHAT WAS DISCIVERED?

→ BIO-OIL FILLED WITH VALUABLE PLATFORM CHEMALS

- Bio-oil – **detail**
    - Aqueous phase rich in anhydrosugars
    - Heavy phase rich in furans



Aqueous phase

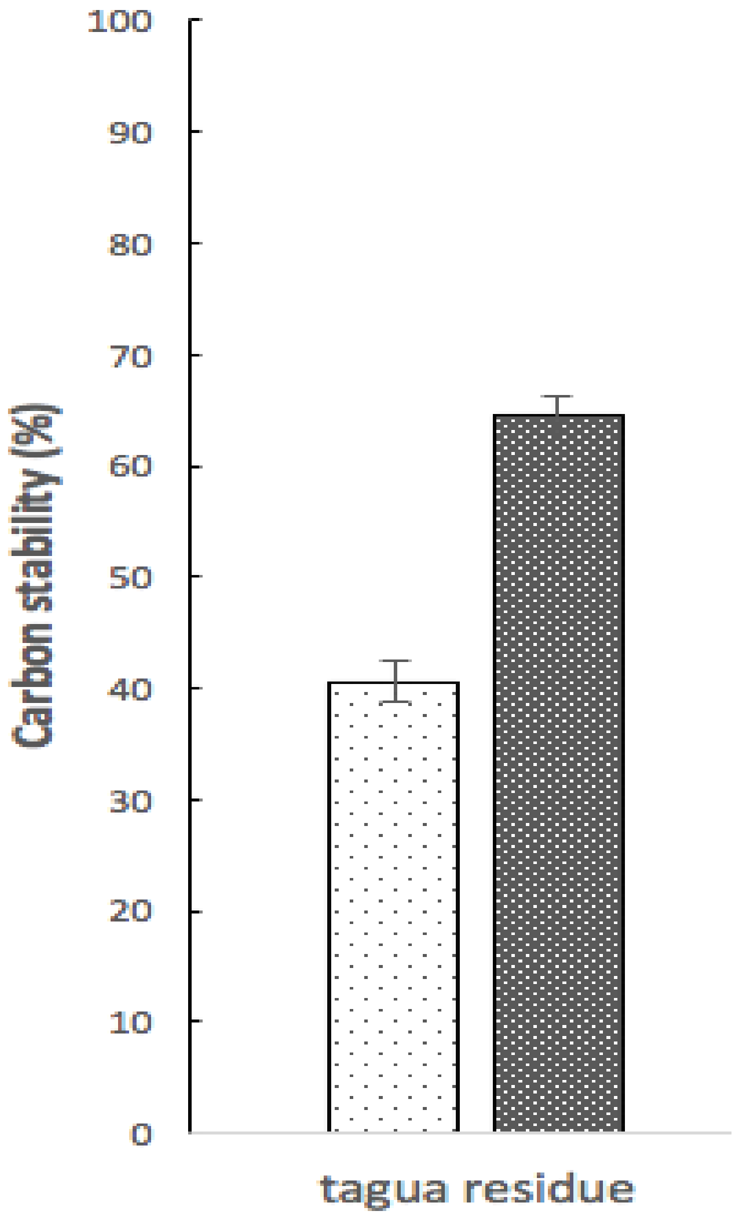


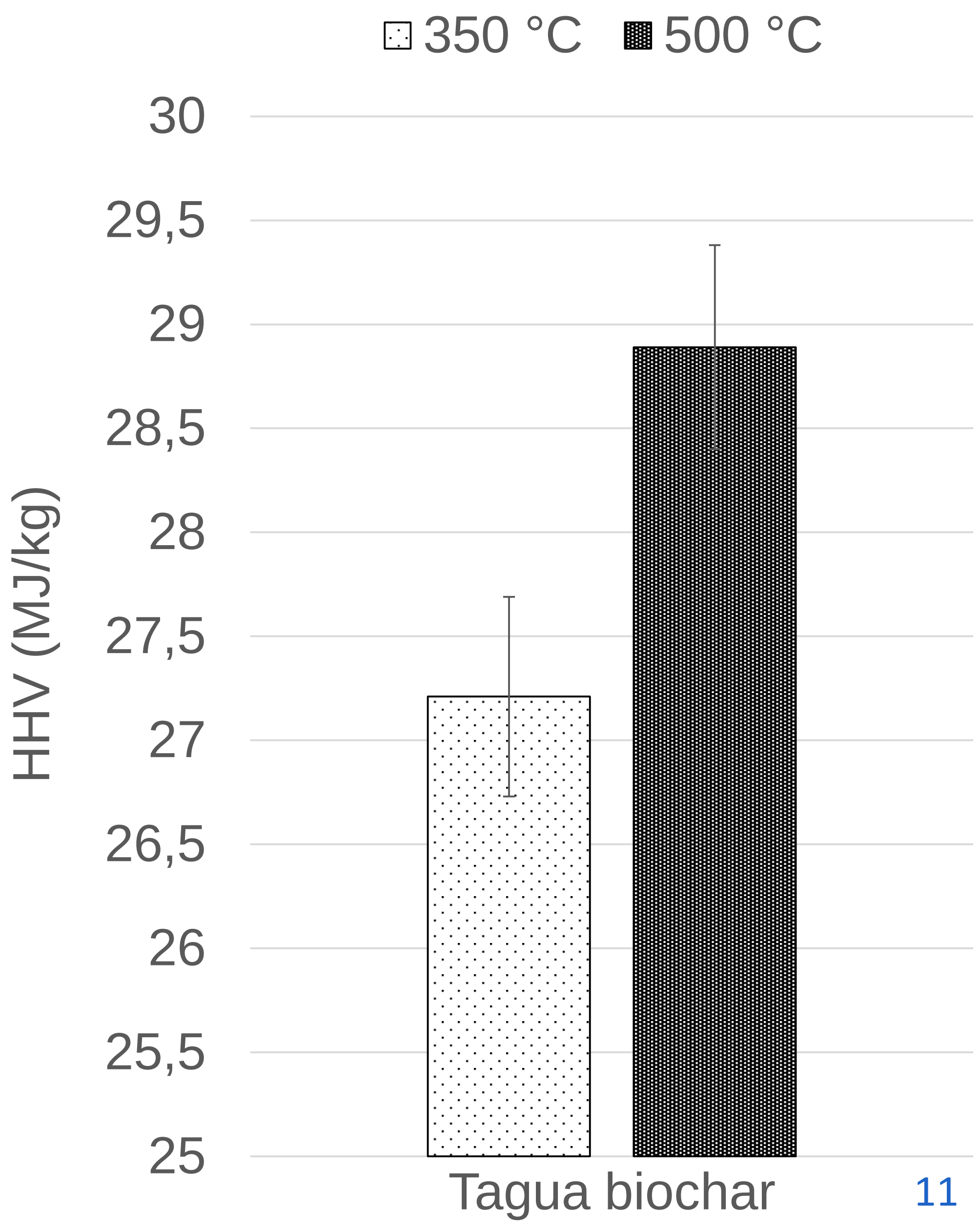
Heavy phase

WHAT WAS DISCIVERED?
→BIOCHAR IS QUALITATIVE

- Biochar – **detail**
  - Upon HTT increase:
    - VM decreased
    - FC d.a.f. increases → carbon stability
    - Carbon stability increased:
      - Higher fraction of stable carbons
      - Both H/C and O/C decrease
    - HHV increased (21 MJ/kg for feedstock)

HHT (°C)	Biochar yield d.b.	VM (wt%)	Ash (wt%)	FC d.a.f. (wt%)	FC yield	H/C	O/C
350	36.87 ±1.41	41.16 ±0.23	3.31 ±0.05	53.91 ±0.77	19.87 ±0.48	0.77 ±0.03	0.29 ±0.02
500	15.82 ±0.73	20.36 ±0.57	7.73 ±0.82	69.22 ±1.82	10.96 ±0.80	0.51 ±0.02	0.20 ±0.04





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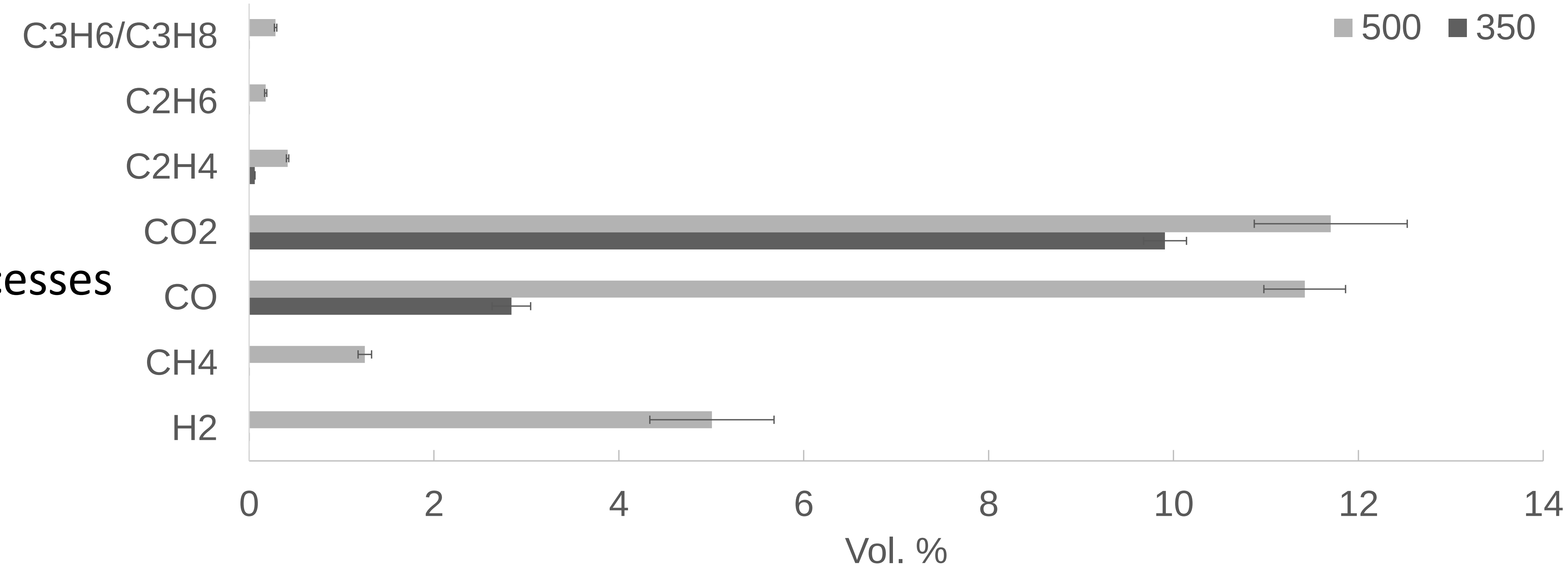
WHAT WAS DISCIVERED?

→ NON-CONDENSABLE GASSES WITH OPPORTUNITIES

- Non-condensable gases – **detail**
  - At 350 °C, only CO and CO_2
  - Upon HTT increase:
    - Appearance of CH_4
    - Appearance of H_2
    - Increase of CO
  - Potential for syngas processes



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WHAT SHOULD WE TAKE HOME?

- Bio-oil rich in high-value compounds
- Bio-oil composition steered by HTT
- Valuable biochar and non-condensable gases are obtained

→ **RE-INTRODUCTION OF VEGETABLE IVORY IN SCIENCE AND INDUSTRY SHOWS POTENTIAL**

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