TEXTILE WASTES TO ENERGY THROUGH TORREFACTION

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ABSTRACT

Production of biochar from cotton and cotton/polyester textile wastes through torrefaction at different temperatures and fuel characteristics of biochars were investigated. FT-IR analysis proved the decomposition of cellulose. On the other hand poliester structure was largely protected and deposited onto cotton fibres which was further showed by SEM analysis. It was observed that 100% polyester wastes are not suitable for biochar production. It was investigated that cotton and cotton/polyester wastes could be converted to biochar and have a great potential for the use as a low-emission environmentally friendly fuel. Resultant biochars had low ash and sulphur content and a lignite equivalent heating value.

INTRODUCTION

Millions of tonnes of textile waste are generated annually, most of which are disposed. Small amount of wastes are only converted into low added value products. Hence, textile wastes have the potential to be utilized as biomass and can be used for energy conversion. Textile wastes are heterogeneous and due to bulky and porous structure their energy density is low. Therefore, they should be converted into homogeneous, dense and carbon-rich structure to be used as energy source, called biochar. Biochar is a renewable feedstock with reduced CO_2 emissions and is used either for energy output or as carbon source[1]. The aim of this contribution is to investigate the production of biochar from textile wastes through torrefaction.

MATERIAL AND METHOD

Textile wastes including cotton (CO), polyester (PES) and cotton/polyester blends (CO/PE) at the ratio of 1:1 were selected due to the their highest consumption rate. Torrefaction experiments were carried out in a lab- scale fixed bed pyrolysis reactor in N_2 stream at 300 °C, 350 °C and 400 °C. Characterization of wastes and biochars (C-CO and C-CO/PES) was conducted through elemental analysis and calorific value determination, SEM and TGA analysis.

The mass yield and energy yield of the torrefied mass are defined as follows:

Mass yield, % = (mass of biochar/mass of textile waste) x 100 (1)

Energy yield, % = mass yield x (HHV biochar / HHV textile waste) (2)

The combustion characteristics of wastes and resultant chars were investigated by TGA under air atmosphere with a flow rate of 100 ml/min and heating rate of 20 °C/min.

RESULTS AND DISCUSSION

Biochar production from PES wastes could not be achieved through torrefaction.

It was shown that CO and CO/PES blended textile wastes can be transformed into a carbon-rich structure with an adequate mass yield at 300 °C and 350 °C (Table 1). Biochar yield decreased with the increase in torrefaction temperature. More important is fact that biochars had negligible amount of sulphur and ash content. In addition, resultant biochars had similar properties to lignite (Fig .1).

Table 1. Characteristics of textile wastes and resultant biochars

	CO	C-CO-300	C-CO-350	CO/PES	C- CO/PES-300	C- CO/PES 350
Mass yield, %	-	50	34	-	74	45
Elemental composition, %						
C	41.69	70.24	71.93	51.66	64.54	65.26
H	5.94	5.08	4.85	5.35	4.07	4.11
N	0.57	0.57	0.62	0.44	0.14	0.33
S	-	-	-	-	-	-
O	51.8	24.11	22.6	42.55	31.25	30.3
HHV, MJ/kg	26.90	32.99	33.15	28.73	30.90	30.75
Energy density	-	1.23	1.23	-	1.08	1.07
Energy yield, %	-	61.32	41.90	-	79.60	48.17

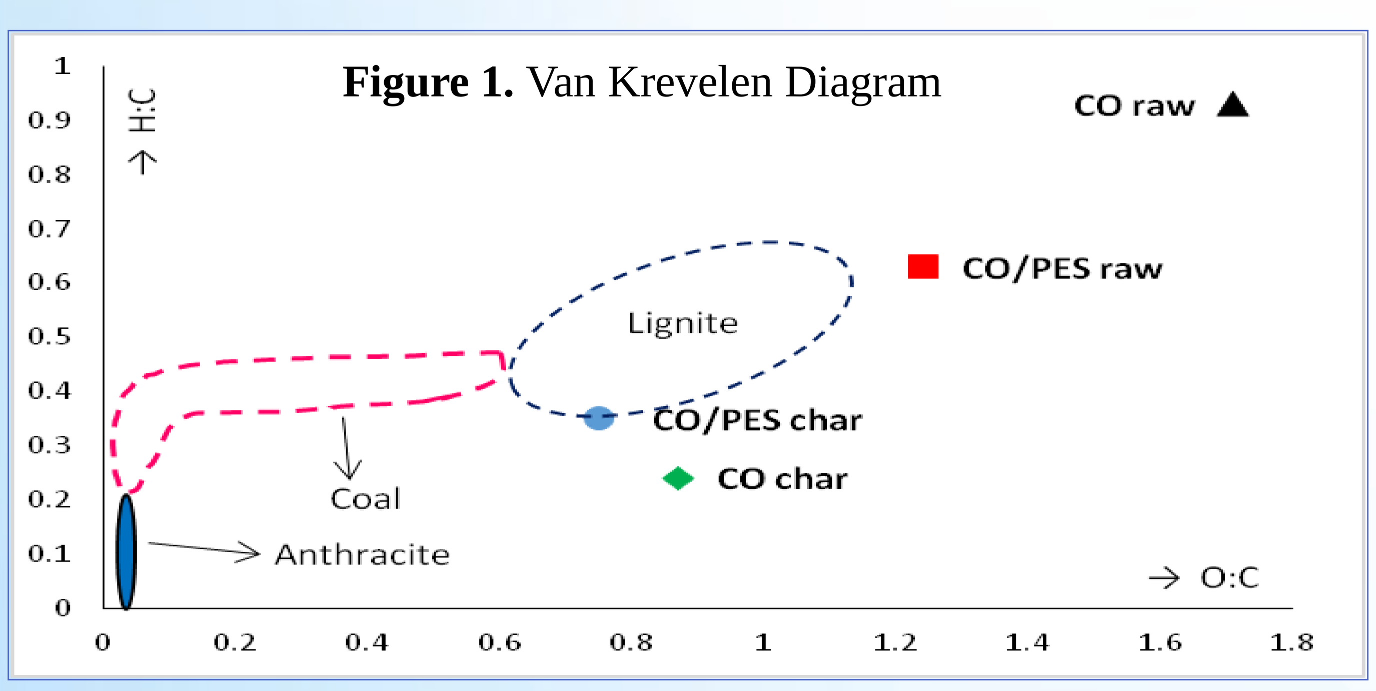


Figure 1. Van Krevelen Diagram

Depolymerisation and dehydration processes are expected to take place during thermal degradation of cellulose [2]. FT-IR spectrum of CO waste and resultant biochar showed that the aliphatic structures were converted into aromatic structures (Figure 2). This indicates that the condensation reactions occured during torrefaction. FT-IR spectra of CO/PES biochars (Fig. 3) indicated that the polyester structure was largely intact, while the cotton part was carbonised. This was further confirmed by the SEM images of the biochar as shown in Fig. 3. The presence of polyester droplets on the cotton is clearly visible.

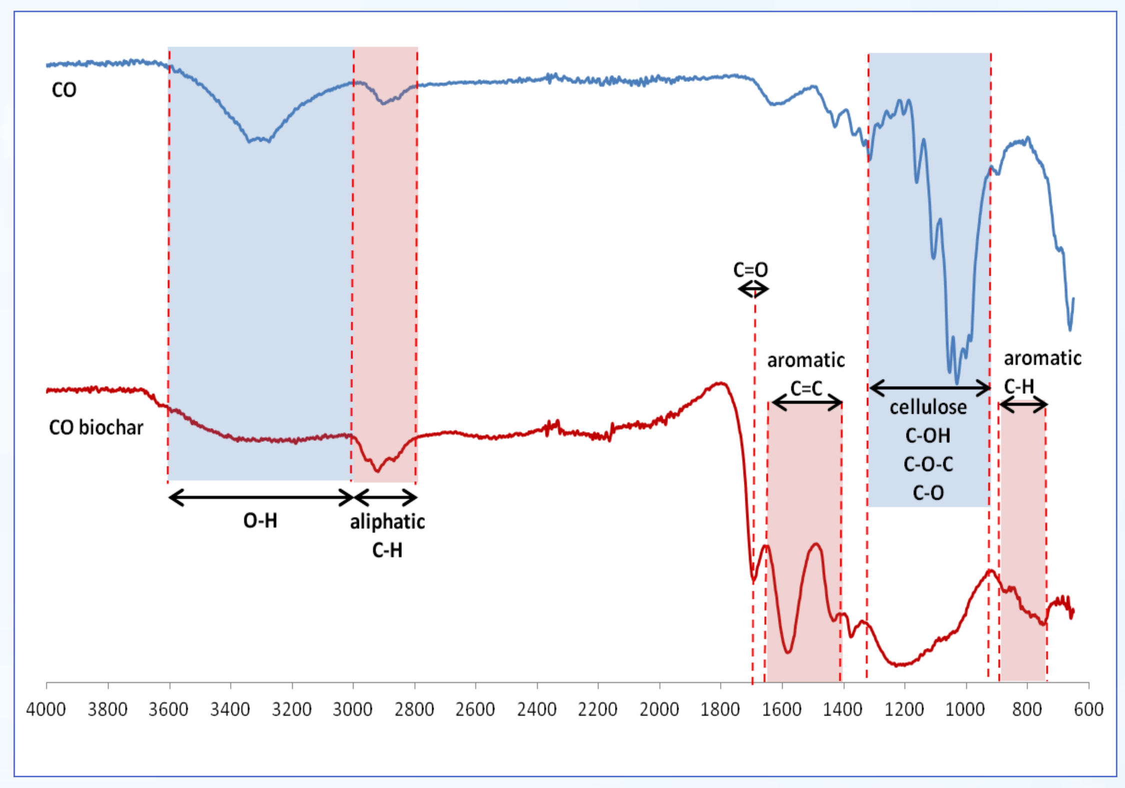
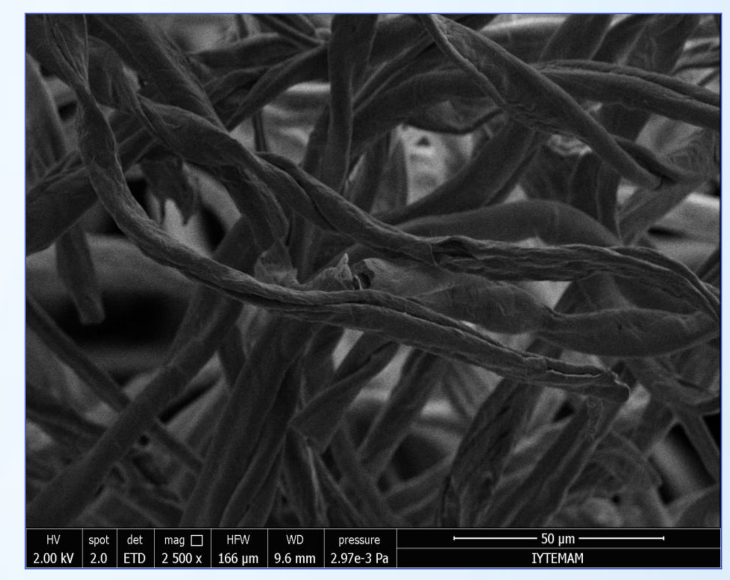


Figure 2. FT-IR spectra of cotton waste and biochar and SEM image of cotton biochar



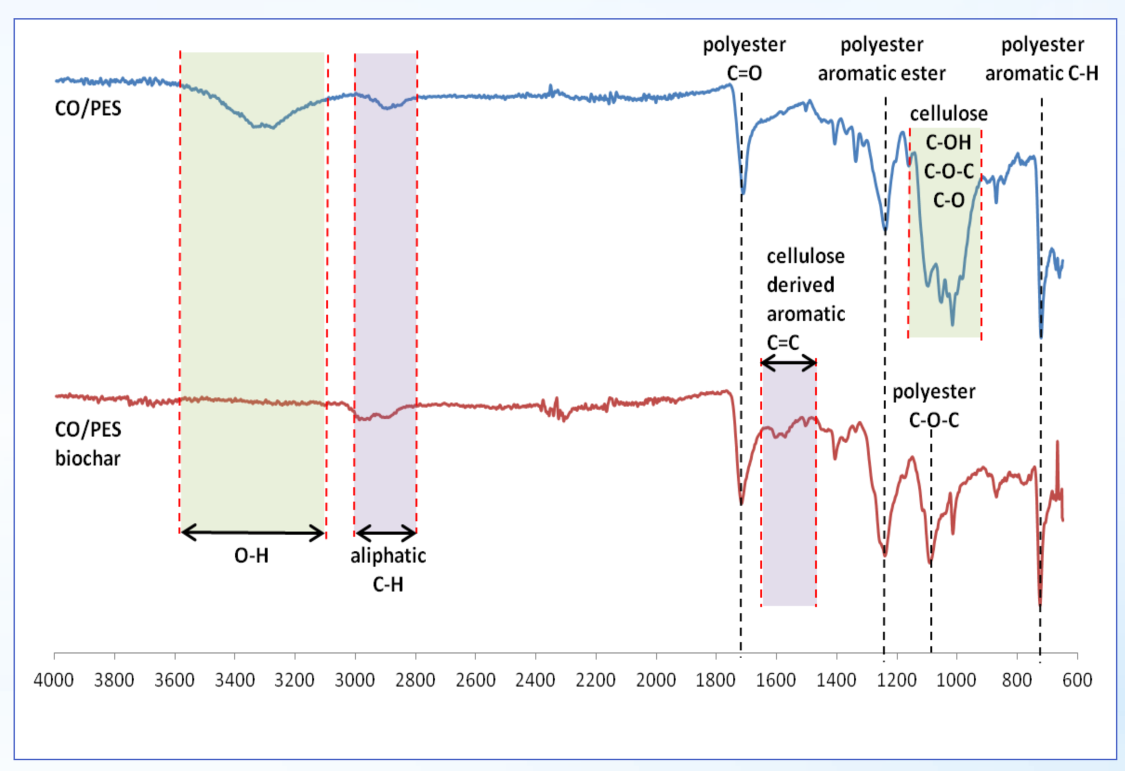
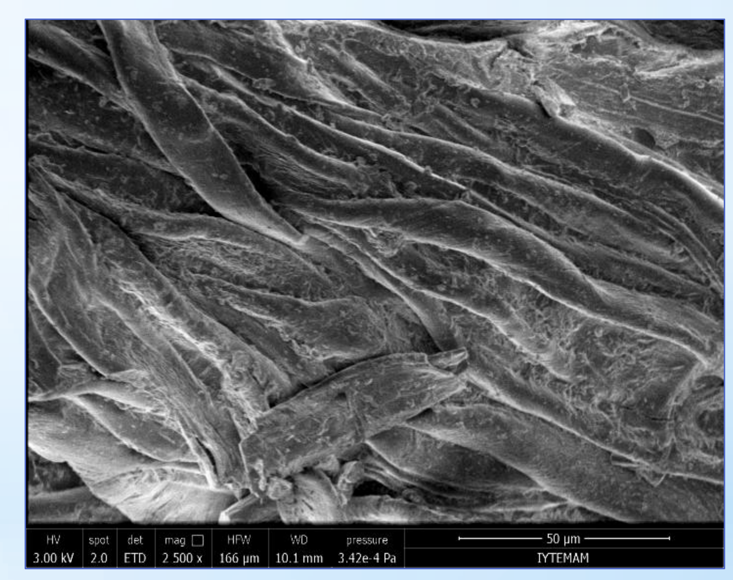


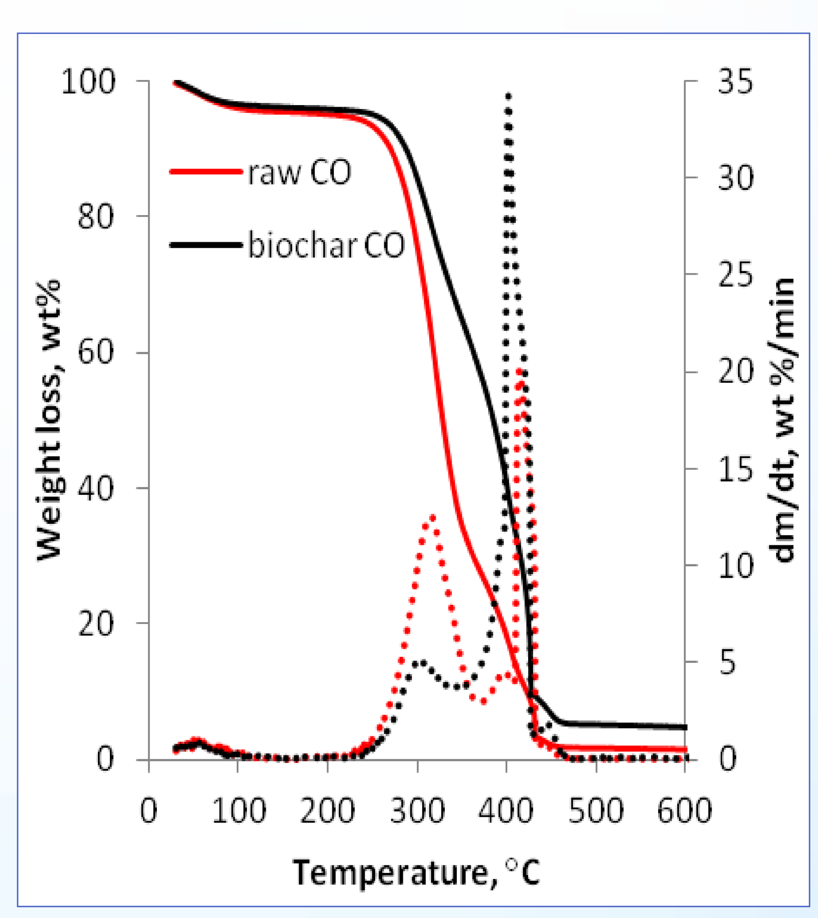
Figure 3. FT-IR spectra of CO/PES waste and biochar and SEM image of CO/PES biochar



Combustion parameters of textile wastes and biochars were calculated from TG/DTG curves (Table 2 and Figure 4). The ignition and burnout temperatures of torrefied CO is higher than that of raw CO. In addition, torrefaction increased the combustion reactivity of CO. In case of CO/PES, three combustion stages were observed, on the other hand, two stages were observed during combustion of torrefied CO/PES. The ignition temperature of torrefied CO/PES is higher than that of raw CO/PES. Interestingly, torrefaction led to a decrease in burnout temperature of CO/PES, whereas it had little impact on the combustion reactivity.

Table 2. Combustion characteristics of textile wastes and biochars

	IT,°C	BT, °C	Tmax,°C	Max.combustion rates, % min^{-1}	Rm
CO	271	751	316;414	0.04;0.04	0.04
C-CO	300	900	299; 402	0.02;0.09	0.09
CO/PES	297	900	328;428;458	0.02;0.02; 0.04	0.03
C-CO/PES	343	546	406;521	0.02;0.01	0.02



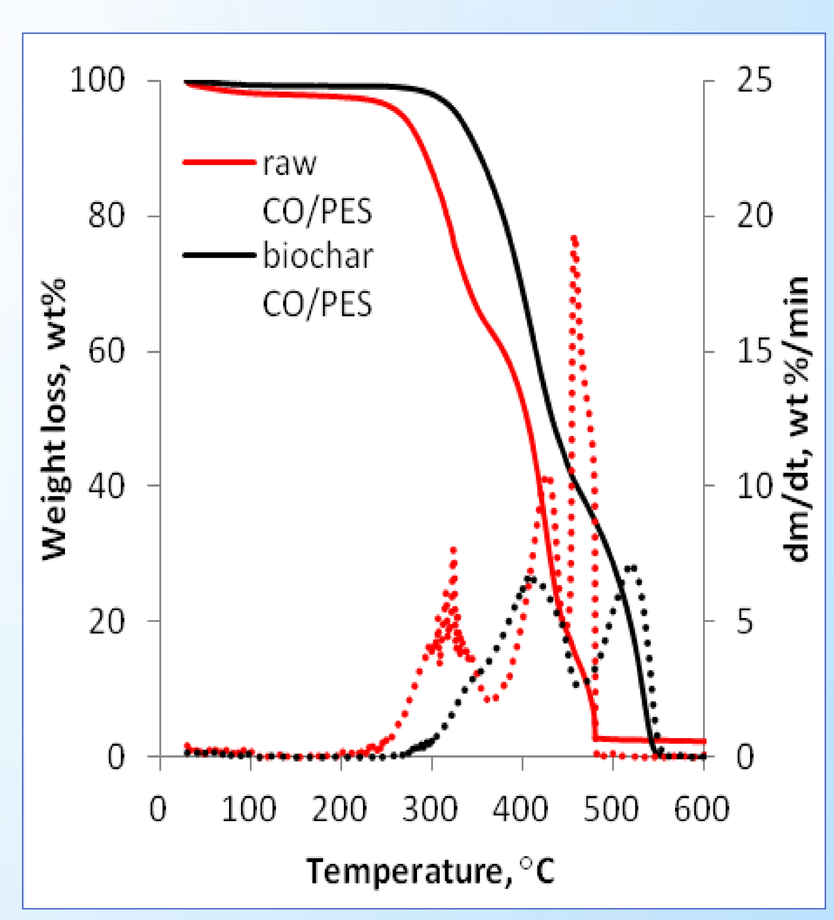


Figure 4. TG-DTG profiles of textile wastes and biochars in air

CONCLUSION

- ✓ CO and CO/PES textile wastes could be converted to biochar through torrefaction
- ✓ Resultant biochars had negligible amount of ash and sulhur with a lignite equivalent heating value
- ✓ Textile wastes can be utilised to obtain low-emission and environmentally friendly energy source

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