Exploitation of Refused Derived Fuel for energetic uses via gasification and recycling of CO_2 streams

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Introduction

Municipal solid wastes are generated by virtually every activity of modern industrial society. The handling and disposal of these wastes is of vital importance, because of their impact on the environment and human health. Thermal treatment is a very appealing method that can replace other waste management techniques such as ocean dumping, landfill disposal and incineration and can be used in order to produce energy.
Gasification is a green technology producing a fuel gas suitable for gas engines, gas turbines, synthesis of biofuels and chemical industry. Carbon dioxide gasification described by the Boudouard reaction, in which CO_2 reacts with carbon producing CO, can contribute to the mitigation of the greenhouse effect, as CO_2 which is the main greenhouse gas is being used to produce fuel gas.
The aim of this work was to investigate the possibility of exploitation of RDF to energetic uses, via gasification with agricultural and forestry residues and recycling of CO_2 streams.

Materials and Methods

The materials used were: cotton residue (COT), grape husks (GH), pine needles (PIN) and RDF which consisted of biodegradable organic materials, paper from magazines,newspapers and packaging. The samples were characterized according to European standards CENT/TC335. Mixtures of agricultural or forestry residues with RDF were prepared at ratios 70:30.
The gasification experiments were carried out in a TG/DTG thermobalance. Samples were pyrolyzed at 350°C and finally gasified up to 950°C. The heating rate was 10°C/min.
An independent parallel reactions model was developed for the kinetic analysis of the process. The rate of conversion of each reaction i was expressed by the following equation:

$$\frac{da_i}{dt} = A_i \exp\left(\frac{-E_i}{RT}\right) P_{CO_2}^{v} f(a_i)$$

where α_i is the reacted fraction, A_i the pre-exponential factor, E_i the activation energy, R the universal gas constant, T the absolute temperature, P_{CO2} the partial pressure of carbon dioxide, v the reaction order with respect to gas partial pressure and $f(\alpha_i)$ describes the change of surface reactivity as a function of the fractional conversion:

$$f(a_i) = (1 - \alpha_i)^{n_i}$$

where n is the reaction order with respect to char conversion.
The char heterogeneity was assumed as follows:

$$-\frac{dm}{dt} = \sum_k c_k \frac{da_k}{dt} \quad i = 1,2,3,\ldots,N$$

where dm/dt is the mass loss rate, k the component, c_k the contribution of the partial reaction to the overall mass loss m_o-m_{char} and α_i the conversion rate $m_{o,i} - m_i / m_{o,i} - m_{char}$.

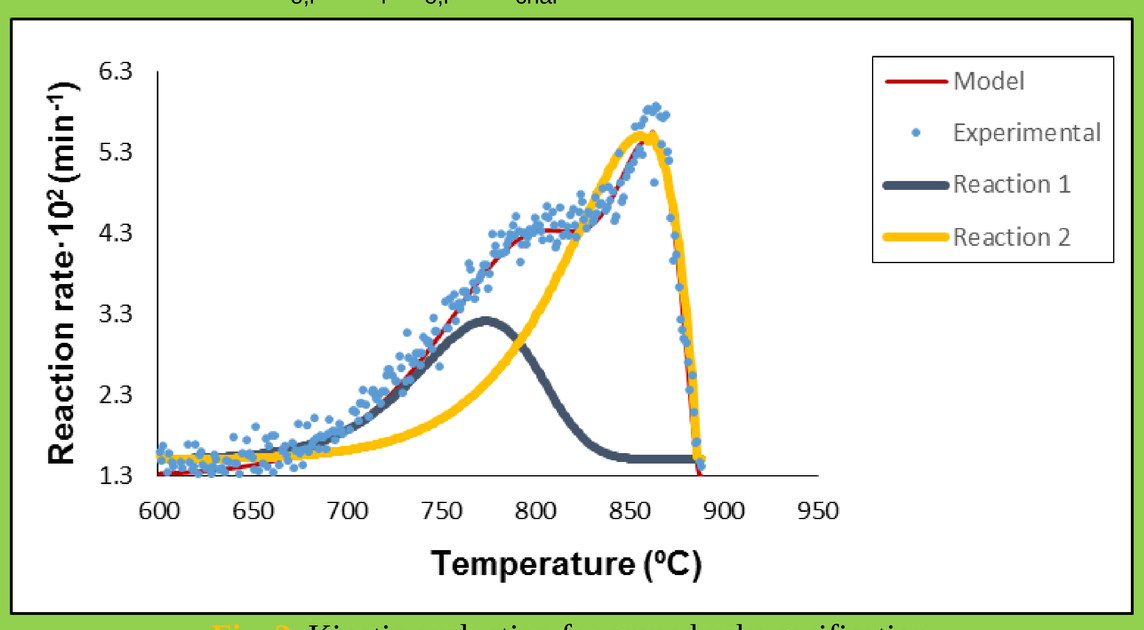

Fig. 2. Kinetic evaluation for grape husks gasification

Results and Discussion

Table 1
Proximate analysis, ultimate analysis and calorific value of raw materials (% dry weight)

Sample	Volatiles	Ash	Fixed Carbon	C	H	N	O	S	HHV[a] (MJ/kg)
PIN	76.7	5.9	17.4	47.7	6.8	0.2	39.3	0.07	21.1
COT	75.4	8.9	15.7	41.5	6.0	1.1	42.3	0.24	17.8
GH	72.1	14.7	13.2	49.4	6.5	2.6	26.4	0.45	25.7
RDF	85.0	15.0	0.05	52.9	8.3	0.3	23.7	------	30.9

[a] Higher heating value

Table 2
Characteristic parameters of gasification

Sample	T_i (ºC)	T_{max} (ºC)	R_{max} (10^2/min)	R_f (10^2/minK)	T_f (ºC)	Yield of CO (%)
PIN	679	871	4.7	1.31	950	75.2
COT	690	837	4.5	1.18	912	66.8
GH	668	864	5.7	1.58	906	82.3
RDF	722	808	3.3	1.07	900	58.4
PIN/RDF	679	854	4.7	1.39	920	77.9
COT/RDF	685	837	4.3	1.22	912	70.9
GH/RDF	668	816	3.9	1.08	906	68.2

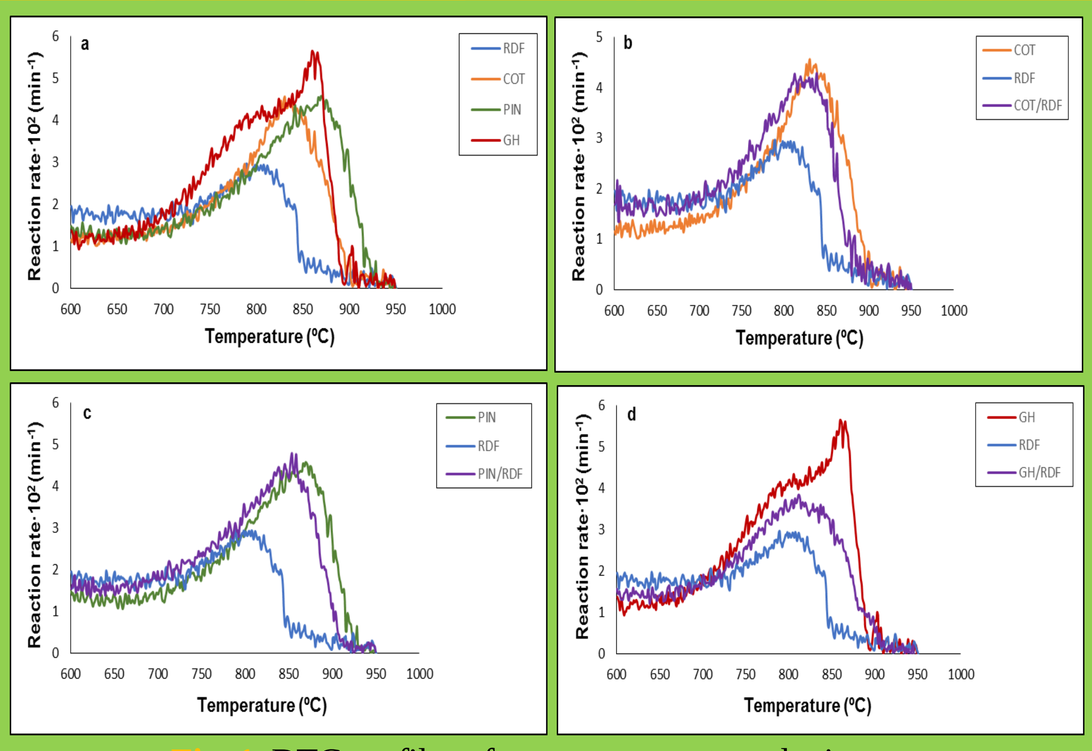

Fig. 1. DTG profiles of raw components and mixtures

Table 3
Kinetic parameters of gasification

Sample	Kinetic parameters	Reaction 1	Reaction 2
PIN	A (1/min)	$6.76 \cdot 10^6$	
	E (kJ/mole)	166	
	c (%)	100	
	n (%)	0.50	
COT	A (1/min)	$1.40 \cdot 10^{11}$	
	E (kJ/mole)	250	
	c (%)	100	
	n (%)	0.78	
GH	A (1/min)	$5.55 \cdot 10^{10}$	$2.80 \cdot 10^{13}$
	E (kJ/mole)	246	280
	c (%)	68	32
	n (%)	0.50	1.06
RDF	A (1/min)	$1.02 \cdot 10^7$	
	E (kJ/mole)	173	
	c (%)	100	
	n (%)	0.50	
PIN/RDF	A (1/min)	$1.83 \cdot 10^8$	
	E (kJ/mole)	193	
	c (%)	100	
	n (%)	0.57	
COT/RDF	A (1/min)	$1.08 \cdot 10^{10}$	
	E (kJ/mole)	225	
	c (%)	100	
	n (%)	0.59	
GH/RDF	A (1/min)	$2.54 \cdot 10^9$	
	E (kJ/mole)	211	
	c (%)	100	
	n (%)	0.86	

Conclusions

All biomass materials were characterized by high amounts of volatiles and low content of ash. RDF had the highest amounts of volatile matter, ash and calorific value and the lowest in fixed carbon.
The gasification process was initiated above 600ºC for both raw materials and mixtures. RDF displayed the lowest values of reaction rate, reactivity and yield of CO (58%). Pine needles/RDF was the most reactive among the three mixtures, in contrast to grape husks/RDF, reaching a conversion of 78%.
High activation energy values were required in order for the Boudouard reaction to take place, which ranged from 166 to 280 kJ/mole. The reaction order varied from 0.50 to 1.06. The kinetic model fitted the experimental results with great accuracy.