Thermal energy, fillers and pigments from wood packaging waste

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Wood is one of the most common materials used in industry for packaging mainly due to its versatility, strength, durability, reusability, antibacterial effects, no need of chemical treatments and theoretical low environmental impacts. Indeed, wood crates, boxes, drums, reels, cages, and pallets are typically used to handle, store, load and transport not only fragile and heavy goods, like machines and plants, but also products coming from the food sector.

After prolonged use, wood packaging might show defects or damage that make it not repairable and reusable anymore and, once it becomes unsuitable for its original purposes, it is usually discarded and disposed of as a waste.

Since wood packaging residues still hold a great valorization potential, this work aims at presenting an innovative strategy for its thorough exploitation. This strategy is based on polygenerative gasification and foresees the production not only of thermal energy, but also of char to be used as pigment/filler in plastics (as substitute of fossil fuel-based carbon black).

At first, wood packaging residues (in this case disused pallets) were collected from a local waste management company and chipped on-site. Afterwards, the woodchips were transported to UNIBZ's facilities and milled to reach a particle size suitable for further pelletization. Pelletized wood was then used to feed a commercial rising co-current stationary fluidized bed gasifier (with a capacity of 40 kg/h) and consequently deliver thermal energy and produce char.

Initial tests were run using standard pellets to identify the optimal trade-off in terms of gas composition, operational stability, and char yield. Three conditions (called A, B, C) were investigated varying the vibration of the reactor and the coke bed height (see Table 1).

Table 1. Operating conditions.

-	A	B	C
Vibration	0	5 min, every 15 min	Always on
Coke bed height	87 cm	87 cm	92 cm

Afterwards, the gasifier was operated under the selected conditions using pellets from wood waste. During the tests, operating parameters, gas yield and composition and char yield were continuously monitored to ensure the correct operation of the system. Moreover, a mass balance and an energy performance assessment were carried out after each test. The collected char was characterized in detail and added to a low density polyethylene resin matrix (DOW LDPE 410E) to investigate its suitability as filler/pigment.

Data reported in Table 2 highlight that similar results in terms of mass balance are achieved for all the three operating conditions using standard pellets. However, the highest char yields are achieved for case A and B, with a value of 1.3 and 1.6 wt.%, respectively (Figure 1). Moreover, as shown in Figure 2, it is clear that the operating conditions selected for the test C worsen the stability of the gasifier. For this reason, conditions A and B were selected for test with wood waste.

Table 2. Mass balance results obtained using standard pellets.

kg/h	A	B	C
Biomass	39.7	42.9	38.6
Air	64.0	64.4	63.0
Char	0.5	0.7	0.4
Syngas	103.2	106.6	101.2

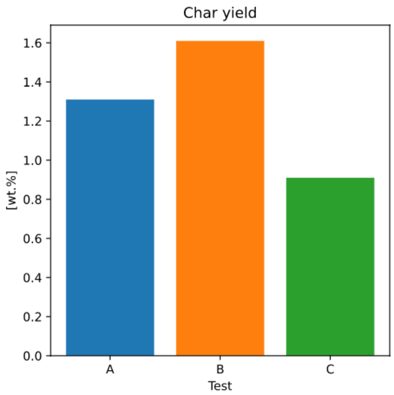

Figure 1. Char yields.

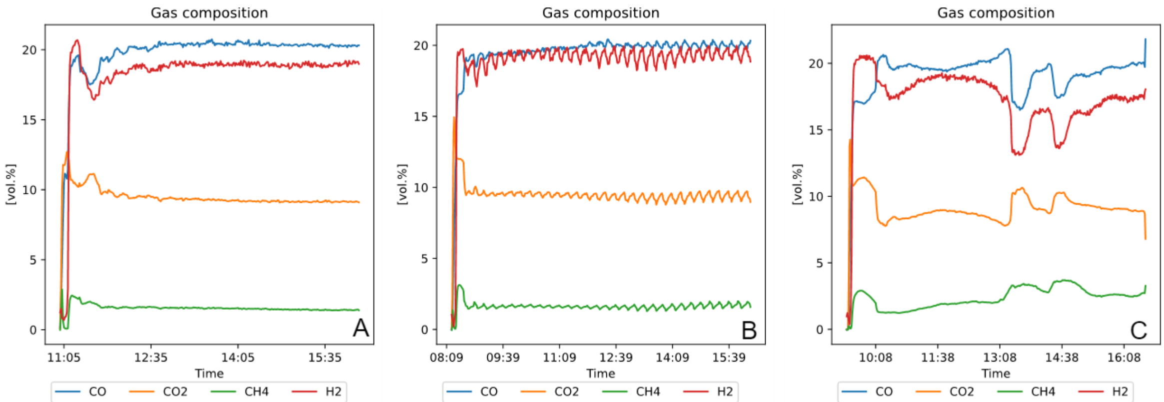

Figure 2. Gas analysis results obtained with standard pellets under the three different operating conditions.

In order to assess the influence of the operating conditions on the char properties, chars obtained from standard pellets under conditions A, B and C were preliminary characterized in terms of elemental and physisorption analysis (see Table 3). The highest carbon content (85.17%) and the lowest ash content (14.68%) were registered for char B, which also showed the best-developed porosity among samples (with a specific surface area of 1075 m^2/g). These results are promising especially with a view to valorizing char as filler/pigment in plastics.

Table 3. Elemental and physisorption analysis results for chars obtained from standard pellets under different gasification conditions.

	units	A	B	C
Moisture	%wt	3.09 ± 0.09	2.58 ± 0.11	4.42 ± 0.02
C	$\%wt_{dry}$	83.70 ± 0.42	85.17 ± 0.29	80.51 ± 0.70
H	$\%wt_{dry}$	0.16 ± 0.02	0.08 ± 0.06	0.00 ± 0.00
N	$\%wt_{dry}$	0.47 ± 0.02	0.58 ± 0.05	0.51 ± 0.10
S	$\%wt_{dry}$	0.29 ± 0.01	0.24 ± 0.01	0.27 ± 0.04
Ash	$\%wt_{dry}$	18.32 ± 1.18	14.68 ± 0.41	19.38 ± 0.11
Specific surface area	m^2/g	587	1075	1058
Pore volume	cm^3/g	0.66	0.91	0.87
Pore size	nm	8.7	7.3	6.5

In conclusion, this work presents an innovative solution for the valorization of wood packaging residues based on polygenerative gasification. However, to ensure its effective implementation, a detailed assessment of the entire value chain (e.g., logistics, transportation, distances, etc.) and the policymakers' support are needed and will be pursued in the following stages of the project.

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