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Carbonization Characteristics of Juvenile Woods from Some Tropical Trees Planted in Indonesia

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The objective of this study was to evaluate the characteristics of charcoals from juvenile woods of albizia (*Paraserianthes falcataria*), gmelina (*Gmelina arborea*), mindi (*Melia azedarach*), and mangium (*Acacia mangium*). Carbonization was performed at 400, 600, and 800°C for 10 min with a heating rate of 6°C/min. The physical, bioenergetic, and chemical properties were evaluated. Maximum char yield was obtained at 400°C and the increase of carbonization temperature resulted in a decrease of char yield. At the same carbonization temperature, char yield was higher in wood with greater initial density, i.e. ordered from the highest to the lowest: mangium, mindi, gmelina, and albizia. The heating values in all woods increased after carbonization, with maximum values at 600°C. Maximum energy densification ratio and energy yield were obtained at carbonization temperature of 600°C and 400°C, respectively. Char yield of 23.62–39.03%, heating value of 25.16–33.85 kJ/g, energy densification ratio of 1.45–1.72, energy yield of 39.09–60.10%, ash content of 0.80–3.94%, volatile matter of 14.61–38.69%, and fixed carbon of 58.58–83.27% were obtained in all charcoals from juvenile woods and were comparable with those of mature woods, showing suitability for the production of charcoal fuel.

Key words: carbonization, juvenile wood, tropical species, heating value, proximate analysis

INTRODUCTION

The demand for forest products continues to rise as world population and incomes grow (FAO, 2014). These demands will have to be met from a static or declining resource. Countries deal with this challenge in many different ways, including the application of a mix of approaches aiming at broadly promoting sustainable forest management and land use planning. In addition, there have been improvements in harvesting and processing technologies and increases in plantation establishment.

Planted forests play a very important role in providing wood supply in Indonesia. In 2013, 19.55 million m3 out of the total 23.23 million m^3 of wood supplied came from planted forests (Ministry of Forestry, Republic of Indonesia, 2014). In Indonesia, planting fast growing tree species has been widely established in industrial, state-owned enterprise, and community planted forests.

Albizia (*Paraserianthes falcataria*), gmelina (*Gmelina arborea*), mindi (*Melia azedarach*), and mangium (*Acacia mangium*) are promising fast growing tree species to be developed for industrial planted forests and community forests. Albizia is one of the most important pioneer multipurpose tree species, and it is preferred for industrial forest plantations in Indonesia due to its very fast growth, ability to grow on various soil conditions, and its favorable silvicultural characteristics (Krisnawati *et al.*, 2011). Gmelina is indigenous to India and neighboring countries and planted in many tropical countries. Moreover, it can adapt to various soil conditions and is known to improve soil through nitrogen fixation (Allen and Allen, 1981). Mindi has been introduced in commercial plantations in Indonesia, particularly in state-owned enterprises plantation areas and community forests, as it is well adapted to warm climates, poor soils, and seasonally dry conditions (Harrison *et al.*, 2003). Mangium has become the most abundant tree species in forestry plantation programs in Southeast Asia. In Indonesia, the total area of mangium tree plantations reached more than 1 million ha (Yamashita *et al.*, 2008). Mangium is characterized as a fast growing species, adaptable to a wide range of acidic soils (pH 4.5–6.5), with a tolerance for low fertility and impeded drainage in devastated sites (Awang and Taylor, 1993).

In our previous studies, we have reported on the properties of those four tropical species including their anatomical characteristics (Kim *et al.*, 2012), physical and mechanical properties (Kim *et al.*, 2014), combustion properties (Park *et al.*, 2015), natural durability properties (Febrianto *et al.*, 2015), and weathering (ultraviolet radiation) properties (Park *et al.*, 2016). The results showed that those four species have relatively low density, low durability, and low mechanical properties that are not suitable for structural timbers. Forest industry sectors should be encouraged to adapt to the use of the species from planted forests. One of the technologies that might be suitable for this is carbonization.

Carbonization is defined as the pyrolysis process in inert atmosphere by which high carbon content solid resi-

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