PERFORMANCES AND POLLUTANTS ANALYSES OF SOLID RECOVERED FUEL WOOD AND WOOD AIR GASIFICATION IN DOWNDRAFT REACTORS

G. Vonk[1,2,3], J-P. Houée[1], B. Piriou[2], D. Wolbert[3] and G. Vaitilingom[2]
1 Enerxyl, 16 rue de la gare 22130 Landébia, France, gwendal.vonk@cirad.fr – houee@wanadoo.fr
2 Cirad, UPR 114 BioWooEB, 73 avenue J-F Breton, 34398 Montpellier Cedex 5, France, bruno.piriou@cirad.fr - gilles.vaitilingom@cirad.fr
3 Laboratoire Sciences Chimiques de Rennes – Équipe Chimie et Ingénierie des Procédés, UMR CNRS, ENSCR, Avenue du Général Leclerc, 35700 Rennes, France, dominique.wolbert@ensc-rennes.fr

ABSTRACT
Solid Recovered Fuel Wood (SRFW) is an ideal wood substitute in downdraft fixed bed air gasification processes: SRFW syngas quality and process performances are equivalent to wood syngas on both pilot and industrial scales. Syngas Low Heating Value (LHV) ranges from 4.7 to 5.0 MJ/Nm^3 for SRFW, and from 4.3 to 4.8 MJ/Nm^3 for wood. Differences have been found at pilot scale in H_2S and NH_3 contents: For H_2S, SRFW syngas reaches 3 to 10 ppmv while wood syngas ranges from 2 to 5 ppmv. For NH_3, SRFW syngas reaches 1,000 to 3,000 ppmv while wood syngas ranges from 370 to 500 ppmv. This could be explained by higher sulfur and nitrogen contents in SRFW compared to wood. At industrial scale SRFW syngas shows higher H_2S content than at pilot scale, probably due to a higher char conversion caused by higher temperature.

Keywords: SRF Wood, Wood, Air Gasification, H_2S, NH_3, Downdraft reactor

INTRODUCTION
Wood is a renewable material, with a wide range of uses in construction and furniture. Therefore it leads to waste wood, for which recovery is a matter of concern. According to the so called “Waste Hierarchy” promoted by the European Union[1], the “Energy recovery” step follows the “Material recovery” step and precedes the “Disposal” step. Wastes that enter the Energy recovery step can be prepared as Solid Recovered Fuel (SRF), a higher quality fuel compared to regular Municipal Solid Wastes. SRF are made of non-hazardous wastes such as wastes wood, wastes tires, wastes plastics, etc. One possible way to recover energy from wastes is air gasification which converts solid fuel into synthetic gas (syngas), mainly composed with H_2, CO, CO_2, CH_4 and N_2[2]. However, using wastes as fuel, which contain additives leading to pollutants in thermo-chemical processes, may impact syngas quality and process performances. Downdraft reactors are typically used at small to medium scales (<5MWth) offering a simple process handling and producing a syngas with relative low tar content compare to other reactor designs, but with higher fuel quality requirements (moisture, ash, particle size).[2]
This work aims to evaluate performances and pollutants concentrations in syngas using SRFW in comparison to wood in air gasification. Tests were made on pilot and industrial scales.

MATERIAL AND METHODS

Fuel
Wood, in form of 10cm-long battens or G50-type chips, was provided by the company “Ets Houée” (Brittany, France), which produces wood packaging for fruits and vegetables out of poplar. SRFW is provided by KERVAL Centre Armor, a waste treatment syndicate in Brittany, France. SRFW is composed of waste furniture, waste pallets which are brought by citizens in waste collection sites.

SRFW particle size ranges from 60mm to 150mm. SRFW contains metallic pieces such as door lock. For the pilot tests only, these foreign bodies were removed prior to grinding with a slow speed cutting mill.
Fuel analyses were made in the BioWooEB laboratory of Cirad, Montpellier, France according to the European Norms relative to SRF.

Experimental devices
The pilot scale experiments were performed on an open-top downdraft gasifier developed by BioWooEB, previously described in literature[3]. The inlet air flow is set to 200NL/min. Sampled gas is conditioned according to the "Tar Protocol"[4], and analyzed using a µGC-TCD by Agilent equipped with two columns : MolSieve 5A and PoraPlotQ.
The industrial reactor is an Imbert downdraft gasifier in a 200kWe cogeneration unit, located in the company Enerxyl. A schematic drawing can be found on the company website[5]. The inlet air flow is set to 200m^3/h. Gas analysis is made with a "Vario Plus Industrial" analyzer by MRU Instruments.

RESULTS AND DISCUSSION

Fuel analyses

Table 1: Wood and SRFW proximate and elemental analyses, and Lower Heating Values

	Moisture [w%]	Volatile Matter	Ash	Fixed Carbon*	C	H	N	S	LHV [MJ/kg]
		[w%dry]							
Wood (Poplar)	10.2 ±0.11	82.96 ±0.24	0.70 ±0.13	16.34 ±0.35	49.9 ±1.01	6.1 ±0.05	0.1 ± 0.07	0.015	18.22 ±0.15
SRF Wood	9.66 ±0.13	75.79 ±1.13	2.11 ±0.80	22.11 ±1.92	50.1 ±0.1	5.8 ±0.03	2.48 ±0.08	0.050	18.87 ±0.02

*: by difference

Results

Table 2: Compared Wood and SRFW syngas analyses at pilot and industrial scales

Reactor	Fuel	Oxidation zone temperature [°C]	H_2	CO	CH_4	CO_2	O_2	N_2	LHV [MJ/Nm^3]	Cold Gas Power [kWth]
			[v%]							
Pilot Scale	Wood (chips)	850 - 1050	6.8 ±1	23.8 ±2.8	1.2 ±0.7	5.8 ±3.6	1.1 ±0.1	48.7 ±3.6	4.3 ±0.3	23
	SRFW		16.1 ±2.0	16.3 ±1.1	3.5 ±0.6	18.5 ±3.4	0	45,6	5.0 ±0.2	28
Industrial Scale	Wood (batten)	1000 - 1300	17.5 ±0.5	20 ±1	1 ±0.2	12.5 ±0.5	0	49*	4.8	380
	SRFW		16.5 ±0.5	18.5 ±0.5	1.7 ±0.1	12.5 ±0.5	0.9 ±0.1	50.1*	4.7	380

*: by difference

Wood consumption at pilot scale is 8.5 kg-dry/h, and reaches 7.8 kg-dry/h for SRFW, leading to an Equivalence Ratio (ER) of 0.25 and 0.32, respectively. Gas analyses of the air gasification tests performed on both scales with wood and SRFW are reported in Table 2. Oxidation zone temperature is lower at pilot scale (850-1050°C) compared to industrial scale (1000-1300°C). At pilot scale, syngas from wood shows typical concentrations of charcoal air gasification, while syngas from SRFW shows typical concentrations of wood air gasification[6]. These differences in syngas compositions are due to the fact that wood chips were rapidly converted into charcoal, because the pyrolysis front was not stable and reached bed surface within minutes, which was not the case during tests for SRFW. At industrial scale, syngas from wood and SRFW show similar compositions. Reactor scaling up leads to an increase of CO content, a decrease of CH_4 and CO_2 contents, and a similar H_2 content.

Cold syngas power is higher for SRFW (28 kWth) than for wood (23 kWth) at pilot scale, but is similar for wood or SRFW at industrial scale and reaches 380 kWth. At pilot scale, H_2S content ranges from 2 to 5 ppmv in syngas from wood, while it ranges from 3 to 10 ppmv in syngas from SRFW. At industrial scale, H_2S content ranges from 1 to 5 ppmv in syngas from wood, while it reaches 10 to 20 ppmv in syngas from SRFW. At pilot scale, NH_3 content ranges from 370 to 500 ppmv from wood, while it ranges from 1,000 to 3,000 ppmv from SRFW (Table 3). NH_3 content measurements at industrial scale are in progress.

Table 3: H_2S and NH_3 contents in syngas from Wood and SRFW at pilot and industrial scales

Reactor	Fuel	H_2S [ppmv]	NH_3 [ppmv]
Pilot Scale	Poplar	2 - 5	370 - 500
	SRF Wood	3 - 10	1,000 – 3,000
Industrial Scale	Poplar	1-5	(in progress)
	SRF Wood	10-20	(In progress)

DISCUSSION

Fuel analyses (Table 1) show similar compositions for wood and SRFW, except for nitrogen and sulfur. Indeed SRFW shows 24 times more nitrogen and 2 times more sulfur. This high nitrogen content is due to glue used in particle board, containing urea and melamine.
As expected, wood and SRFW lead to similar syngas quality and process performances, since SRFW are mainly composed of wood. H_2S content are 3 to 5 times higher in SRFW syngas, which matches with SRFW sulfur content 3 times higher than for wood. However, H_2S content is higher at industrial scale than pilot scale (Table 3), as more char is converted into gas, thanks to higher temperature increasing gasification reactions, sulfur held in the char is transferred to the gas. This hypothesis has to be consolidated with the study of sulfur distribution in solid, liquid and gas phases. At pilot scale, SRFW produces 2 to 10 times more NH_3 than wood, as SRFW contains 25 times more nitrogen. A better insight of nitrogen behavior during gasification will be obtained through nitrogen analyses of char and fines particles.
H_2S and NH_3 are a matter of concern, notably in combustion processes since they lead to SO_2 and NO_x, considered as pollutants by emissions standards, e.g. concentration limits for waste incinerators in Europe[7] are respectively for SO_2: 50mg/Nm^3 i.e. 17ppmv and for NO_x: 200mg/Nm3 i.e. 97ppmv.

CONCLUSION

Considering syngas quality and process performances, SRFW is a promising substitute to raw wood in air gasification downdraft processes, both at pilot and industrial scales. Waste wood are produced worldwide and therefore represent a technically and economically accessible renewable fuel. Attention should be paid on pollutant precursors such as sulfur and nitrogen compounds (mainly H_2S and NH_3) in order to develop a rigorous insight of SRF gasification.

References

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