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Design and Characterisation of an ‘Open Source’ Pyrolyser for Biochar Production

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Rhonda Bridges

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ABSTRACT

An ‘open source’ field-scale batch pyrolyser was designed and constructed to produce biochar, which is the solid residue formed when biomass thermally decomposes in the absence of oxygen. The design approach was focused on simplicity for the intended target user, a hobby farmer. This is achieved in a batch process, where temperature ramp rates, gas flows and the end-point are controlled. Solids handling is only required at either end of the process. LPG is used as the initial heating source and later as the ignition source when pyrolysis gases are recycled.

A mathematical model formulation of the process was developed to predict the proportions of products produced as well as the time taken to achieve complete pyrolysis. Reaction kinetics are complex and not fully understood. In this model, simplifications were taken to provide guidelines for the reactor design as well as the effects of moisture on the process efficiencies.

The quality performance of the ‘open source’ pyrolyser was determined by comparing its biochar to that produced in a lab scale gas fired drum pyrolyser. Parameters varied on the lab drum pyrolyser were highest treatment temperature in the range 300 to 700 °C, sample size, moisture content and grain direction for *Pinus radiata*. The properties that were investigated are elemental composition (C, H, N, S), proximate analysis (moisture, volatile matter and fixed carbon) and char yield (% wt/wt). The ash content was determined by residue on ignition. For the lab scale experiments, it was found with increasing peak temperature that yield, volatile matter and hydrogen to carbon ratio decrease. Yield was unaffected by moisture, size and grain direction.

The design of the pilot reactor followed the principle observed with particle size that, in order to get maximum residence time of the vapour and tar in the reactor, the reactor was designed with a perforated core so that the vapours have a tortuous path of travel. This design also meant that heat and mass transfer occurred in the same direction, from the outer wall to the perforated core. In comparison to the lab scale pyrolyser, the same trends were observed in regards to temperature. High yields of 29.7 wt % and 28.8 wt % were obtained from wood with an initial moisture content of 21.9 wt % and 60.4 wt % respectively, confirming yield is unaffected by moisture.

Mass and energy balances were conducted on both the lab scale and pilot scale pyrolysers. For every kilogram of carbon in LPG used on the lab scale pyrolyser, an average of 0.25 kilograms of carbon is produced at 700 °C. Based on the optimum run for the pilot scale, for every kilogram of carbon in LPG used, 2.6 kilograms of carbon is produced at 700 °C.

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