**Supplementary Material**

**Sustainable energy recovery from mixed agri-food waste by hydrothermal carbonisation: Mechanistic evaluation of the evolution of product characteristics**

**Authors**

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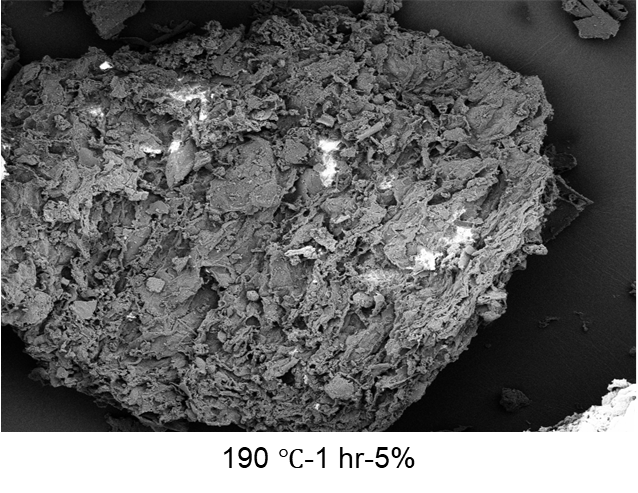
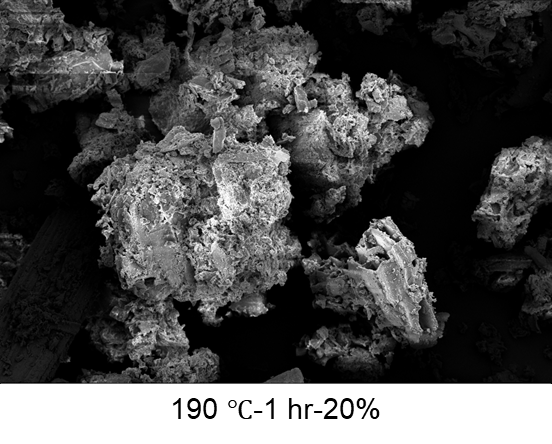
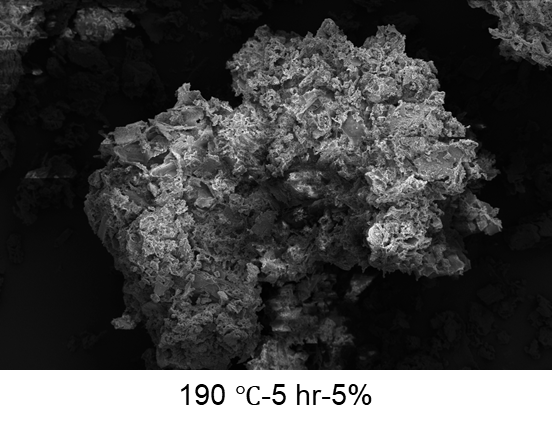
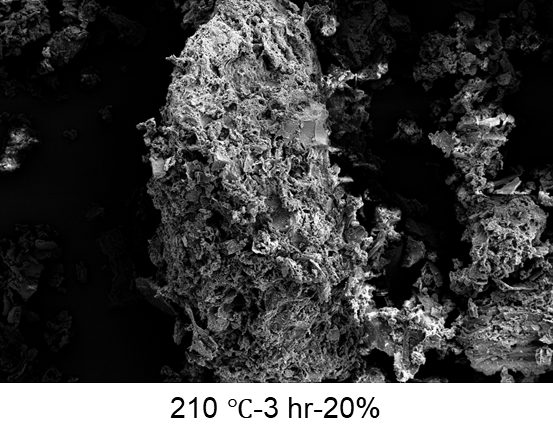
\*E-mail address: [f.o.kassim@lboro.ac.uk](mailto:f.o.kassim@lboro.ac.uk)

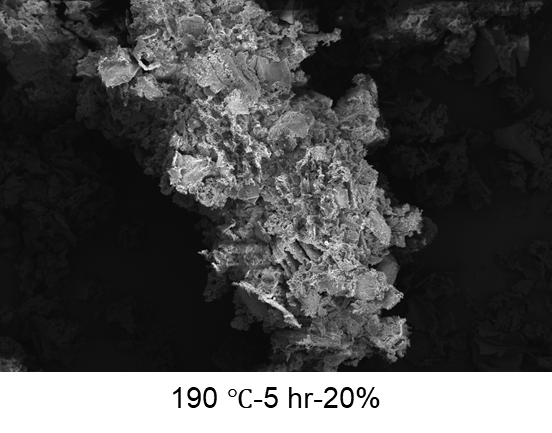
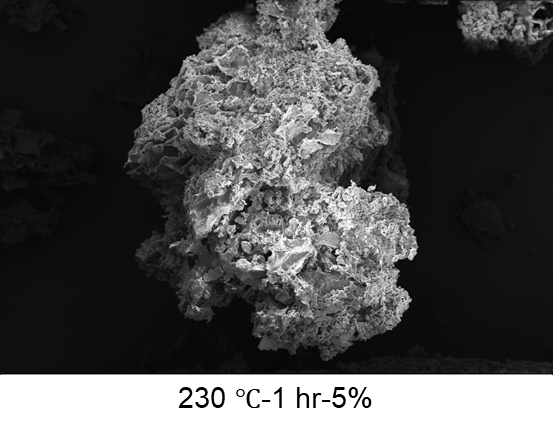
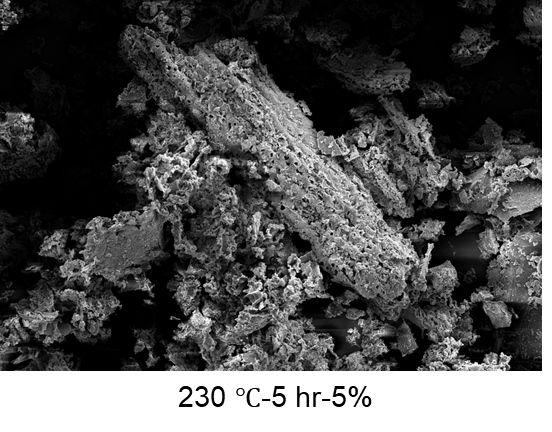
Table S1 Experimental design matrix

|  |  |  |  |
| --- | --- | --- | --- |
| Run number | Temperature (℃) | Time (hr) | Solid loading (%) |
| 1 | 190 | 1 | 5 |
| 2 | 190 | 5 | 5 |
| 3 | 210 | 3 | 5 |
| 4 | 230 | 1 | 5 |
| 5 | 230 | 5 | 5 |
| 6 | 190 | 3 | 12.5 |
| 7 | 210 | 1 | 12.5 |
| 8 | 210 | 3 | 12.5 |
| 9 | 210 | 5 | 12.5 |
| 10 | 230 | 3 | 12.5 |
| 11 | 190 | 1 | 20 |
| 12 | 190 | 5 | 20 |
| 13 | 210 | 3 | 20 |
| 14 | 230 | 1 | 20 |
| 15 | 230 | 5 | 20 |

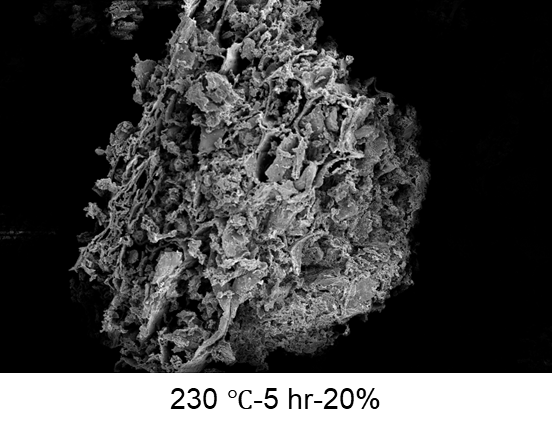
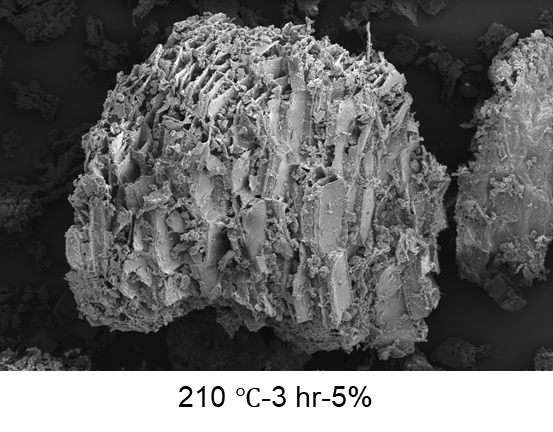
Table S2 Fuctional groups of raw-MAFW and hydrochar

|  |  |  |
| --- | --- | --- |
| Wavenumber (cm-1) | Functional group | Band assignment |
| 3400 | O─H stretching | Hydroxyl groups |
| 2920, 2850 | C─H asymmetric and symmetric stretching | Aliphatic |
| 1730 | C═O stretching | Esters in hemicellulose |
| 1700 | C═O stretching | Carbonyl, ester or carboxyl from cellulose and lignin |
| 1636 | C═O stretching | Amide I band of protein |
| 1615, 1515 | C═C stretching | Aromatic skeletal in lignin |
| 1383 | C─O stretching | Syringyl group in lignin |
| 1248 | C─O stretching | Guaiacyl group in lignin |
| 1160 | C─O─C unsymmetric stretching | Glycosidic bond in cellulose |
| 1112, 1060, 1032 | C─O stretching | Ether bonds in cellulose |
| 800-790 | C-H deformation in aromatic compounds | Aromatics |

   A picture containing bread, stone

Description automatically generated

   A close-up of a rock

Description automatically generated with low confidence

Fig. S1. SEM micrographs of raw agri-food waste and hydrochars at different operating conditions (Scale: 20 µm; Mag: ×500)

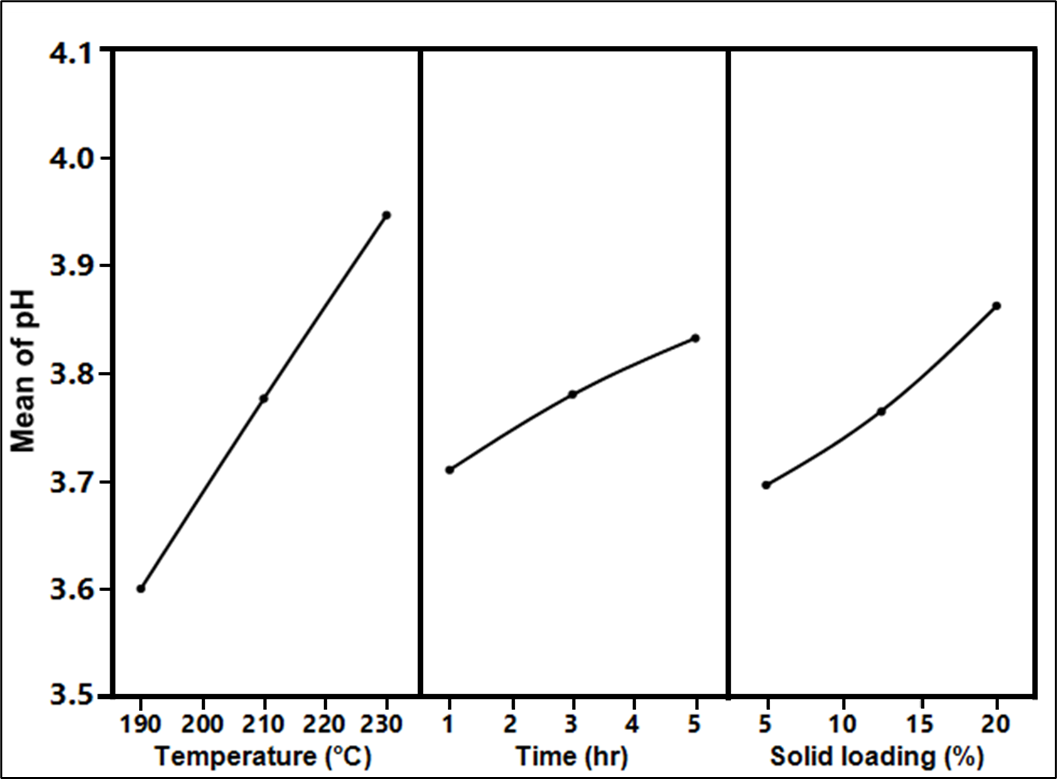


Fig. S2. Main effect plot for pH

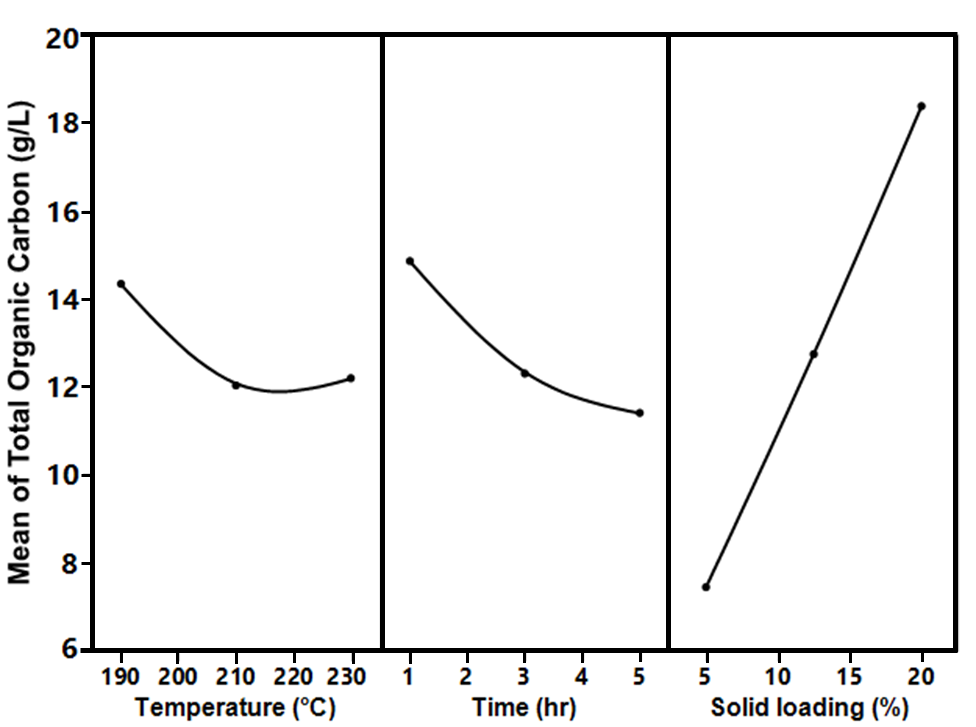


Fig. S3. Main effect plot for total organic carbon

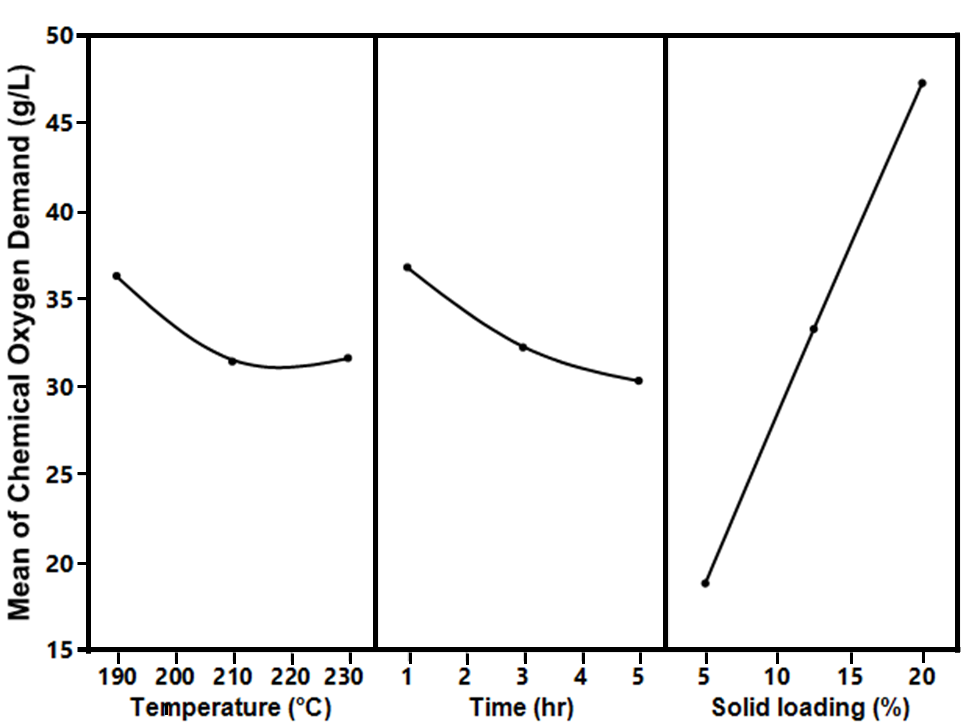


Fig. S4. Main effect plot for chemical oxygen demand

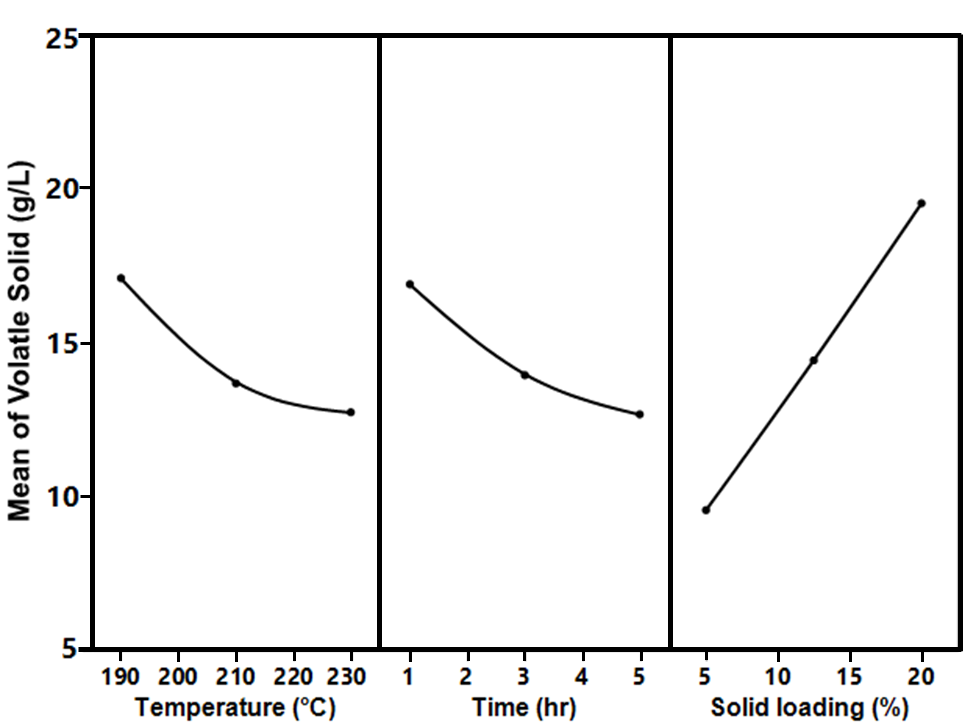


Fig. S5. Main effect plot for volatile solid

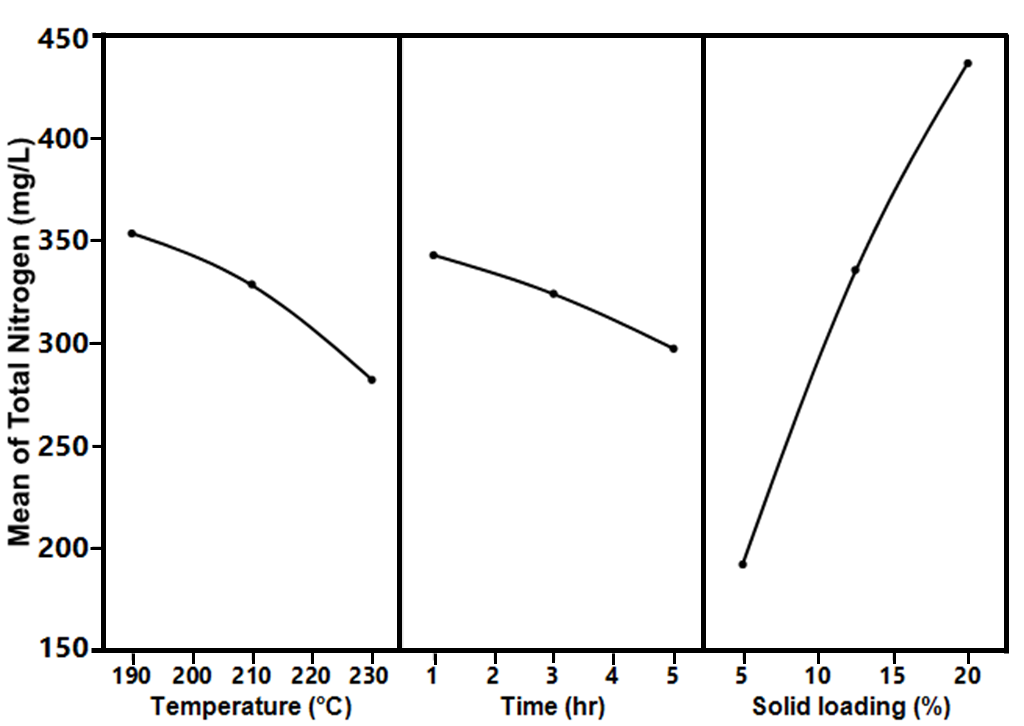


Fig. S6. Main effect plot for total nitrogen

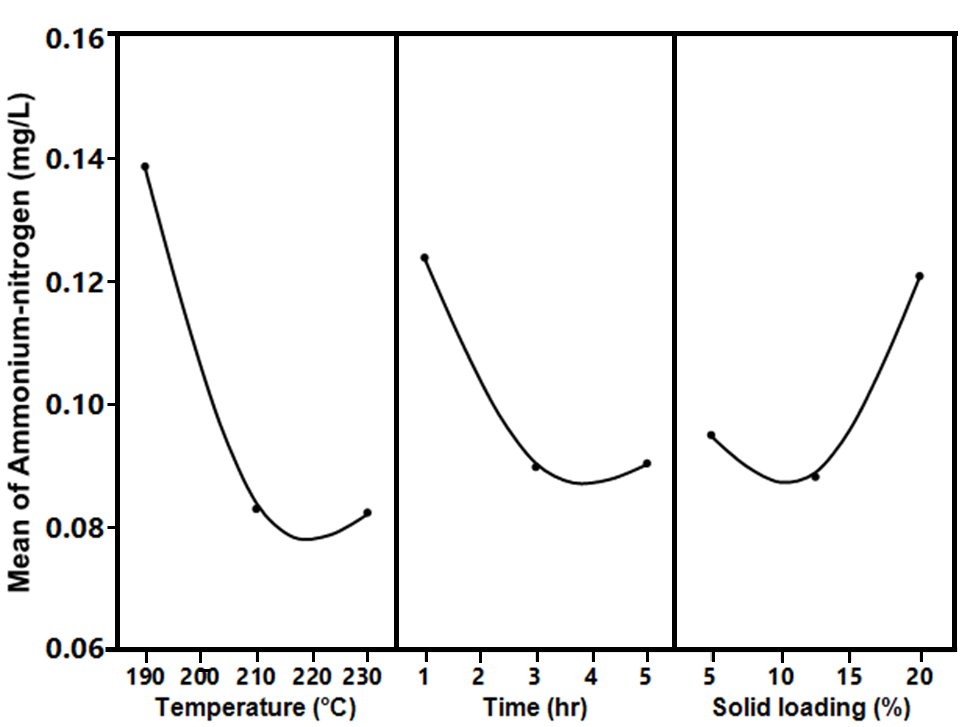


Fig. S7. Main effect plot for ammonium-nitrogen

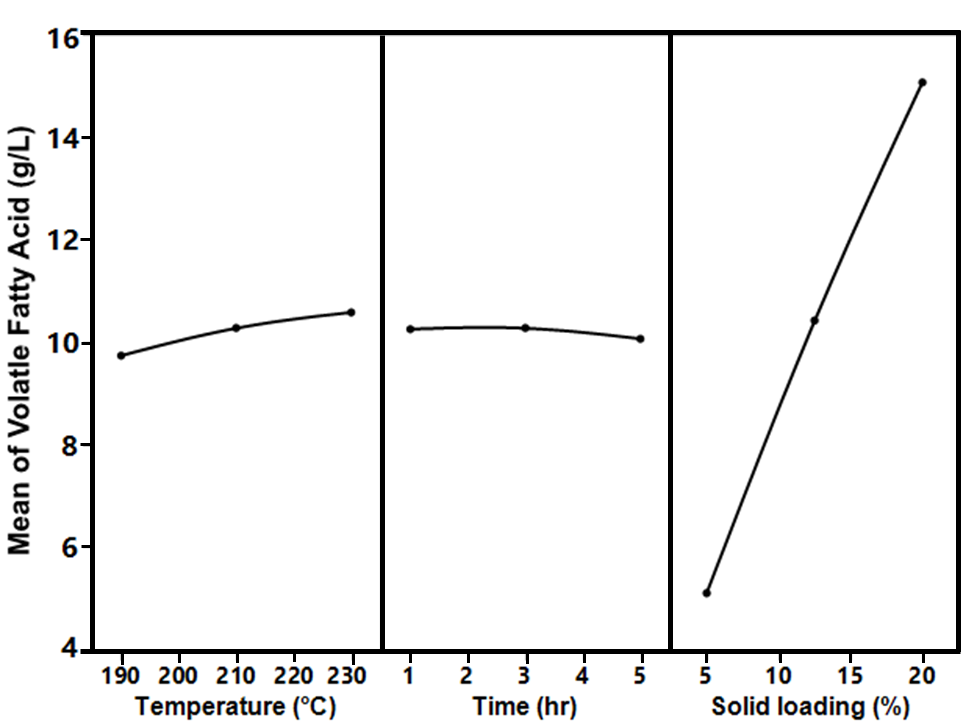


Fig. S8. Main effect plot for volatile fatty acid

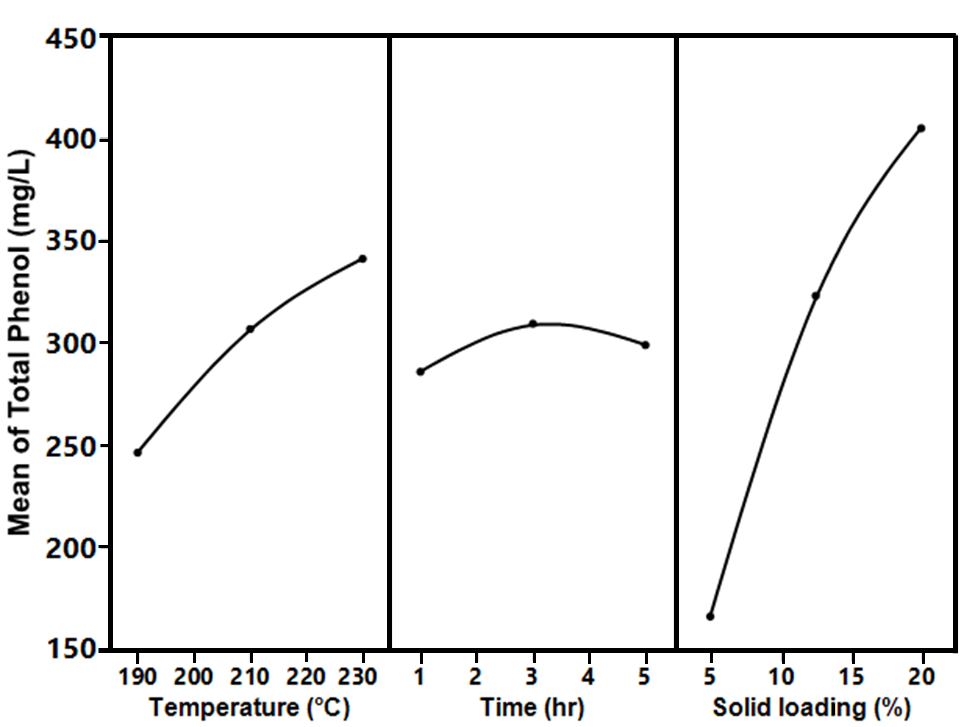
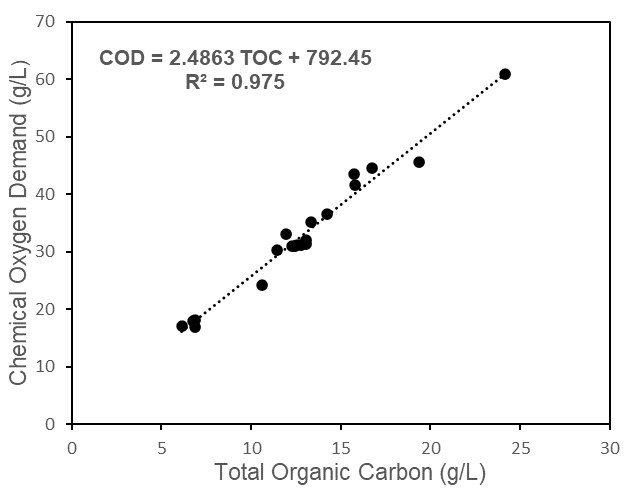
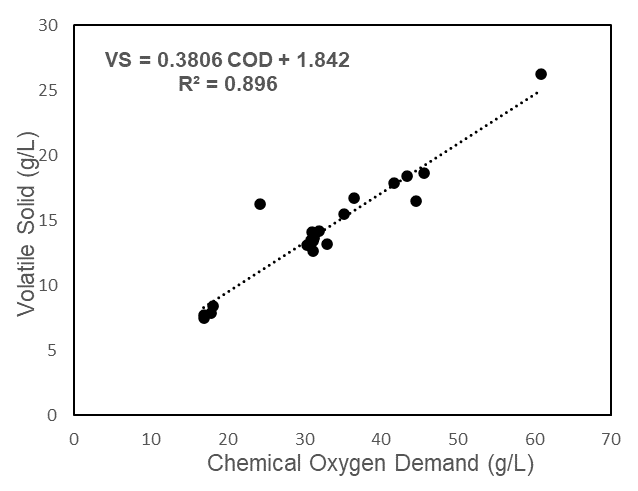


Fig. S9. Main effect plot for total phenol

(a)

(b)

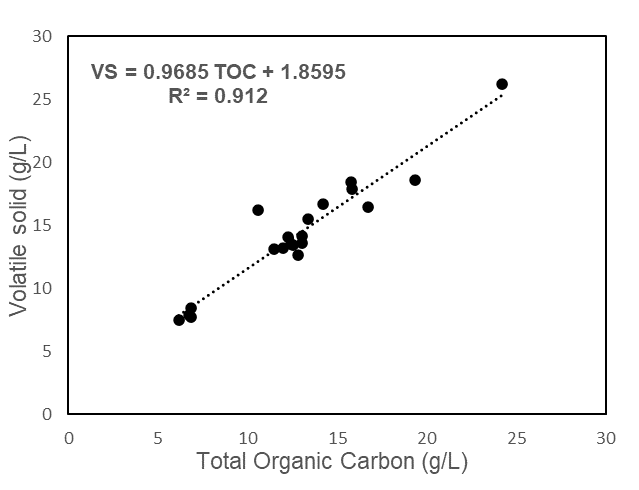
(c)

Fig. S10. Correlation of (a) chemical oxygen demand and total organic carbon (b) volatile solid and chemical oxygen demand (c) volatile solid and total organic carbon

Table S3 Benefits and limitations of different process water valorisation techniques.

|  |  |  |
| --- | --- | --- |
| Valorisation techniques | Benefits | Drawbacks |
| Recirculation | * Reduction of freshwater consumption. * No requirement for additional reactor. * Enhanced hydrochar energy yield. | * Amount of process water recirculated is restricted to initial water requirement. * Accumulation of organic component in recycled process water. * Final treatment of process water still required. |
| Anaerobic digestion | * Enhancement of energy recovery due to recovery additional biofuel (i.e., biomethane) * High efficiency of organic matter utilisation | * Process inhibition due to toxic intermediates * Suitable for non-toxic PW * Limited nutrient utilisation * Low process energy requirement |
| Wet oxidation | * High capability for treatment of process water rich in toxic intermediates. * High organic matter conversion * Resultant process water has improved biodegradability | * Limited nutrient utilisation * High process energy requirement |
| Nutrient recovery | * High-value product recovery * Efficient utilisation of nutrient | * Limited organic matter utilisation. * Low pollutant removal rate * Extraction efficiency is limited to nutrient concentration in process water. |
| Chemical recovery | * Recovery of value-added chemicals * Efficient utilisation of chemical compounds | * Limited application for process water with highly complex composition * Extraction efficiency is limited to the specific chemical concentration in process water |