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FOREST WASTE AS A POTENTIAL ALTERNATIVE ENERGY SOURCE

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Abstract

Following a method based on the procedure given by Hubbard *et al.* [1] the calorific values of combustion in oxygen at 298.15 K were measured by static-bomb calorimetry for forest residues. This waste mainly coming from mount reforestation, construction of firebreaks, etc., constitutes an important risk to originate forest fire. From combustion experiments the mean calorific value of all species studied was found close to 19 000 $kJ \cdot kg^{-1}$, similar to calorific values of Municipal Waste. It can be concluded that this forest residues can be used as an additional fuel to be added to Municipal Solid Waste in energy recovery plants. By doing this, energy, in this moment lost as abandoned residues, can be recovered. At the same time the elimination of this waste minimizes the risk of forest fires. Our results reasonably agree with literature values.

Keywords: energy source, forest waste

Introduction

Forest fires cause not only economical loses but also soil degradation as well as environmental and ecological damages. For this reason, to prevent them is an important task to be taken on. The different vegetal residues such as forest weed, tree branches, etc. present in the forest are potential agents to originate forest fires. Owing to this, their elimination becomes an objective in order to diminish the danger of this kind of fires. In Galicia (Spain) forest fires originate in the last years damages for billions of pesetas.

Activities related to reaforestation, firebreaks, forest cleaning, etc. originate forest waste. This kind of residues, mainly constituted by Ulex europaeus L., Pteris aquilina L., Rubus fructicosus L., Cytisus scoparius (L.) Link, and other less abundant forest species, typical of our country, are potentially dangerous

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for the environment because of their inflammability. Owing to this, they may become detonant both to initiate and, lately, to propagate forest fires.

Using an isoperibol water stirred bomb calorimeter, calorific values of this forest residues were measured.

As it is well known, heat values of about 5 200 $kJ\cdot kg^{-1}$ are enough to produce autocombustion. Taking into account that this kind of vegetal residues are mainly cellulose materials with heat values close to 16 000 $kJ\cdot kg^{-1}$ it is clear the possibility of using them as a fuel to be added to municipal waste in energy recovery plants. In this way, forest waste can be regarded as a new alternative energy source instead of a potential danger related to forest fire.

Experimental

Forest residues used in our experiments were collected after cleaning one hazardly chosen hectare of forest. The material was carefully mixed in order to get a homogeneus sample proportional to the amount of different species in the area. This sample was reduced by coning and quartering to a final sample of about 1 kg.

The sample was divided in two fractions named A and B. Both fractions were dried for 12 h at 105°C, in a natural convection stove SELECTRA 2000210 (homogeneity ±1.60% and stability ±0.75%), to determine their initial moisture content, and then processed by a cutting mill in order to make easier the pellet preparation. Cutting mill was RETSCH SM-01. Fraction A was burned in the bomb calorimeter and fraction B was chemically analysed. Test samples were kept in a refrigerator SAESA CH 50142 in order to be checked in case of suspicious results.

Method and apparatus

Sample pellets about 1 g size [2] were prepared from the blended powder using a home made press. Balance was BOSCH S 2000/20 with sensibility of ±0.01 mg. The pellet was perfectly placed in a stainless steel crucible put within a sealed static bomb PARR-1108, made of Carpenter 20 Cb-3 special stainless steel. The pellet was connected to the ignition system (platinum wire) through a cotton thread fuse which empirical formula is $CH_{1.686}O_{0.843}$ with $-\Delta_c U^o = 16\,250\ J\cdot g^{-1}$.

In all the experiments the bomb was charged with oxygen at 3.04 MPa and 1.0 cm^3 of water on the bottom. The bomb calorimeter was submerged in a calorimeter can filled with 4631 g of distilled water weighed by a METTLER P-11 balance sensibility ±0.1 g.

The unit was placed in an isothermal jacket with an air-gap separation of 10 mm between all surfaces. The jacket is maintained at constant temperature by circulating stirred water controlled at 298.15 K by a temperature controlled, TRONAC PTC-41, provided with a probe, a heater and a cooling coil. This device kept constant temperature within ±0.003 deg week.

Owing to slight differences of the amount of water added to the calorimeter for each experiment, it was necessary to correct a small change in the energy equivalent. Both the water in the jacket and that in the calorimeter can were stirred at constant speed.

Temperature changes across the experiment were measured to 10^{-4} deg at intervals of 15 sec using a stable and sensitive platinum resistance thermometer ASL S 391–100 through a resistance bridge ASL F-26 connected to a computer AMSTRAD PC-1512 DD.

Ignition is achieved by discharging a 1 256 or 2 900 μF capacitor through a platinum wire attached to a cotton thread. Electric energy correction for ignition was determined from the change in potencial across the capacitor plates.

Correction for nitric acid formation was –59.7 $kJ \cdot mol^{-1}$ [2].

The temperature rise measured in every experiment was corrected for stirring and exchange heating.

The equivalent energy of the calorimeter was determined using the combustion of benzoic acid, BCS CRN-ISOP reference sample from Bureau of Analysed Samples Ltd., having a specific energy of combustion under standard bomb conditions, of 26 431.8±1.9 $J \cdot K^{-1}$ (0.0085%), where the uncertainty quoted is the standard desviation of the mean.

The results obtained are demonstrated on Tables 1–5.

Table 1 Mean calorimetric results

	HHVdry / $kJ \cdot kg^{-1}$	LHVgross /$kJ \cdot kg^{-1}$
Wood (RSU)	17 629	14 423
Forest residues	19 234	4 729

Table 1 shows mean results measured for 'forest residues' and those obtained for wood in municipal solid waste collected in Vigo, Spain.

In Table 2 gives results for a typical combustion experiment.

Table 3 gives some physical properties of the different species.

In Table 4 results are given for elementary chemical analysis C, H, O, N, Cl, S and some metals.

The results of combustion experiments are shown in Table 5 where it can be seen the big difference between HHVdry and LHVgross values.

Table 2 Results are shown for a typical combustion experiment of Rubus fructicosus L. (RF-1) sample

m (air-sample) / g	0.93944
m (vacuum-sample) / g	0.94051
m (fuse) / g	0.00200
ΔT_{corr} / K	0.76282
E_i / $J{\cdot}K^{-1}$	25.39
E_j / $J{\cdot}K^{-1}$	26.52
Δm (H_2O) / g	0.0
$-\Delta U$ (IBP) / J	16 860.53
ΔU (HNO_3) / J	6.27
ΔU ign / J	1.34
ΔU_Σ / J	15.16999
$-m\Delta_c U^o$ (fuse) / J	32.48
HHV dry / $kJ{\cdot}kg^{-1}$	17 955
HHV gross / $kJ{\cdot}kg^{-1}$	7 547
LHV dry / $kJ{\cdot}kg^{-1}$	16 608
LHV gross / $kJ{\cdot}kg^{-1}$	5565

Table 3 Physical properties of the different species

	Density / $kg{\cdot}m^{-3}$	Moisture / %	Furnace ashes / %	Bomb ashes / %
S. scoparius Link	860	66.68	2.36	0.79
U. europaeus L.	830	61.32	2.21	0.71
R. fructicosus L.	940	57.97	3.99	1.95
P. aquilinum L.	530	72.53	4.97	2.25

The Higher Heating Value (HHV) is defined as the quantity of heat generated by complete combustion of a mass unit of sample at constant volume in an oxygen atmosphere assuming that both the water contained in the sample and that generated from the combined hydrogen, remains in liquid form.

If it is assumed that the water in the products remains in the form of steam the Lower Heating Value (LHV) can be calculated as the heat released by the combustion.

The relationship between values is:

$$LHV = HHV(1-H_2O)-2\,440(H_2O+9H)$$

where 2 240 kJ·kg^{-1}is the heat of vaporization of water at 25°C 9H means the final mass of water formed by hydrogen content H in the dry sample and H_2O is the corresponding value of moisture contained in it.

Table 4 Results for elementary chemical analysis

Content / %	S. scoparius Link	U. europaeus L.	R. fructicosus L.	P. aquilinum L.
C	50.55	49.70	47.22	46.66
H	7.04	6.88	6.13	5.93
O	40.03	42.07	44.58	44.42
N	2.01	1.00	2.01	1.83
S	0.21	0.23	0.16	0.23
Cl	0.16	0.12	0.18	0.93
Volatile metals /mg·kg^{-1}				
Cu	38.39	15.00	16.71	13.88
Cd	1.60	3.33	1.67	1.73
Zn	22.39	89.28	16.71	20.15
Pb	0.80	1.80	0.80	8.67
Mn	199.90	60.00	10.00	185.70

Table 5 Results of combustion experiments

		HHV dry / kJ·kg^{-1}	LHV gross / kJ·kg^{-1}
S. scoparius Link	sample 1	20 697	4 753
	sample 2	20 687	4 749
	sample 3	20 752	4 771
	sample 4	20 918	4 826
U. europaeus L.	sample 1	20 315	5 776
	sample 2	20 244	5 748
	sample 3	20 372	5 798
	sample 4	20 713	5 930
R. fructicosus L.	sample 1	17 955	5 565
	sample 2	17 987	5 579
	sample 3	17 991	5 580
	sample 4	17 947	5 561
P. aquilinum L.	sample 1	17 668	2 725
	sample 2	17 842	2 772
	sample 3	17 756	2 749
	sample 4	17 902	2 789

Comments

From the combustion experiments the mean calorific value of all species studied was close to 19 000 kJ·kg^{-1}. This calorific value is slightly higher than that 18 000 kJ·kg^{-1} determined for wood in municipal waste of Vigo, Spain [3].

It can be concluded that this forest waste can be used as an additional fuel to be added to municipal solid waste in energy recovery plants. By doing this, energy, in this moment lose as abandoned residues, can be recovered. At the same time the elimination of this waste minimizes the risk of forest fires.

It can be seen that HHVdry values are reasonably similar while LHVgross are very much different. This difference can be justified in terms of moisture percentages (35% for forest and 12% for wood in MSV). Also higher values in forest residues can be due to resin compounds and essential oil present in this kind of residues.

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Zusammenfassung — Nach einer auf der von Hubbard *et al.* [1] empfohlenen Vorgehensweise beruhenden Methode wurden die Heizwerte für die Verbrennung von Forstrückständen in einer Festkalorimeterbombe in Sauerstoff bei 298.15 K gemessen. Dieser Abfall entstammt hauptsächlich der Wiederaufforstung, dem Schlagen von Feuerschneisen usw. und stellt einen wichtigen Risikofaktor bei der Entstehung von Waldbränden dar. Anhand der Verbrennungsversuche fand man für alle untersuchten Arten einen mittleren Heizwert in der Nähe von 19 000 kJ·kg^{-1}, ähnlich dem Heizwert von Kommunalmüll. Man kann annehmen, daß diese Forstrückstände neben Kommunalmüll als zusätzlicher Brennstoff in Energie-Rückgewinnungsanlagen verwendet werden können. Hierdurch kann brach zurückgelassene Energie rückgewonnen werden. Gleichzeitig reduziert die Beseitigung dieser Forstrückstände das Risiko von Waldbränden. Unsere Resultate stimmen gut mit Literaturangaben überein.