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Characterization of mahogany leaf litter (*Swietenia macrophylla King*) as a raw material of decay resistance biocomposite

To cite this article: N P Aryani *et al* 2019 *J. Phys.: Conf. Ser.* **1321** 022022

Characterization of mahogany leaf litter (*Swietenia macrophylla King*) as a raw material of decay resistance biocomposite

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Abstract. Leaf litter is an organic waste that can be degraded biologically in nature. Based on the previous research, mahogany trees in Universitas Negeri Semarang (UNNES) campus produce about 10 ton ha^{-1} leaf litter in campus forest area and 2.5 ton ha^{-1} along campus street within three-month-period. By this abundant amount of leaf litter, it is quite difficult to overcome the problem of litter management. Therefore, the idea of leaf litter utilization as a raw material of biocomposite is promising to reduce the use of wood as an important commodity of human needs. However, the characterization of leaf litter feasibility for biocomposite production has not been done. This research aims to characterize the physicochemical properties of mahogany leaf litter. Leaf litter was oven-dried for 5 h at 50 °C and then was ground using a mechanical blender to obtain leaf litter powder. Then, the proximate (moisture, proteins, fat and carbohydrate content) and Fourier transform infrared spectroscopy (FTIR) analysis were performed. The results show that the content of crude ash is 9.90 ± 0.65%; crude protein content 24.83 ± 0.79%; crude fat content 11.37 ± 1.05%; volatile compound 65.14 ± 4.77%; charcoal content 7.66 ± 0.71%; and moisture content 6.61 ± 0.69%. The FTIR spectrum shows that leaf litter has low water content and indicates the content of phenolic compounds such as flavonoid. The physic-chemical properties of mahogany leaf litter indicate that mahogany leaf litter is suitable to be used as the decay resistance of biocomposite material.

1. Introduction

Organic waste can be degraded biologically both naturally and with human intervention. However, this organic waste becomes one of the components of waste that has a large enough volume and becomes a problem. The problem of organic waste is not only in urban areas but also in rural areas. Organic trash such as leaf litter becomes a reasonably complex problem that is quite disturbing for the aesthetic appearance of the surrounding. Several attempts have been made to overcome the leaf litter problem. Mostly, rural communities use them to feed the animals or to be processed as compost fertilizer. Worse, some people unpleasantly pile up the litter, burn it, and give more problems of the air pollution [1].

Leaf litter and other organic waste are also a problem in urban areas, where the waste produced on weekdays reach 260 tons/day and increases 3-6% during holidays [2]. Universitas Negeri Semarang (UNNES) as one of the leading public universities in Central Java produces organic waste at 12.5 m^3 a day, and most of the waste is leaf litter from numerous and varied trees in campus forest area and along the campus street [3]. Mahogany trees in UNNES campus area have the potential to produce the litter of about 10 ton/ha/3 months in campus forest area and 2.5 ton/ha/3 months along the street around campus [4]. The division of waste management in UNNES has been applying the treatment on organic waste by composting the leaf litter as organic fertilizers. However, the excessive production of the leaf litter sometimes is challenging to manage to cause the problem of the uncomfortable campus environment. Also, during the rainy season, the leaf litter that is scattered in the drainage system can clog the water flow.

Poor waste management, especially the organic waste will cause some adverse impacts on society, such as public health threats, air and water pollution, obstacles and disruption of community activities, and degradation of the quality of facilities and infrastructures [5]. Therefore, an effective and efficient alternative for waste treatment is needed to solve waste problems. One of the promising solutions to leaf litter problems is to convert it into the light and durable materials through composite engineering [6]. In this case, mahogany leaf litter processing into biocomposite is expected to overcome the problem of waste as well as to be an alternative product in reducing wood utilization in human needs that can lead on forest destruction [7]. However, the physic-chemical properties of mahogany leaf litter need to be characterized to make sure that the litter is suitable as the raw material of biocomposite. In this study, we investigated the characteristics of mahogany leaf litter obtained from UNNES area.

2. Materials and Methods

2.1. Leaf litter sample collection and preparation

Mahogany (*Swietenia macrophylla* King) leaf litter was collected around the campus of Universitas Negeri Semarang (UNNES) in the morning. It was then oven-dried at 50 °C for 5 h. After the drying process, the leaf litter was milled using a mechanical grinder until a fine powder was obtained. Leaf powder was further analyzed to determine the moisture content, ash content, fat content, charcoal content, crude protein content, and volatile component levels.

2.2. Proximate analysis

Proximate analysis was carried out using modified SNI 01-2891-1992 method with three replications.

2.3. FTIR analysis

A total of 1 g sample of mahogany leaf powder was ground with 10 g of KBr in agate mortar (sample: KBr ratio at 1:10). The leaf powder with KBr was ground and was mixed thoroughly; the sample was inserted into the printer plate of KBr plate. Subsequently, the plate was pressed until a transparent plate was obtained. The plates were then employed into the PerkinElmer Spectrum Version 10.03.06 FT-IR spectrophotometer. The spectrum was described in the form of transmittance curves at wave numbers 4000-200 cm^{-1}.

3. Results and Discussion

Physic-chemical analysis of leaf litter biomass is the first step to evaluate the potential of biomass for biocomposite production before further processing. The proximate analysis is the most important analysis for calculating moisture content, volatile components, charcoal content, crude fat content, crude protein content and ash content of biomass. Table 1 shows the results of the proximate analysis of the mahogany leaf litter (*Swietenia macrophylla* King) after drying treatment at 50 °C for 5 h.

Table 1. Results of proximate analysis of mahagony leaf litter

Biomass	Proximate analysis (% weight)					
	Ash content	Volatile content	Charcoal content	Water content	Crude fat content	Crude protein content
Mahagony (*Swietenia macrophylla* King)	9.90 ± 0.65	65.14 ± 4.77	7.66 ± 0.71	6.61 ± 0.69	11.37 ± 1.15	24.83 ± 0.79

* Values are mean ± SD (n = 3)

Based on the analysis, the average value of leaf litter moisture/water content was lower than 13% which is suitable for application as a raw material of the biocomposite board. In the composite particle board manufacturing process, the water content of wood particle is important to determine the moisture content. The water level in raw materials is difficult to remove after the coating process. Therefore, the drying process is necessary to remove available moisture. According to the protocol, the raw material must have the water content in between 2% to 5%, and it will increase to 4% to 6% after addition of certain adhesive or matrix [8]. The drying process on mahogany leaf litter was short, and the water content the leaf litter was 6.61 ± 0.69 %. The drying process was 5 h to reduce the possibility of leaf fiber breakdown since the leaf fiber is the most critical factor to support the biocomposite strength [9]. Also, the particle moisture content is inversely proportional to its density where the lower the water content, the higher the composite density will be [10]. Density is a measure of the compactness of particles in particle board, the higher the density of the particle board, the higher the strength [11]. In another study, the stability of the particle composite increased significantly with increasing of density. Also, the particle composite density depends on the density of the materials and its porosity. The high density of composite particles determines the porosity of the composite, which is more compact with small porosity to avoid the excess amount of water absorbed in the material.

Ash is an inorganic residue as a result of organic compounds burning. Ash content is related to the mineral content of a material in which the higher the ash content, the higher the mineral content in the material will be. Ash content with grey color will be obtained after burning at the range of temperature from 600-750 °C. It can be determined by measuring the weight obtained and compared to the weight before drying. During the burning process, water and other volatile materials are evaporated, and the organic matter is burned to produce CO_2, H_2O, and N_2.

Another component of mahogany leaf litter powder is protein at 24.83 ± 0.79%. Protein, fiber, and particle density in the manufacture of the composite can serve to determine the quality of composite materials. In this case, protein act as fiber binders that increase the fiber-to-surface cohesion by forming complexes [12]. In proteins, there are polypeptide chains that can move freely and interact with other polymers. Moreover, the moisture content in the mahogany leaf litter powder can act as a plasticizer, which can reduce the protein's exothermic temperature and increase the movement of protein polypeptide chains, thereby enabling it to interact more readily with other polymers [13]. The optimum protein content in the manufacture of particle composites is> 20% [4].

Fourier transforms infrared (FT-IR) spectrum analysis result as shown in Figure 1 indicates several functional groups. Typical bands observed in the spectrum of phenolic compounds were obtained from vibrations of O-H and C-O in mahogany leaf litter powder. As can be seen in the graph, O-H vibration tends to widen in the range from 3500 to 3200 cm^{-1} area with a peak at 3394.65 cm^{-1}. This vibration shows the presence of O-H groups that form hydrogen bonds. The absorption at wavenumber 1067.60 cm^{-1} indicates the presence of a C-O group. The vibration of C-O in phenolic compounds produces strong bands in the area of 1300-1050 cm^{-1}. There is low water content in the leaf litter powder indicated by the spectrum. This result is in line with the results of the proximate analysis which shows that the moisture content of leaf waste after drying treatment at 6%.

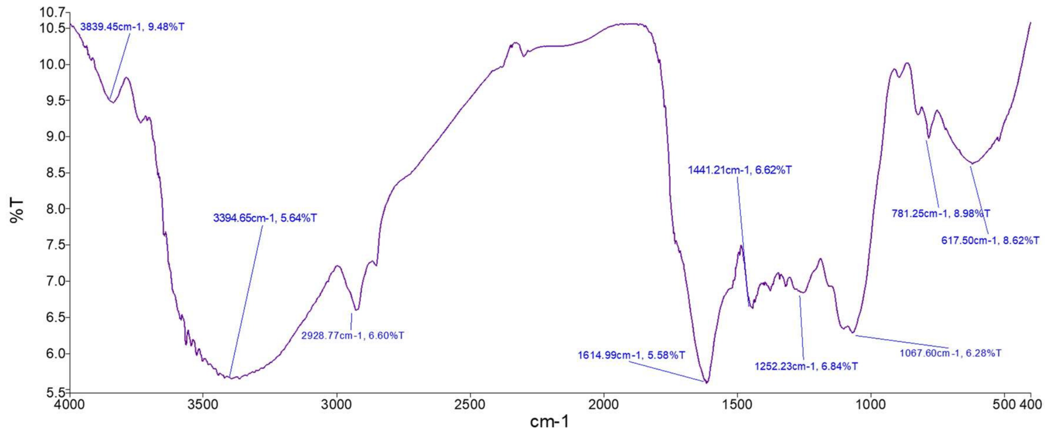

Figure 1. Spectrum results of FT-IR mahogany leaf waste after oven-drying at 50 °C for 5 h

Also, the results show that leaf waste contains phenolic compounds which can be flavonoid compounds. Flavonoids are the largest group of phenol compounds, simple monocyclic phenols, phenylpropanoid and phenolic quinones. Phenol compounds can bind with proteins where the general properties of phenol compounds can increase cell permeability and precipitate proteins. Also, flavonoid compounds can inhibit microorganisms because of its ability to form complex compounds with microbial proteins. Flavonoids work using protein denaturation thereby increasing the permeability of cell membranes. Then, protein denaturation a disrupts cell formation; therefore, it changes the composition of the protein component. The disturbed cell membranes increase cell permeability which results in damage to bacterial, or fungal cells leading to cell death. Many research reveals that flavonoids are compounds that denature the protein and function as the natural antibacterial and antifungal by cell membrane protein denaturation irreversibly [14]. Therefore, the mahogany leaf litter is a good candidate of the raw material of biocomposite by taking advantage of the phenolic compounds in the form of flavonoids. These compounds can support the composite resistance profile against the wood-decay fungal attack. Several studies have shown that woody plants have a resistance mechanism to attack fungus. For example, ulin wood and spruce wood have defense mechanisms against *Trametes versicolor* and *Serpula lacrymans* due to secondary metabolites of tannin compounds [15].

4. Conclusion

The results show that mahogany leaf litter physic-chemical properties indicate its suitability for application in decay-resistance biocomposite processing with low water content at 6.61 ± 0.69%. Also, the FTIR spectrum shows that leaf litter has low water content and indicates flavonoids which can act as natural antibacterial and antifungal.

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