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A proposed biomass char classification system

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GRAPHICAL ABSTRACT

A sunflower particle showing how the internal structuring present in the original particle can influence the morphology of the char particles post pyrolysis.

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ABSTRACT

A new classification system is proposed for the morphological characterisation of char structures from biomass. These char structures are unlike the coal chars that have an established nomenclature via the International Committee of Coal and Organic Petrology (ICCP) which divides char structures into thin walled and thick walled spheres and networks, mixed dense and mixed porous, fusinoids and solids. The chars from biomass show a tendency, depending on heating regime, to produce different types of internal pore structure (cellular and porous) and aspect ratio (high and low) compared with coal chars. For this reason a new classification system has been developed to cover these new structures which should assist in combustion, co-firing and gasification research where these intermediate char structures play an important role in conversion efficiency. Low heating rates (using a muffle furnace at 1000 °C and 3 min) were used to create chars from 9 different biomass types, with a range of lignocellulosic compositions. Char type appeared to depend on the biomass type itself and original lignocellulosic composition (cellulose, lignin and hemicellulose content) and cell structure.

1. Introduction

The use of biomass for energy production is increasing in many parts of the world, either through blending with fossil fuels or firing as a fuel in its own right. Biomass is considered to be CO_2-neutral [1–6] and therefore plays of a role in CO_2 reduction strategies. Biomass also has the additional benefit of inherently lower levels of sulphur [2,3,7] and nitrogen [2,7], in most cases. However, there are significant differences when compared to coal in terms of

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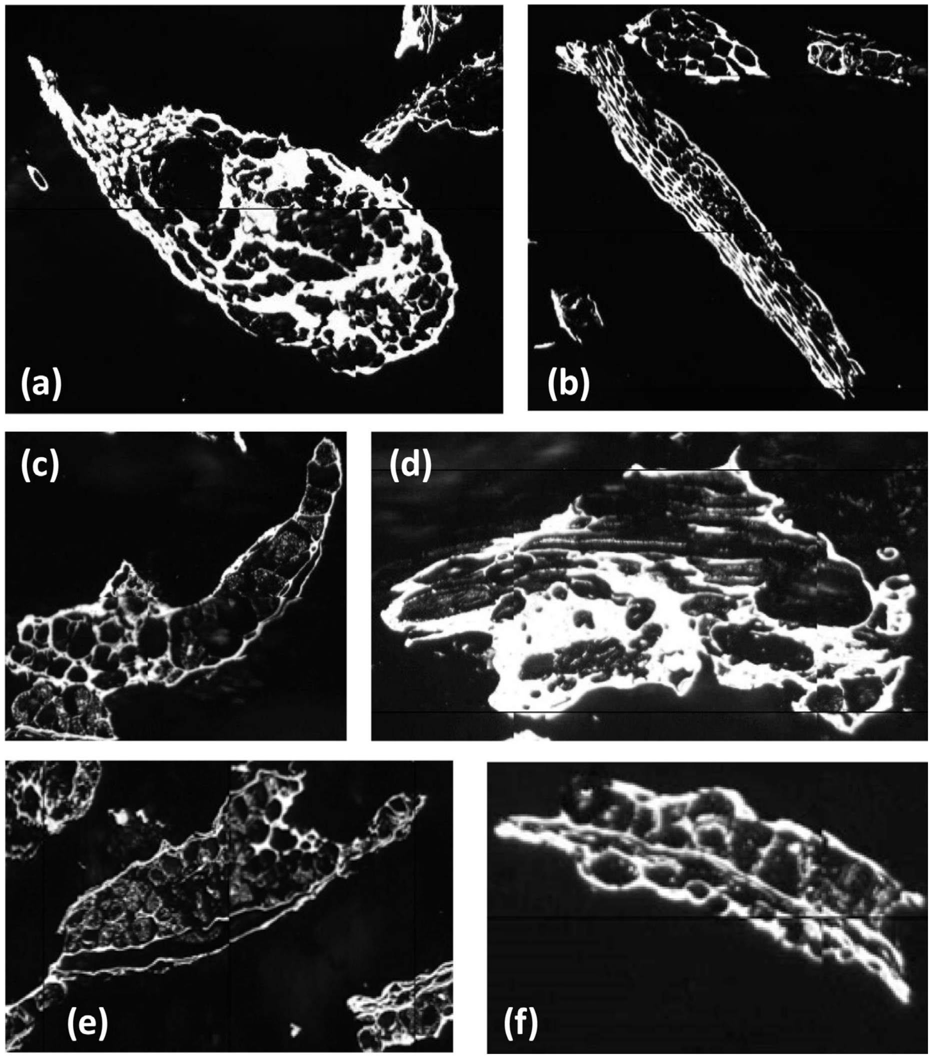

Fig. 1. Examples of low (a) and high (b) aspect ratio, thin wall (c) and thick wall (d), porous (e) and cellular (f) for wheat shorts chars.

higher moisture and volatile contents and lower levels of fixed carbon and ash [8]. However, despite these differences, they both follow comparable reaction stages during conversion [9,10]:

i. *Pyrolysis* – the devolatilisation and volatile release of materials, which often soften and swell while ejecting gaseous products of moisture and hydrocarbons, resulting in the formation of carbon-rich char
ii. *Conversion* of the intermediate carbon rich char particles in the presence of an oxidant gas, i.e. combustion
iii. *Deposition* or collection of mineral residues along with any unburnt carbon particles

Generally, a degree of overlapping occurs between step (i) and (ii) [11–13], however the process by which fuels are converted to heat are principally the same, as is the need to understand how these carbon structures from step (ii) affect the overall conversion efficiency. Much work has been focussed and published on coal char investigations [10,11,14–29], including the link between coal macerals and their associated char morphotypes [11,22,28]. The link between biomass characteristics and char morphology is less well known.

Biomass has three major lignocellulosic components, namely cellulose, hemicellulose and lignin. These three components are the major constituents of plant cell walls, a substantial portion of the dried biomass [30], and make up to over 90 wt% of the plant cells on an air-dry basis [31]. Cellulose is composed of long chains of cellobiose units [32], lignin is a complex, high-molecular-weight structure containing cross-linked polymers of phenolic monomers, and hemicellulose consists of branches of short lateral monosaccharides [33]. The glucose produced during photosynthesis is converted either into cellulose, which makes up the main structural component in cell walls, or stored in the form of starch granules in amyloplasts [33,34]. Starch is stored in tree twigs, fruits seeds, rhizomes, and tubers for the next growing season. The cellulose in cell walls are packed into microfibrils by the long-chain cellulose polymers linked by hydrogen and Van der Waals bonds, which are protected by hemicellulose and lignin [33]. The percentage of each component varies by biomass, and the influence of biomass composition on biomass char formation has not been explored in literature.

Recently, there has been an increase in the number of biomass char studies [35–38]. The morphology of the char structures has been analysed via Scanning Electron Microscopy (SEM) imaging [39–41] and optical microscopes [42,43]. With the increasing body of work into biomass chars, there is a need for a classification system to characterise the chars which accommodates the variances in structure compared to coal chars. Coal char has the following discriminating features [10];

1. *Char Wall-Thickness* – there has always been a distinction made between thin walled (classically known as *tenui*-) and thick walled (known as *crassi*-) chars. Differences in classification systems [44–47] are made around the threshold between thick and thin but most systems concede that chars generally can be seen as thick or thin – whereby the logic follows that thin chars will burn out more