Valorization of pyrolysis by-products for the protection of biomaterials

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Keywords: biomass, bio-oil, entomology, mycology, pyrolysis, pyroligneous acid

Context and objective

From biomass pyrolysis process, non-condensable gases and condensed liquid are usually produced as by-products (Pimenta *et al.* 2018). The latter, also known as pyrolysis liquid or bio-oil, is an important compound due to its potential. It contains a lot of organic compounds such as acid, aldehydes, ketones, esters, furans, and phenols. Historically, bio-oil has also been utilized for many uses, such as soil conditioning, pesticide, and, interestingly, as herbicide, fungicide, and bactericide in plants (Tiilikkala *et al.* 2010, Pimenta *et al.* 2018). In short, bio-oil has been well-used to control microorganisms, especially those who attack and/or harm other biological matters.

Regarding biological matters, wood has been widely utilized around the world in various uses, ranging from arts, furniture, to civil engineering. At the same time, being a biomaterial, wood is susceptible to threats from biological agents such as fungi and insects. Wood preservative is thus important in the utilization of wood; moreover, with the recent trend of valorizing all parts of renewable resources including the by-products of industrial biomass process such as pyrolysis, it is of interest to utilize the bio-oil as wood preservation for protection against harmful organisms. Such an idea of using bio-oil as a wood preservative is not new; other studies have done it before (Temiz *et al.* 2013, Oramahi & Yoshimura 2013). However, few studies are focused on a biomass co-valorization processes coupling (i) the pyrolysis process to produce energy and gases, and (ii) the keeping and the valorization of condensable chemical compounds issued from this first thermochemical process into valuable chemical compounds, more particularly for their antifungal and antitermite activities.

A research focused on the "Energy valorization of lignocellulosic products and their by-products for the protection of bio-materials", started in March 2018, is dedicated to the valorization of the sugar cane bagasse. It has been reported that several varieties of fibrous sugar cane, which contain a high amount of fiber have been developed in Réunion Island, a region where the sugar industry plays an important role in the agricultural sector (Sabatier *et al.* 2015). Thus, this work will use several varieties of bagasse obtained from fiber cane instead of sugar cane alone. Therefore, the objectives of this research are to: (i) characterize the biochar and the bio-oil according to the pyrolysis process parameter and the biomass used, and to (ii) evaluate the potential of said bio-oil as wood preservatives.

Material and methods

The sugar cane bagasse provided by BioWooEB CIRAD were used as a reference, meanwhile, the other bagasse from different varieties will be tested in the future. Pyrolysis of bagasse was conducted using the experimental set up of fixed bed reactor (Fig 1). Various temperatures (T=400°C, 500°C) and holding time t_h (30 and 60 minutes), and a heating rate of 10°C/minutes were applied. Pyrolysis products, consisting of biochar and bio-oil, were recovered for further analysis. The biochar would be characterized for their proximate and ultimate analysis for energy valorization.

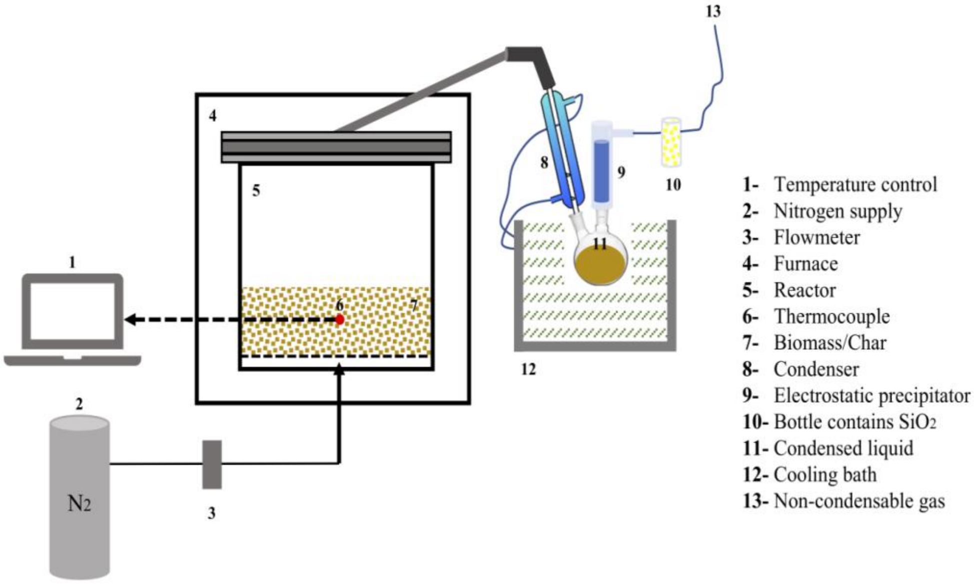

Fig. 1: Experimental set-up of the pyrolysis reactor

For evaluating the antifungal capability of the recovered bio-oil, we conducted fungal growth inhibition tests against two types of wood-decaying fungi: *Coriolus versicolor* (white-rot) and *Coniophora puteana* (brown-rot). Sterile culture medium was prepared from malt (40 g), agar (20 g), and bio-oil with 1% and 5% (v/v) of concentration for each treatment in distilled water (1 L) (according to Oramahi & Yoshimura 2013). The medium then placed in a 9 cm petri dish, and centrally inoculated with a fungus. The fungal growth will be monitored every day for 2 weeks. The treated sample will be compared to the control (petri-dishes contained only malt-agar medium) and inhibition rate will be determined.

Results

The evolution of temperature during the pyrolysis experiments have been followed and noted to correspond well with the planned/expected scheme (Fig. 2). Regarding the yield, it has been found that the highest bio-oil yield (55.38%) was obtained from the pyrolysis with the highest temperature (500°C) while the highest bio-char yield (33.38%) was obtained from the lowest temperature (400°C). Therefore, it could be seen that the trend between the two yields (bio-oil and biochar) are the opposite of each other. Further relationships between them and the other parameters (holding time, heating rate, etc.) will be studied. More pyrolysis experiments would also be conducted with other bagasse types.

The fungal tests are still ongoing at the time of writing. Future work will focus on characterizing bio-oil and continuing antifungal and antitermite tests. Finally, following the antifungal and antitermite evaluation, the formulation of preservative to impregnate the wood samples would be conducted. We would then conduct various tests on the fixation of the preservative, durability, eco-toxicity, and the dimensional stability conferred to these new modified wood products.

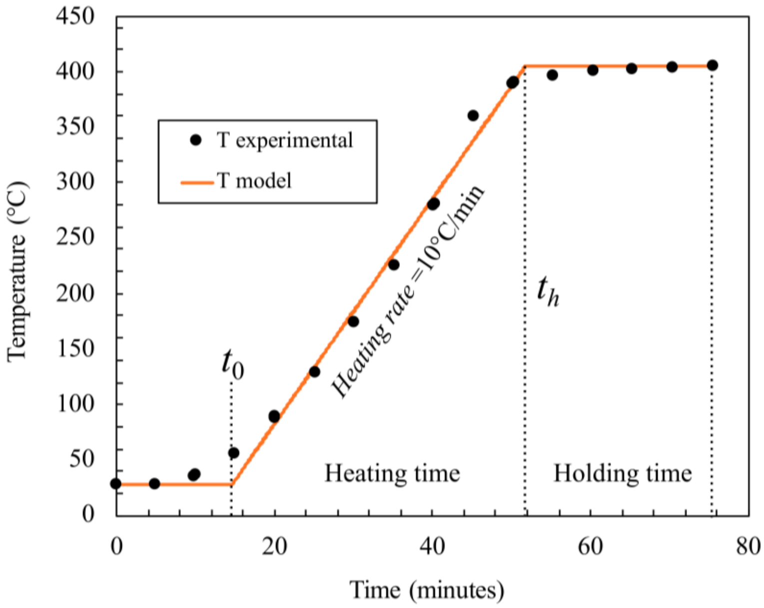

Fig. 2: Comparison between the expected pyrolysis process (*T* expected) and experiment (*T* experimental) with *t* as time passed in *x*-axis and *T* temperature in *y*-axis; $t_0 = t$ when effective heating started, $t_h = t$ when heating stopped, *T* holding reached, and holding started.

Acknowledgement

The authors acknowledge Indonesia Endowment Fund for Education (LPDP) for the doctoral scholarship.

References

Oramahi H.A., Yoshimura T. (2013) Antifungal and antitermitic activities of wood vinegar from *Vitex pubescens* Vahl. *Journal of Wood Science* 59: 344–350.

Pimenta A.S., Fasciotti M., Monteiro T.V.C., Lima K.M.G. (2018) Chemical composition of pyroligneous acid obtained from eucalyptus GG100 clone. *Molecules* 23: 426.

Sabatier D., Martiné J., Chiroleu F., Roussel C., Letourmy P., Antwerpen R.V., Gabrielle B., Ney B. (2015) Optimization of sugarcane farming as a multipurpose crop for energy and food production. *GCB Bioenergy* 7: 40-56.

Temiz A., Akbas S., Panov D., Terziev N., Alma M.H., Parlak S., Kose G. (2013) Chemical composition and efficiency of bio-oil obtained from giant cane (*Arundo donax* L.) as a wood preservative. *Bioresources*. 8(2): 2084–2098.

Tiilikkala K, Fagernäs L, Tiilikkala J. (2010) History and use of wood pyrolysis liquids as biocide and plant protection product. *The Open Agriculture Journal* 4:111–118.