Waste particle board valorization via fast (catalytic) pyrolysis towards value-added chemicals and fuels

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Waste biomass (e.g. agricultural and forestry residues) as well as municipal wastes based on treated wood products (e.g. used furniture) can pollute the ecosystem if left untreated. Within the concept of circular (bio)economy, the recycle and valorization of wood-based wastes is an important renewable source of energy, fuels, chemicals and polymers. Thermochemical methods (combustion, gasification, pyrolysis) are proven to be efficient methods in recovering bio-energy and chemicals from waste biomass. Among these methods, fast pyrolysis maximizes the yield of liquid products called bio-oils. Various feedstocks can be utilized in fast pyrolysis, such as agriculture wastes, wood chips, kraft lignin from pulp and paper industry, particle boards, MDF etc. [1,2]. Fast pyrolysis is a relatively intense, in terms of temperature (400-700ºC), thermochemical process which in the case of lignin for example is capable to break down the polymeric structure into smaller fragments in the absence of oxygen, toward the production of bio-oil which consists mainly of alkoxy-phenols and oxygenated aromatics [3-4]. Since it contains a relatively large fraction of oxygen and reactive functional groups such as carbonyls, bio-oil is not stable and has a lower heating value than conventional petroleum crude oil. Bio-oils can be further upgraded in-situ via deoxygenation to BTX aromatic compounds and (alkyl)phenols via catalytic fast pyrolysis. Surface properties and acidity of the catalyst can control the product yields (oil, gases, char) and the bio-oil composition [3-5]. In particular, fast pyrolysis of particle board, which accounts for a considerable fraction of municipal waste wood products, is reported as a sustainable method for furniture waste management. Because municipal wood wastes including particle boards contain additives such as adhesives, they are expected to induce different pyrolysis mechanisms and products compared to pure wood and lignocellulosic biomass [1,2]. Therefore, investigation of the catalytic pyrolysis of waste wood is of fundamental importance for waste recycling as well as for renewable fuels and chemicals production.

Since literature around pyrolysis of particle boards as a recycling method is limited, in the present work we have investigated the fast (catalytic) pyrolysis of vine pruning (in the form of wood chips that are used to form the particle board), cured phenol-formaldehyde (PF) resin solids (used as adhesive in the particle board) and the particle board itself made from 12% w/w resin in vine pruning chips. The experiments were conducted on a lab-scale fixed bed pyrolysis reactor, using silica sand as the inert heat carrier at 400, 500 and 600ºC (for non-catalytic pyrolysis) or a ZSM-5 zeolite catalyst for in-situ upgrading of the pyrolysis vapors at 500 and 600ºC. The pyrolysis vapors were condensed in -15ºC bath, in glass-traps, whereas non-condensable gases were collected in gas collection bags. Additional fast pyrolysis experiments were performed on a Py/GC-MS system to investigate the relative composition of the pyrolysis vapours. The scope of this work is to identify and optimize the liquid (bio-oil), gas and char products obtained from the pyrolysis of the particle boards, and compare these data with those obtained from the fast pyrolysis of the corresponding vine pruning chips and cured PF resin alone.

The main products of fast pyrolysis of the above feeds were bio-oil, gases and bio-char. Vine pruning resulted in 32-51 wt.% bio-oil, 24-34 wt.% solids and 13-26 wt.% gases. Considering the bio-oil composition of vine pruning, alkoxy-phenols are mainly detected (19-30%) as well as carboxylic acids (1-21%), esters (20-22%) and ketones (7-12%). Cured PF resin solids resulted in 12-27 wt.% bio-oil, 63-82 wt.% solids and 2-7 wt.% gases. Considering the bio-oil composition of PF resin, phenol is mainly detected (69-100%) as well as aromatic compounds (68 %). The particle board resulted in 30-55 wt.% bio-oil, 22-37 wt.% solids and 10-25 wt.% gases. Considering the bio-oil composition of particle board, alkyl phenols are mainly detected (52-75%) as well as alkoxy-phenols (6-16%), carboxylic acids (≤ 13%) and esters (≤ 6%).

The above results indicate that the fast pyrolysis of particle boards is indeed a combination of the mechanisms/products that apply in the pyrolysis of the vine pruning chips (lignocellulosic biomass) and cured PF resin alone. The latter is capable to provide pure (alkyl)phenol bio-oils that can be utilized for the products of PF resins to be re-used in the manufacture of particle boards, plywoods or MDF, thus proving a full recovery and reuse of the resin. Furthermore, with the use of the acidic zeolite catalyst, the obtained bio-oil is enriched in BTX mono-aromatics and naphthalenes, also useful in the chemicals and polymer industry, as well as in the refineries and fuels production.

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