Recycling of textile waste through pyrolysis process

Roozbet Kalateh, Aimaro Sanna, Danmei Sun, James McVee
School of Engineering & Physical Sciences, Heriot-Watt University
School of Textiles and Design, Heriot-Watt University

Outline

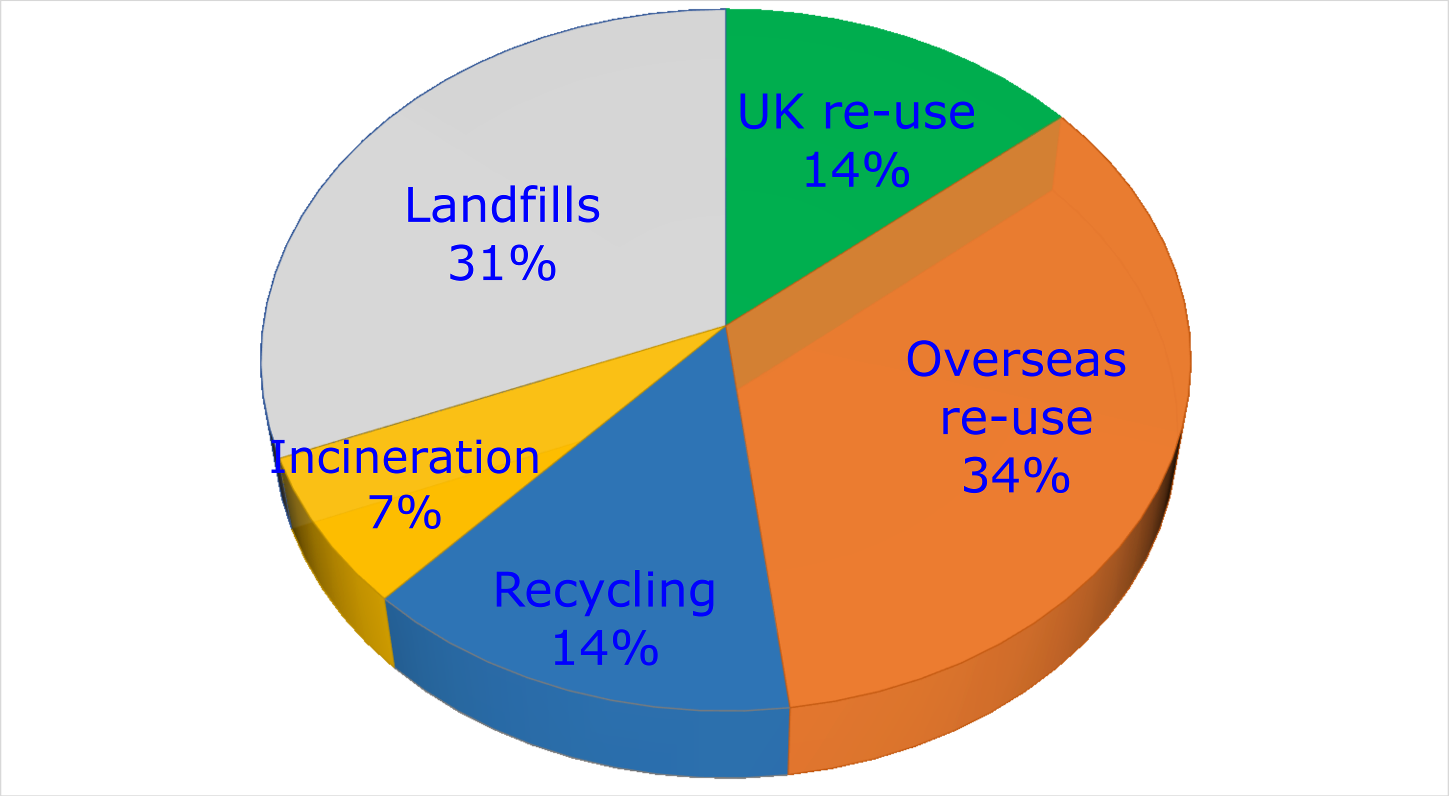
- Issues of textile waste
- Research objectives
- Technologies of textile waste management
- Experimental studies, research results
- Conclusions and implications

Issues of textile waste

- 67% of textile waste from factories was disposed in landfills. In addition, the consumption of clothing and non-clothing textiles was approximately 1.7 million tones in 2014 in the UK alone.
- If left in landfills
  - Release of harmful greenhouse gases such as methane
  - Contamination of soil and groundwater due to leaching of chemicals and dyes
  - Increased cost of landfill space
  - Brand dilution

Textile waste in the UK

70 Kg of textiles waste per person per year in the UK.



$$Total\ waste = 70 \times 65000000$$
$$= 4.55\ million\ tons/year$$

$$Landfills = 31\% \times 4.55$$
$$= 1.41\ million\ tons/year$$

Textile waste in Harris Tweed

- A globally well known brand, their products in various forms are sold world-widely and their production volume keeps increasing every year.

- Waste management: The industry creates two main types of waste, selvedges and roll ends. This accounts for around **10 tonnes** of waste annually with an estimated cost of **£400,000** split between the three companies, this figure will increase in line with the growth of companies.

New legislation - SCAP

The Sustainable Clothing Action Plan (SCAP) was launched in 2009 to increase the sustainability of textile sector. One way this is hoped to be achieved is through the SCAP 2020 Commitment which sees retailers, government departments and the British Retail Consortium (among others) sign up to voluntary targets to reduce the waste, water and carbon footprints of clothing by 2020.

Objectives

- Feasibility study of pyrolysis process (mass & energy balance)
- Design and test a lab scale reaction device
- Products evaluation

Technologies/Methods of textile waste management

- Recycling/reusing
- Biochemical methods, e.g. fermentation
- Thermal methods
  - Combustion
  - Gasification
  - pyrolysis

Thermal chemical method

Methods	Temperature (°C)	Oxygen	Residence time (s)
Slow pyrolysis	400	No	>86400
Intermediate	500	No	10-30
Fast pyrolysis	500	No	1
Gasification	750-900	Yes	variable
Combustion	>1500	Yes	-

Types of pyrolysis reactors

Reactor (pyrolyser)	Bio oil yield (%)	Operational complexity	Particle size	Biomass variability	Scale up	Inert gas flow
Fixed bed	75	Medium	Large	High	Hard	Low
Bubbling bed	75	Medium	small	Low	Easy	High
Recirculating bed	75	High	Medium	Low	Hard	High
Rotating cone	70	Medium	Medium	High	Medium	Low
Auger	70	Low	Medium	High	Easy	Low
Vacuum	60	High	Large	Medium	Hard	Low

Experimental set-up

We developed a device with a customised semi-fixed bed reactor for the pyrolysis. Although the design is laboratory scale, it allows to collect the char, tar and oil produced during the pyrolysis of wool waste under different conditions.

It allows:

- the optimal temperatures for the production of bio-char
- The process conditions required to maximize syngas production
  Quality and quantity control of the char and tar

Experimental conditions

	Temperature, ºC	Wool Size	Injected Gas
1	350	whole	CO_2
2	500	whole	CO_2
3	700	1 by 4 cm	CO_2
4	800	1 by 4 cm	CO_2
5	900	1 by 4 cm	CO_2
6	800	Loose	CO_2
7	800	1 by 4 cm	N_2
8	800	Loose	N_2

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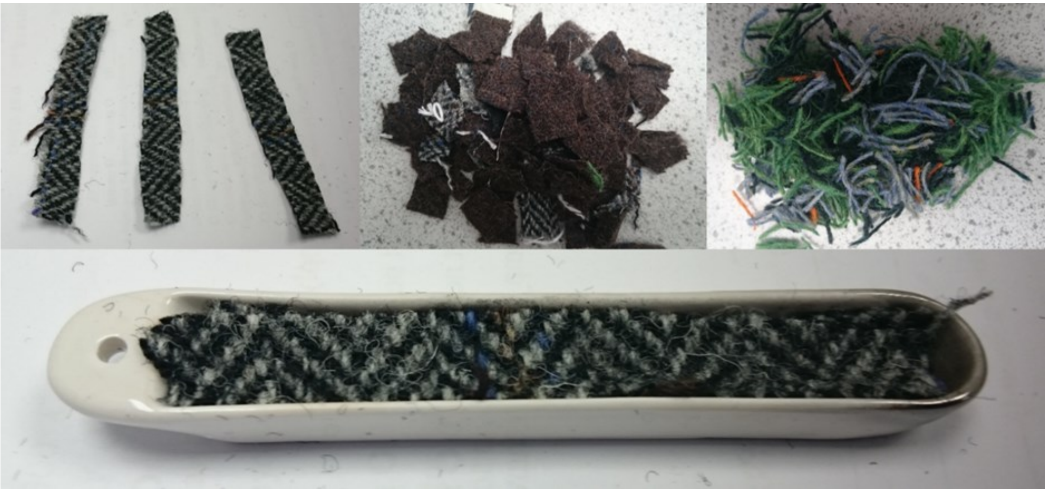
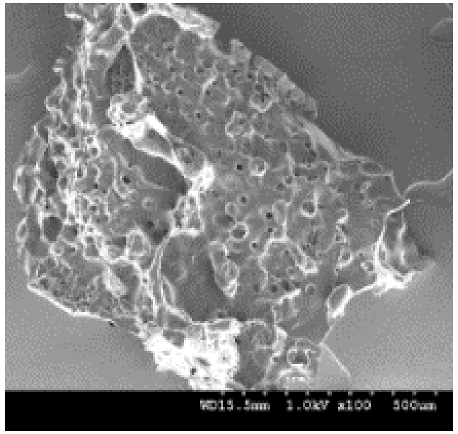
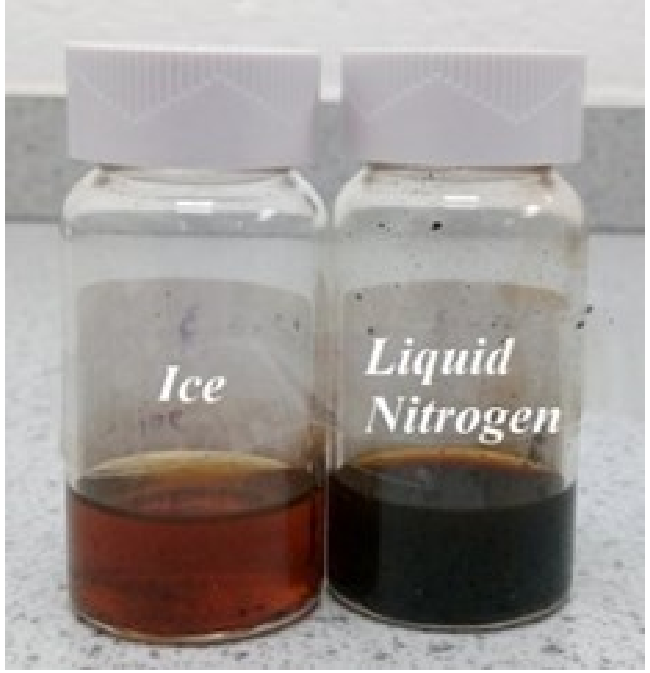
Input materials, output products

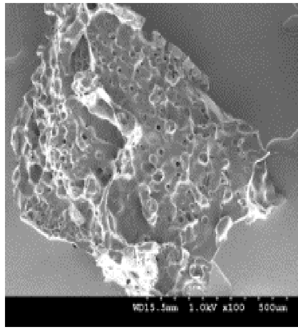




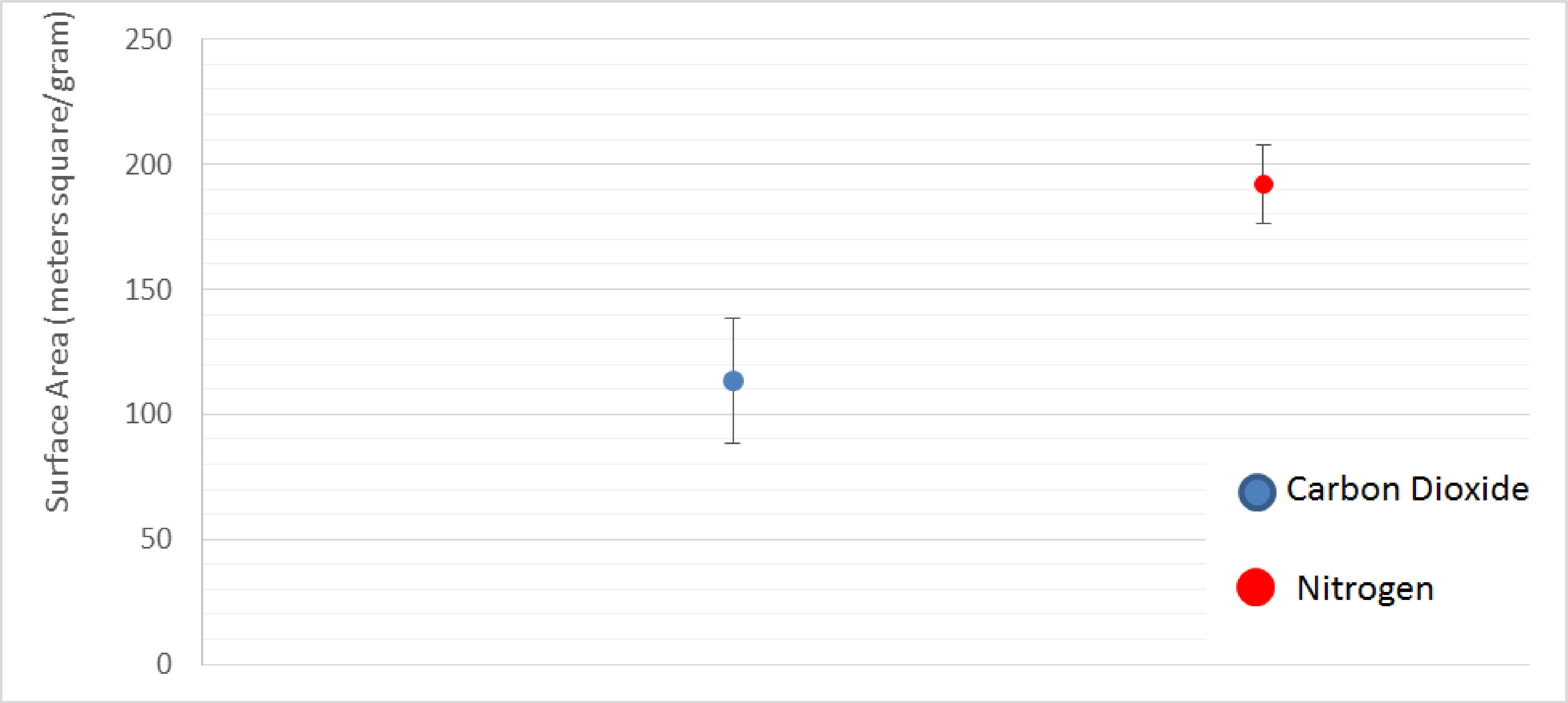


Elemental analysis of Bio-char

	C %	H %	N %	O %	O/C Ratio	H/C Ratio
1	72.41	5.49	16.25	5.86	0.08	0.08
2	62.30	3.70	13.79	20.21	0.32	0.06
3	75.25	3.23	15.01	6.52	0.09	0.04
4	76.81	0.51	11.19	11.48	0.15	0.01
5	82.41	0.48	9.97	7.14	0.09	0.01
6	75.84	0.82	11.47	11.87	0.16	0.01
7	81.06	1.48	13.91	3.55	0.04	0.02
8	79.33	0.91	12.57	7.19	0.09	0.01
Average	75.68	2.08	13.02	9.23	0.13	0.03

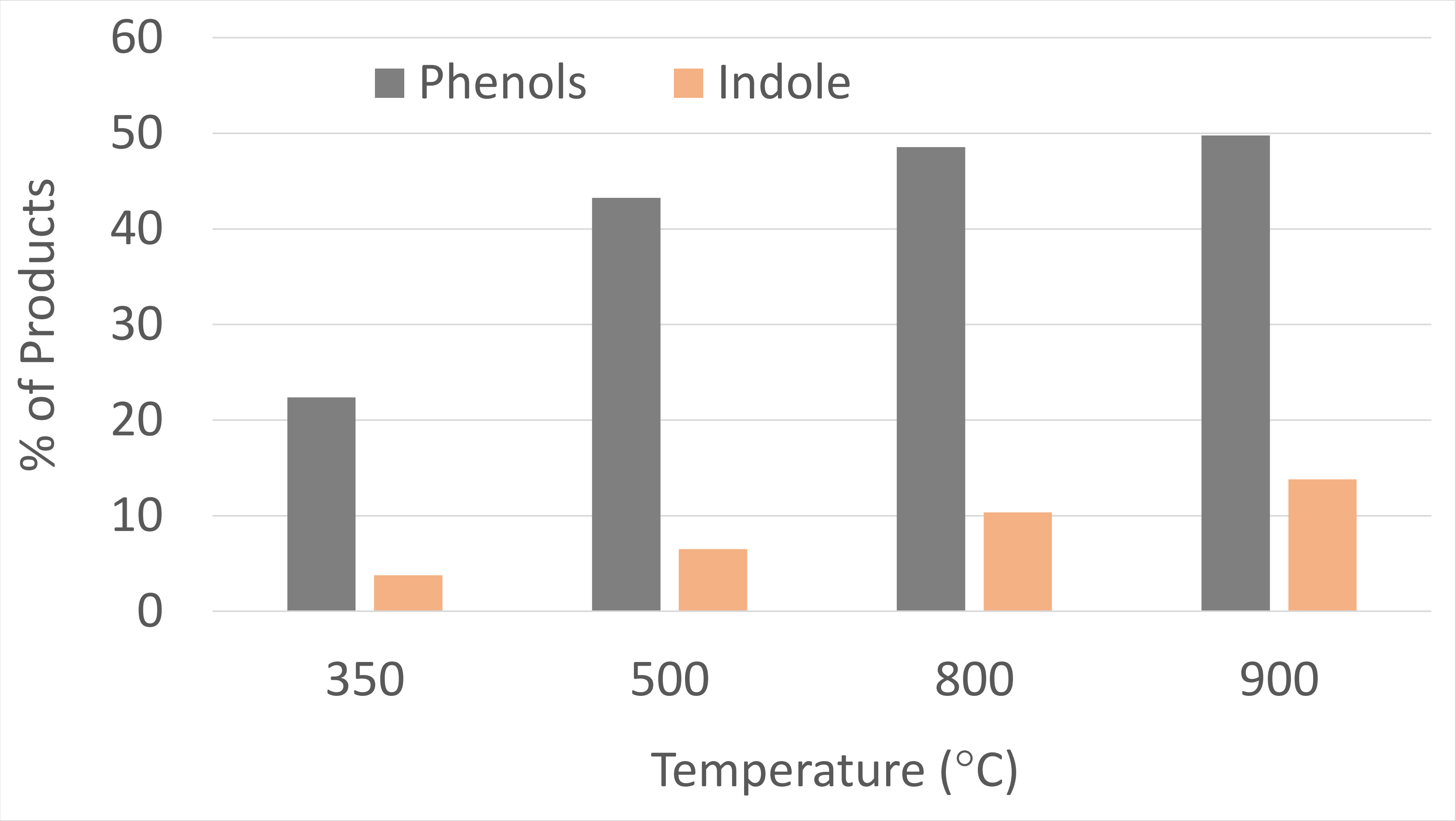


Effect of carrier gas on surface area of bio-char



Effect of feed size on surface area of bio-char

Effect of temperature on liquid/tar production



Syngas production at different temperatures

Vol%	700 °C	800 °C	900 °C
H_2	0.02	0.01	0.02
CH_4	1.28	1.20	0.76
NH_3	1.49	1.52	2.06
H_2O	4.18	5.65	7.94
HCN	0.75	0.74	0.91
CO	31.08	42.08	64.84
C_2H_6	0.17	0.11	0.21
C_4H_{10}	0.85	0.66	0.49
CO_2	58.90	46.85	21.36
C_2H_7N	0.86	0.72	0.45
C_5H_{12}	0.04	0.00	0.00
C_2H_5NO	0.00	0.00	0.00
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Conclusions

- Up to 15% of bio-char can be produced from the current experimental set-up with very high C-content and N-content when produced at 800 and 900°C.
- Temperature plays more important role compared to other variables.
- A liquid(tar) product rich in phenolics (£40/litre) and etherocyclic aromatics (e.g. indole, £50/100gram) is generated representing a potential source of profit.
- Tar brings operational issues due to potential blockage of piping and difficult in removing it.
- Syngas can be combusted in Combined Heat and Power to produce heat/electricity.

Contact

Dr Danmei Sun

Email: D.Sun@hw.ac.uk

Dr Aimaro Sanna

Email: A.Sanna@hw.ac.uk