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Pyrolysis and Combustion Kinetics of Tobacco Waste Using Nonisothermal Thermogravimetric Analysis

Introduction

China is the largest producer and consumer of tobacco in the world. In the processing of tobacco for producing cigars and cigarettes, about 20 % waste was generated. Like other lignocellulosic biomass, tobacco waste is also mainly composed of cellulose, hemicellulose, and lignin, therefore, some high value-added biofuels can be produced through thermochemical conversion of tobacco waste.

The aims of this work are
(1) to discuss the kinetic mechanism of the pyrolysis and combustion of tobacco waste;
(2) to obtain the effective activation energies for the pyrolysis and combustion of tobacco waste.

Materials & Methods

The tobacco waste samples primarily consisting of tobacco leaves were collected from a cigarette factory in Huanggang City, Hubei Province, China in October, 2013.

1. The proximate analysis, elemental analysis, inductive coupled plasma spectrometer (ICP) analysis were performed to get the physicochemical properties.
2. The thermogravimetric (TG) analysis at 5, 10, 20, 40, 80 K min^{-1} under N_2 and air atmosphere were performed to get kinetic information.
3. The Savitzky-Golay smoothing method (SG method) was used for the smoothing of experimental kinetic data.
4. The iterative linear integral isoconversional method (Cai-Chen method) was used for kinetic modelling of the pyrolysis and combustion of tobacco waste.

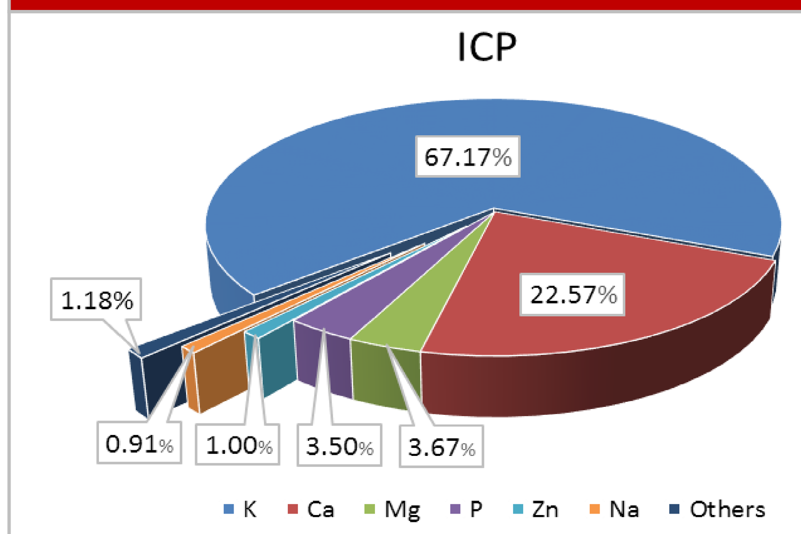
Results & Discussion

The tobacco waste sample contains more ash and N than other lignocellulosic biomasses. Nicotine is one of N-containing compounds in tobacco. (Table)

Physicochemical properties of tobacco waste	
Proximate analysis (wt.%, wet basis)	
Moisture	4.31 ± 0.05
Ash	19.88 ± 0.26
Volatile matter	59.75 ± 0.17
Fixed carbon [a]	16.06
Elemental analysis (wt.%, dry-ash-free basis)	
C	46.96 ± 0.12
H	5.92 ± 0.02
N	3.55 ± 0.04
S	0.66 ± 0.03
O [a]	42.91

[a] By difference

ICP analysis



The tobacco waste sample exhibited enrichment in the contents of K and Ca. Thus, tobacco waste was usually used as organic fertilizer for improving crop yields. (Figure 1)

Figure 1. Relative contents of metallic and non-metallic (excluding C, H, O, N, and S) elements in tobacco waste.

The derivative thermogravimetric (DTG) curves, which were obtained by means of the numerical differentiation of TG curves, have many fluctuations. The Savitzky-Golay method was found to be effective for the smoothing of the DTG curves. (Figure 2)

Differentiation and smoothing of TGA data

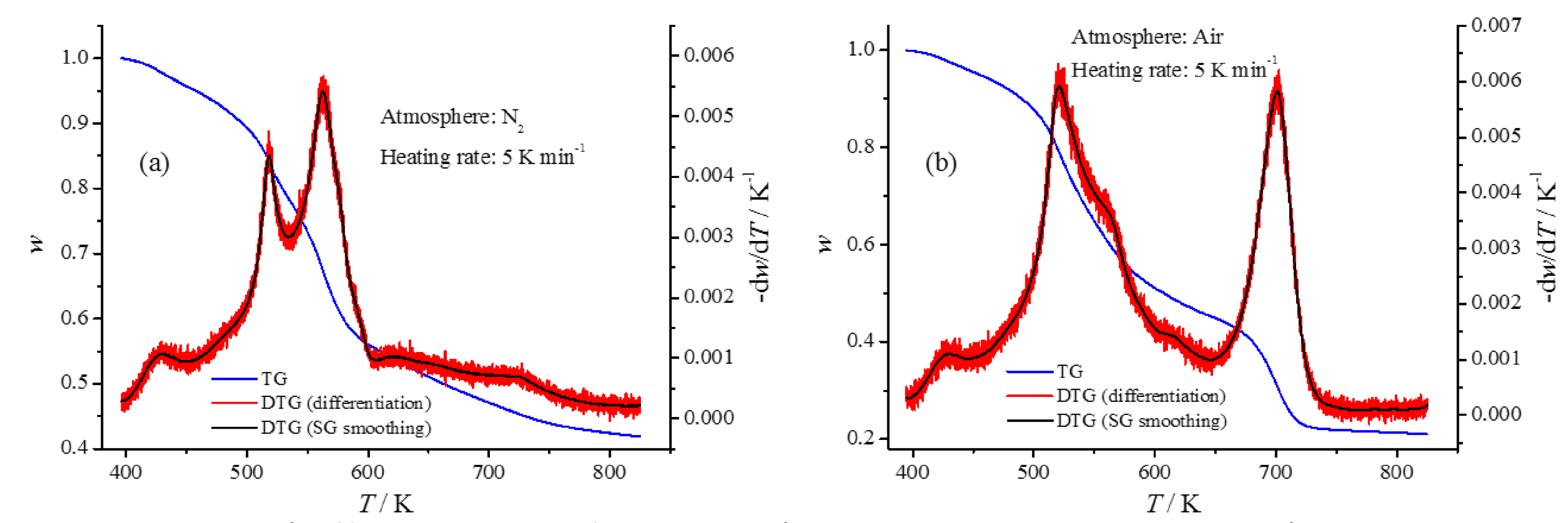


Figure 2. Noisy (differentiation of TG curves) and smoothed DTG curves (the heating rate of 5 K min^{-1} as an example). (a) the pyrolysis of tobacco waste; (b) the combustion of tobacco waste.

This double peak of pyrolysis is associated with decomposition of some complex organic structure of the tobacco, such as hemicellulose, cellulose, lignin, sugars, pectin, etc. The decomposition under air atmosphere apparently takes place by first pyrolysis with char formation then burning char at higher temperature. (Figure 3)

Analysis of DTG curves

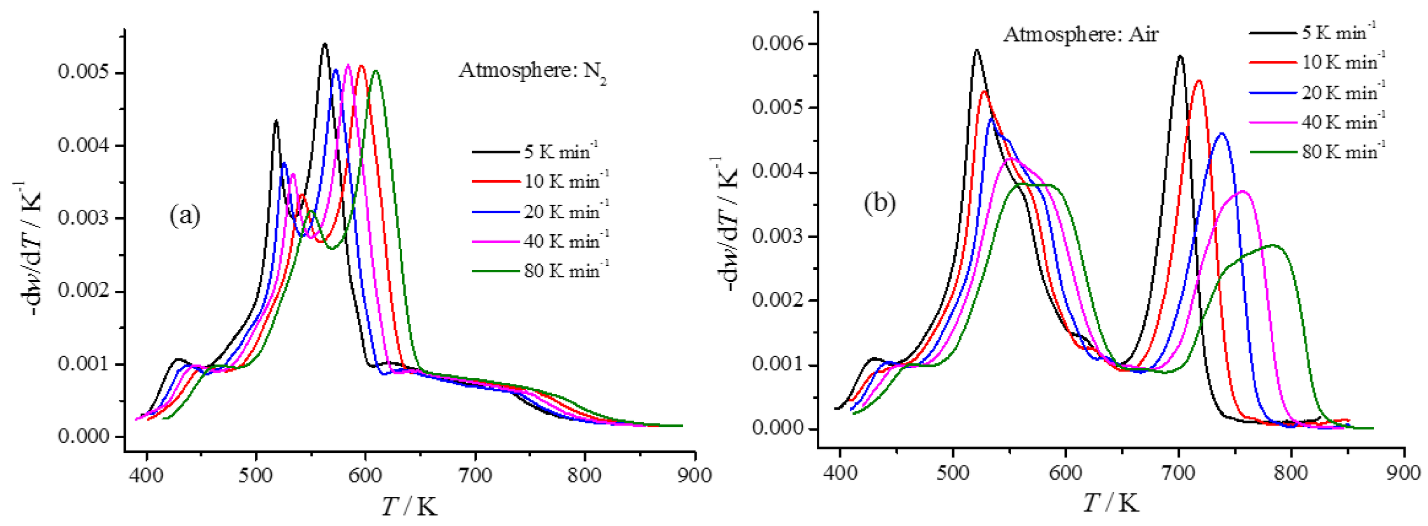


Figure 3. Smoothed DTG curves at the heating rates of 5, 10, 20, 40 and 80 K min^{-1} for the pyrolysis (a) and combustion (b) of tobacco waste by using the Savitzky-Golay smoothing method.

The effective activation energies of the pyrolysis (about 144 - 335 kJ mol^{-1}) and combustion (about 118 - 258 kJ mol^{-1}) of tobacco waste show strong dependence upon the extent of conversion. The effective activation energies of combustion at decomposition stage were similar to those obtained in pyrolysis, then the value experiences an ebb and flow when char combustion. (Figure 4)

Isoconversional kinetic analysis

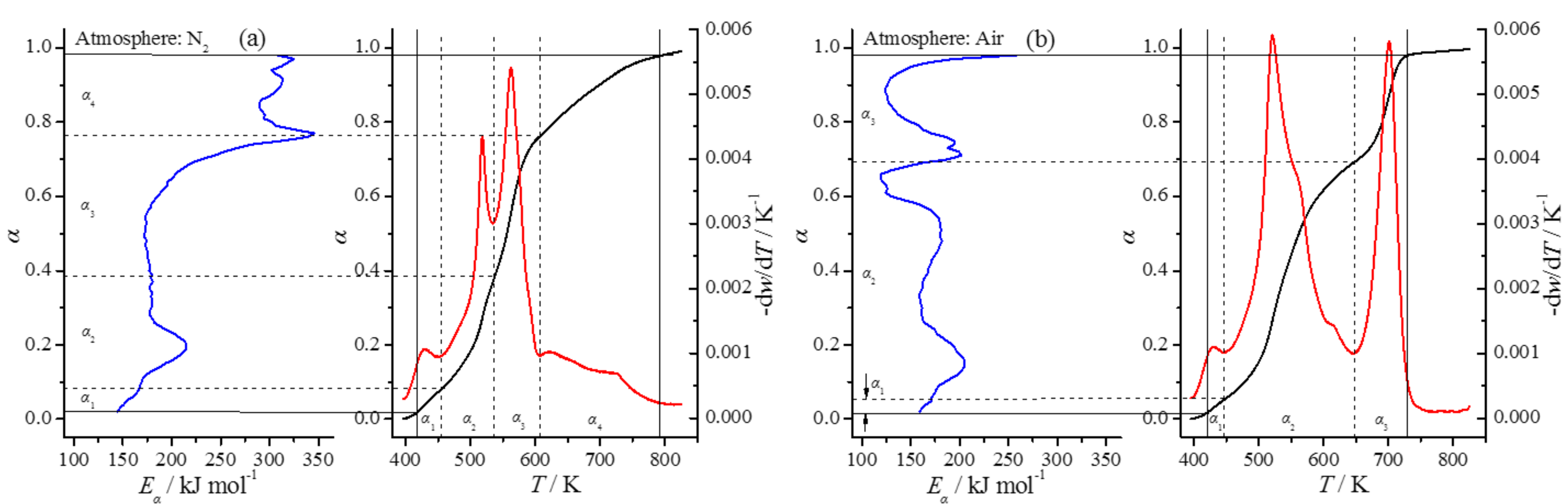


Figure 4. Relationship between the effective activation energies and the temperature and conversion degree for the pyrolysis (a) and combustion (b) of tobacco waste.

Conclusions

1. The Savitzky-Golay smoothing method was effective for the pretreatment of the TG data.
2. The pyrolysis of tobacco is the first stage of the decomposition forming char residue that burns afterwards in the last stage of the combustion.
3. The effective activation energies obtained by the isoconversional method for the pyrolysis and combustion of tobacco waste vary strongly with the extent of conversion. The obtained activation energies are in the ranges of 144 - 335 kJ mol^{-1} and 118 - 258 kJ mol^{-1} for pyrolysis and combustion, respectively.

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