Characterisation of biochar from maize residues produced in lab-scale batch reactor without using carrier gas

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Introduction and Objectives

- Maize residue is one of the most available crop residues worldwide which can be converted into biochar for simultaneously addressing agricultural, environmental, and energy issues.
- The objectives were to investigate the effects of pyrolysis conditions on the properties of biochar and to identify optimal conditions to obtain a good quality biochar for soil amendment.

Material and Methods

- Maize feedstock was separated into four fractions (cob, husk, leaf and stalk) and pyrolysed in a batch reactor.
- Response surface methodology (RSM) coupled with Box-Behnken Design (BBD) was applied.
- Pyrolysis conditions including *A*: temperature (300-600 °C), *B*: heating rate (5-15 °C/min), and *C*: residence time (30-90 min) were investigated.

Fig. 1. (a) biomass fractions, (b) pyrolysis reactor, (c) cob biochar.

Results

- Optimal conditions to obtain biochar with low volatile matter (VM) and high ash, pH, and electrical conductivity (EC) were identified as shown in Table 1.

Table 1. Optimal pyrolysis conditions and biochar properties

Biochar	Cob	Husk	Leaf	Stalk
Temperature (°C)	588	600	600	584
Heating Rate (°C/min)	11	5	15	15
Residence Time (min)	90	90	79	66
VM (wt.% db)[a]	11.61	7.38	8.39	15.00
Ash (wt.% db)	4.75	11.42	26.55	12.10
pH	9.14	10.96	11.51	10.89
EC (mS/cm)	4.05	12.37	6.79	10.96
Desirability	0.97	0.96	0.95	0.96

[a] db – dry basis.

$$VM_{Husk} = 99.85 - 0.28A - 0.55B - 0.18C + (2.30E{-}03)AB + (7.91E{-}05)AC + (4.39E{-}03)BC + (2.22E{-}04)A^2 - 0.04B^2 + (7.15E{-}04)C^2$$

$R^2 = 0.9783$, RMSE = 1.52

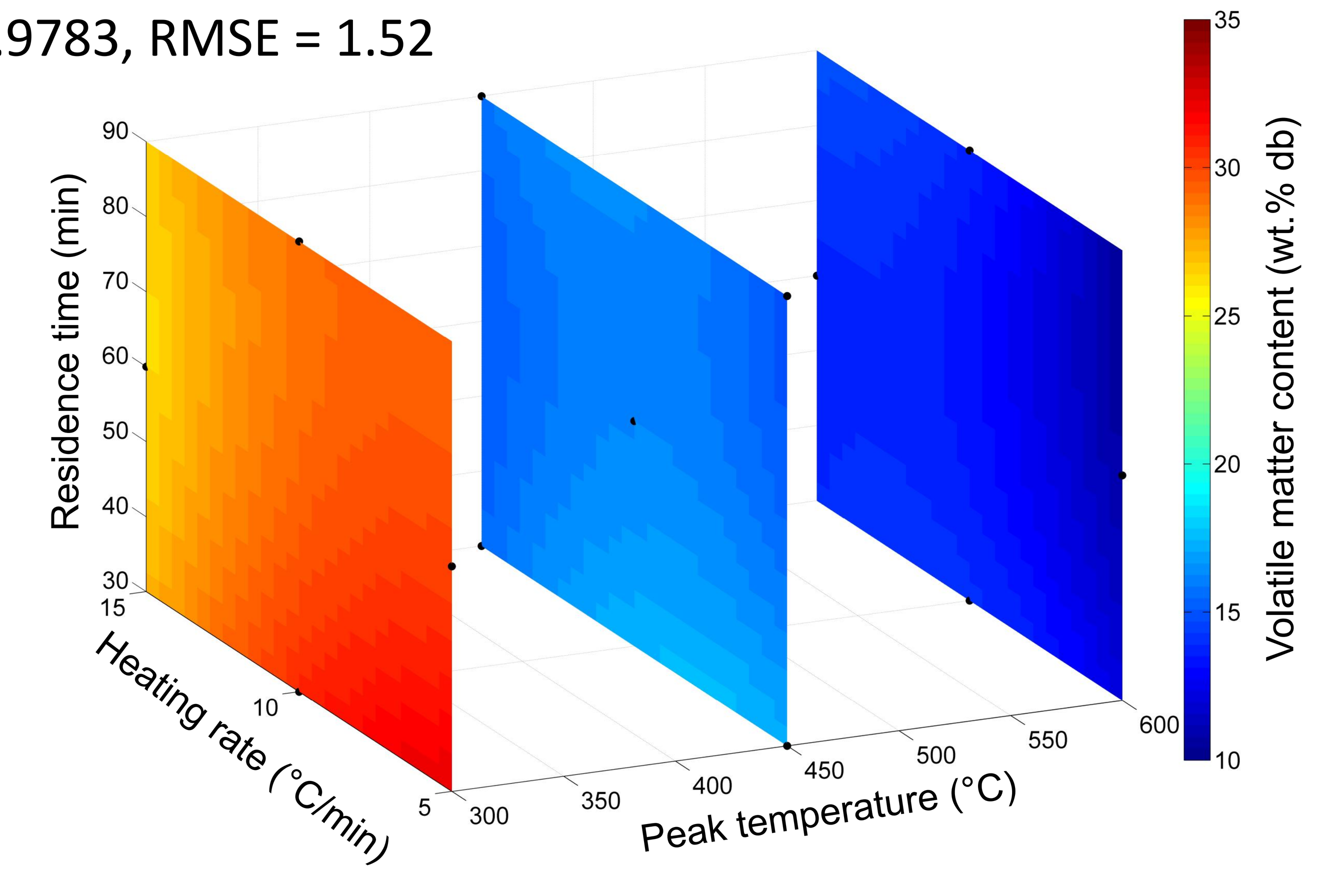

Fig. 2. Sliced plot of the response surface model for volatile matter (VM) in husk biochar.

$$Ash_{Leaf} = -8.84 + 0.12A - 0.10B + 0.09C + (5.57E{-}04)AB - (4.97E{-}06)AC - (1.57E{-}03)BC - (1.21E{-}04)A^2 - (4.69E{-}04)B^2 - (6.78E{-}04)C^2$$

$R^2 = 0.9245$, RMSE = 2.16

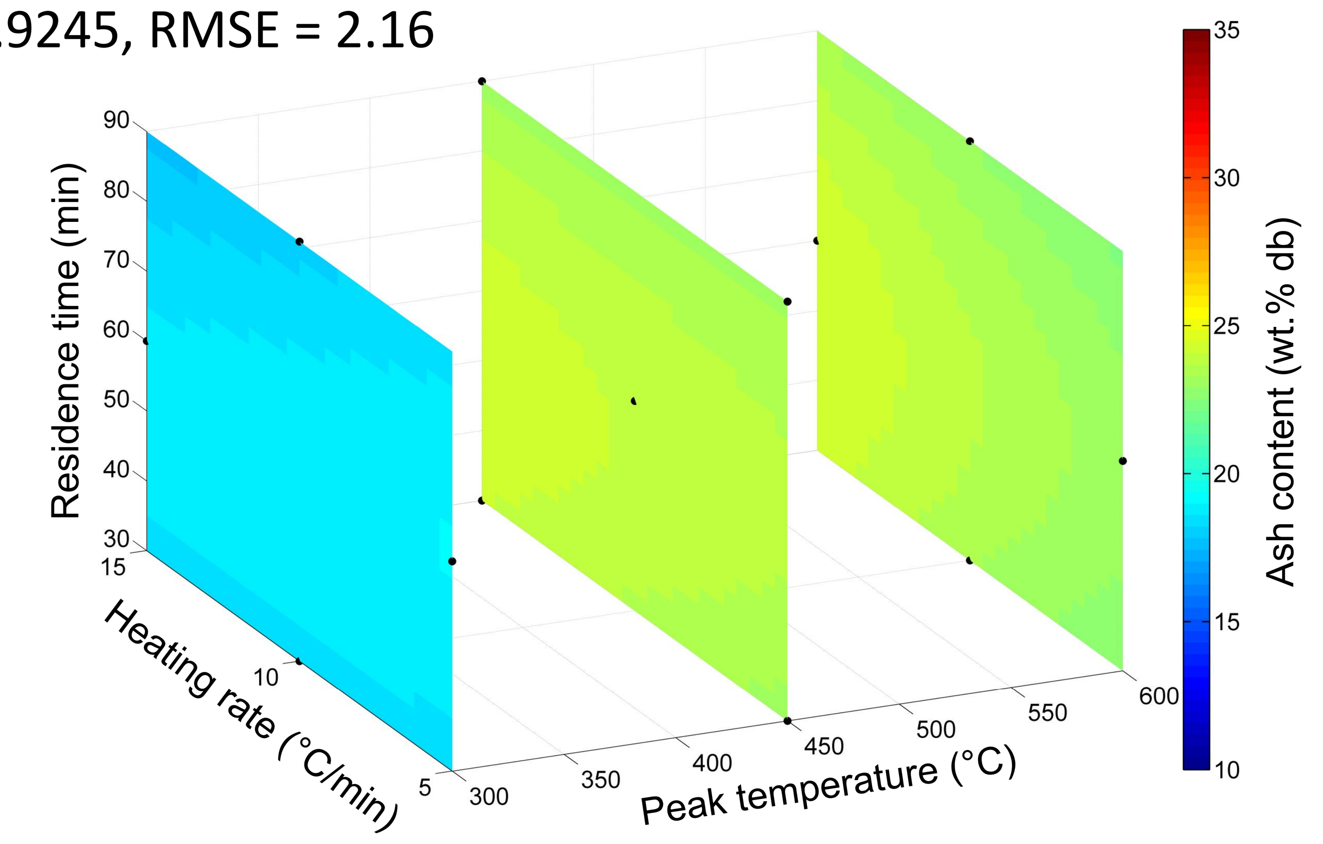

Fig. 3. Sliced plot of the response surface model for ash in leaf biochar.

- Surface morphology was more porous (micropores) when increasing the pyrolysis temperature (Fig. 4).

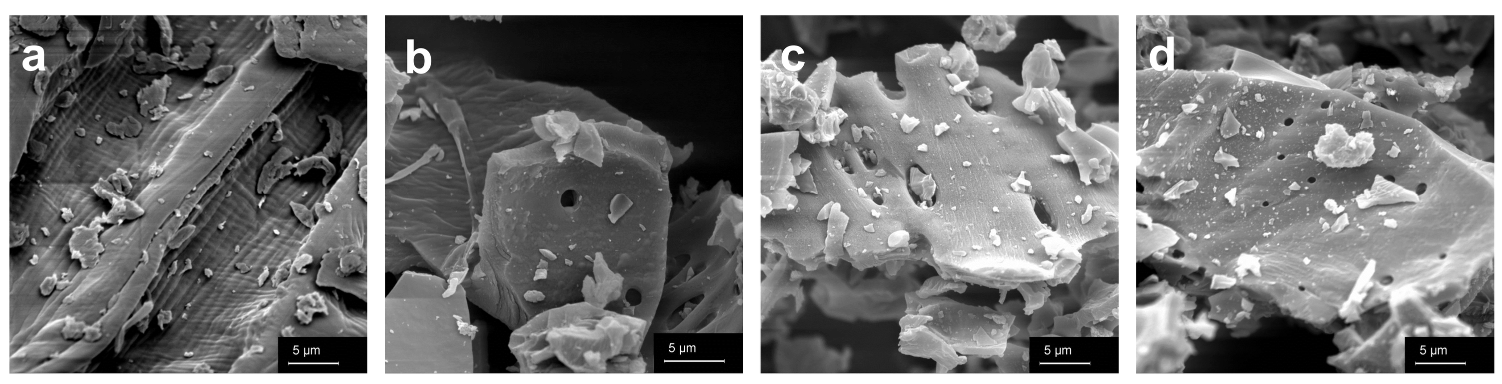

Fig. 4. Scanning electron microscopy (SEM) images of (a) cob and cob biochar produced at (b) 300 °C, (c) 450 °C, (d) 600 °C.

Conclusion

- Temperature was the most influential factor on the volatile matter, ash, pH, and EC of biochar from maize residues, followed by residence time and heating rate.
- Husk and leaf biochar obtained under high temperature, fast heating rate, and long residence time were more desirable for soil amendment.

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