Properties and utilization possibilities of Mindi (*Melia azedarach* L.) wood from agroforestry plantation

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Abstract. The increasing output of agroforestry can be achieved by optimizing and improving its wood product. Mindi (*Melia azedarach* L.) is one of the fast-growing species planted in traditional agroforestry in Cangkringan, Sleman, Yogyakarta. In this field observation and literature study, the physical and mechanical properties of Mindi wood and the calorific value of the wood waste were evaluated. Finally, the allowable tension (safe load) from Mindi wood for practice application has been calculated. The result indicates that the wood of Mindi is suitable for building construction and furniture material. Its differential shrinkage is in the same range as Teak wood. The allowable tension of Mindi Wood is higher than *Quercho blanco* wood from Sud America. Furthermore, wood waste of Mindi is suitable for heating material and torrefaction effort will improve its calorific value. Due to its fast growth, good stem quality and its low shading effect of the canopy Mindi is recommended for agroforestry development.

Keywords: *Melia azedarach* L., agroforestry, building construction, heating material

1. Introduction
Agroforestry practice in Indonesia as a tropical country has advantages due to the big opportunity condition in growing biomass. Agroforestry does not only provide habitats for a wide range of flora but also plays an important role in supporting economic development, the livelihoods of the rural people and the provision of environmental services. Balancing between planting and wood utilization is the key factor for the sustainability of agroforestry. In this way Indonesia has an advantage because of the tropical region, which means optimum wood or biomass production.

The tree of *Melia azedarach* belongs to the mahogany family (Meliaceae) which produces many valuable timbers. Due to its property profile (density, dimensional stability, strength properties, and natural durability) makes *Melia azedarach* a promising general utility timber that can be recommended for a variety of structural and non-structural uses [1]. Furthermore from the agroforestry practice and observation of the wood utilization of *Melia azedarach* show considerable growth potential and produce an attractive, good quality timber [2]. Strategy and the proper decision of species and art of industry development would be the best way to increase agroforestry productivity.
2. Material and Method
This study conducted by field observation and literature review. Field observation of the agroforestry practice was conducted in Cangkringan, Special Region of Yogyakarta, Indonesia, where agroforestry established as traditional land utilization. The field observation focused on the growth, harvesting, and utilization of *Melia azedarach* in that rural region. The literature review was conducted on the physical and mechanical properties of *Melia azedarach* which basically based of the following former research and publications such as Wood properties and utilization possibilities of *Melia azedarach* from agroforestry plantation of Java, Indonesia [2], Torrefaction for improving the calorific value of wood waste of *Melia azedarach* for renewable utilization [3], Paraiso (*Melia azedarach* var. "Gigante") woodlots: an agroforestry alternative for the small farmer in Paraguay [4], Quality of Plywoods obtained from *Melia azedarach* combined with Pinus taeda, produced with urea-formaldehyde and phenol-formaldehyde resins [5] and Biological, physical, and mechanical wood properties of Paraiso (*Melia azedarach*) from a roadside planting at huaxtla, Jalisco, Mexico [1].

3. Results and discussions
The fast growth habit, deep root system, addition of large quantities of organic matter through leaf and litterfall, compatibility with agricultural crops, valuable of the sawlogs and production of substantial quantities of poles and fuelwood make *Melia azedarach* an excellent species for agroforestry combination [4]. The tree could be harvested in 12 years, with an average DBH of 40 cm. Half of the trees may be harvested at this time and if the another remaining tree harvested in year 15, the average DBH would be 50 cm.

3.1. Physical and mechanical properties
*Melia azedarach* is one of the fast-growing species, with the average ring increment of 8.5 mm with a percentage of earlywood of 81.232 % [2]. This indicates that this species increases the diameter of 17 mm per year and could be categorized as the fastest-growing species in the agroforestry area. The average specific gravity of *Melia azedarach* was 0.534 which is compared to the outer part (0.553) the inner part of the wood has a lighter specific gravity (0.522). This wood has radial and tangential shrinkage of 4.537 % and 7.594 % respectively [2]. With the Shrinkage anisotropy of 1.7, this wood is classified as stable and could be utilized in the region with a high variation of humidity.

The mechanical properties evaluation showed that *Melia azedarach* has a bending strength of 100.571 N/mm² with the outer part of the wood (104.5 N/mm²) a little bit stronger compared to the inner part of the wood (96.502 N/mm²). This evaluation of small clear specimens does not cover the real utilization of the wood, due to the reality wood will be used with its real condition for example with knot, variety direction of fiber and another wood defect. Based on this reality utilization, evaluation of the wood in the form of service test resulted in bending strength of 81.6 N/mm². Furthermore, based on those number calculated allowable tension of *Melia azedarach* Wood is 13.74 N/mm² higher than *Quercho blanco* wood (12.39 N/mm²) were originated from Sud America [6].

*Melia azedarach* wood presents the potential for plywood panels production, the plywood panels produced with *Melia azedarach* veneers showed better results in static bending and in shear strength tests [5]. Furthermore *Melia azedarach* panels presented low wood failure percentage in the glue line shear tests, however, values of shear strength above 1.0 Mpa comply with the norm EN 314-2 (1993).

3.2. Energetic properties
Wood waste biomass of *Melia azedarach* from agroforestry plantation is an important energy source to fulfill the real needs of rural society. Modifications of this biomass will make it more suitable in domestic applications. Hence the composition and properties of biomass is subjected to many natural and human
factors, improving quality enable their application as sustainable fuel in highly energy content. This effort can be achieved through torrefaction. Biomass torrefaction is a method carried out at 200-300 °C in the absence of oxygen. The occurring decomposition reactions at this temperature level cause the biomass to become completely dried and to lose its tenacious and fibrous structure. Torrefaction increases the calorific value and the biomass hygroscopic nature can be destructed to yield a high hydrophobic energy material. Following is the original characteristic of *Melia azedarach* wood waste.

| Table 1. Quality parameters of wood waste of *Melia azedarach*, Linn [3] |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Moisture content (%)        | Ash content (%)             | Volatile matter (%)         | Fixed carbon (%)            | Calorific value (cal./g)    |
| Wood waste Melia azedarach  | 14.753                      | 0.737                       | 64.949                      | 19.561                      | 3949                       |

From those original, characteristic was conducted an effort to obtain high-quality fuel material. The result showed that by torrefaction at 220 °C the calorific value will increase from 3949 cal./g to 4797 cal./g (21.48%) and by torefaction, at 240 °C the calorific value will increase from 3949 cal./g to 4899 cal./g (24.04%). Further advantages of this torrefaction treatment is the reducing of transportation cost due to the weight reduction and densified calorific content of the wood.

| Table 2. Torrefaction for improving the calorific value of wood waste of *Melia azedarach*, Linn [3] |
|-----------------------------|-------------|-----------------------------|-----------------------------|-----------------------------|
| Sample                      | Calorific value (Cal./g) | Moisture content (%)       | Ash content (%)             | Volatile matter (%)         | Fixed carbon (%)            |
| Control                     | 3949        | 14.753                      | 0.737                       | 64.949                      | 19.561                      |
| Torefaction temperature     | 4797        | 2.432                       | 0.828                       | 71.377                      | 25.364                      |
| 220 °C for 90 minutes       | 4899        | 3.262                       | 1.175                       | 72.674                      | 22.890                      |
| Torefaction temperature     | 4899        | 3.262                       | 1.175                       | 72.674                      | 22.890                      |
| 240 °C for 90 minutes       |              |                             |                             |                             |                             |

Torrefied biomass of *Melia azedarach* is brown to dark-brown and this change make torrefied biomass is very attractive for combustion, besides the thermal conversion of biomass also logistic properties could be improved through torrefaction process due to the reducing moisture content.

4. Conclusion

Based on the physical and mechanical properties and the calculated allowance load, it could be concluded that *Melia azedarach* is one of the ideal species for agroforestry development. Planting *Melia azedarach* trees in agroforestry practice have potential advantages in the following ways: organic matter is added to the soil through leaf drop and root decomposition; aeration of the soil through the action of tree roots; retrieval by deep tree roots of nutrients leached below the root zone of annual crops; prevention of further soil erosion and fertility loss by the formation of a permanent protective vegetative covering.
The waste biomass of *Melia azedarach* is more superior in calorific value over the wood waste. This justifies its further development of agroforestry in form of technical implementation of appropriate technology which can be applied in the rural region. Wood waste biomass in the agroforestry is an important energy source to create a more sustainable society. Torrefaction will convert this biomass diversity within a narrow range of biomass specifications.

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