

Kenaf Core Particleboard and Its Sound Absorbing Properties

Mohamad Jani Saad^{1,*} and Izran Kamal²

¹Rice and Industrial Crops Research Center, Malaysian Agriculture Research and Development Institute (MARDI) 43400 Serdang, Selangor Darul Ehsan

²Advanced Processing and Design Programme, Forest Research Institute Malaysia (FRIM), 52109 Kepong, Selangor Darul Ehsan

*Corresponding email: jani@mardi.gov.my

Abstract

In this study, kenaf (*Hibiscus cannabinus*) core particleboards as insulation boards were manufactured. The boards were fabricated with three different densities i.e. 350 kg/m³, 450 kg/m³ and 550 kg/m³ at urea formaldehyde resin (UF) loadings of 8%, 10% and 12% (w/w) based on the dry weight of the kenaf core particles. The fabricated boards were evaluated for its noise acoustical coefficients (NAC) by following the ASTM E1050-98 standard requirements. The study revealed that boards with higher kenaf fiber loading and UF loading gave less NAC.

Keywords: *hibiscus cannabinus*; density; urea formaldehyde

1. INTRODUCTION

In recent years, natural fibers are increasingly being used in many products such as biocomposite products, automotive lining components as well as acoustic absorption barriers. In Malaysia, there is plenty of agricultural waste like coconut trunk (*Cocos nucifera*), rice straw and husk (*Oryza sativa*) and oil palm trunk and empty fruit bunch (*Elaeis guineensis*). Researches have revealed that actually these wastes are not really wastes because they can become sources of natural fibers. The natural fibers obtained from the wastes can be modified into useful products with technologies. There are a lot of advantages possessed by natural fibers such as: renewable, non-abrasive, cheaper, abundance and less health and safety concern during handling and processing [1, 2]. The findings have evoked a mindset that everything that we thought wastes are actually useful and should not be thrown away just like that. We just have to find ways to modify them to something more useful.

Researches to find alternative materials to be utilized in the making of acoustical panel especially in the reduction of noise level have been extensively conducted. The common acoustical panels are made from synthetic fibers such as glass fiber and known to be hazardous to our health as well as to the environment. Fabrication of products from the material is also quite expensive and costly. Due to that, more attention has been given to natural fibers as alternative materials in order to produce products with a combination of high acoustic and thermal properties but with less impact to the environment and human health. Natural fibers are chosen to be alternative materials because they have very low toxicity which is good to protect the environment [3].

Previous researches have confirmed that there are some natural fibers which have high potential to be applied as alternative materials of sound absorbing materials. Paddy straw was reported suitable for acoustic panel because of its high elasticity and porosity [4, 5]. A single layer acoustical panel from paddy husk reinforced with sodium silicate showed that the optimum sound absorption coefficient happened at higher silicate content under high range frequencies [6]. Coconut coir has shown good sound absorption under higher frequencies but inferior performance was observed under lower frequencies. An oil palm fibre has showed the high noise absorption due to its higher density [2, 7].

Among the alternative resources, crop like kenaf is more considerable for that purpose because of its fiber properties, especially its bast fibers (outer fibers) which are low cost, low density, good toughness, suitable for recycling, acceptable strength properties and biodegradability [8]. In Malaysia, Kenaf is still new, however, promotions to encourage acceptance upon it among Malaysians, is given fairly great. Kenaf is a warm season annual fiber crop closely related to cotton (*Gossypium hirsutum L., Malvaceae*) and okra (*Abelmoschus esculentus L., Malvaceae*) [9]. Two of the potential advantages that this crop possess are the ability to grow fast as well

as the two types of fibers it has i.e. bast (outer part) and core (inner part) which can be utilized as raw materials for the production of paper products, building materials, absorbents, textiles and livestock feed [10]. Kenaf is able to reach a height of 3 to 5 m within a period of 3 to 5 months, depending on the environment condition of the place it is planted. Kenaf is able to supply between 12 and 25 t/ha of biomass annually, when it is planted under warm and wet conditions [10].

The kenaf core is light and porous, having a bulk density of 0.10-0.20 g/cm³. It can be crushed into light-weight particles. Currently, kenaf core has received less attention compared to bast in paper and bio composite industries, even though numbers of researches have revealed that kenaf core is useful to produce insulation composites [10, 11], medium-density particleboards [12, 13], fire retardant-treated particleboards [12,13,16], polymer composite [21], thermo-acoustic applications and sound barriers (17-18).

Until now, urea formaldehyde resin (UF) remains as one of the most popular resins in composites industry despite the introduction of many advanced resins. The advantages that this conventional resin possesses are low cost, ease of use under a wide variety of curing conditions, low cure temperature, water solubility, and resistance to microorganisms and to abrasion, hardness, and excellent thermal properties (19).

In this study, kenaf core was used because it is low density and has absorbency advantage. The kenaf core was used to produce kenaf core particleboards. The particleboards then were tested for their acoustical property (the sound absorption coefficients) with regards to different resin content to fabricate the particleboards.

2. MATERIALS AND METHODS

2.1 Materials

Four-month old kenaf were harvested at the Kenaf Research Plot of MARDI Serdang, Selangor, Malaysia. Only kenaf stalks of the harvested kenaf were brought to the workshop for further processing. The kenaf core fibers were separated from the bast fibres using a decorticating machine. The separated kenaf core is in chip form. Then the kenaf core chips were flaked to a particle size of between 2-3 mm using Pallmann PHT 120/430 knife ring flaker. The particles were then dried in an oven at a temperature of 70⁰C for two days to achieve 5% moisture content (MC).

Urea formaldehyde (UF) resin at 64% solid content was used as a composites binder. The binder was added with 10% (wt) ammonium chloride solution as a

hardener and 1% (wt) of wax to prevent the produced composites from absorbing moisture excessively from the surrounding.

2.2 Sample Preparation

The kenaf core particles were mixed with the resin using a blender machine. Three percentages of resin loadings were used to mix with the particles separately i.e. 8%, 10% and 12%. Each of the resin loading was based on the oven dry weight of the kenaf core particles. The targeted board densities were 350 kg/m^3 , 450 kg/m^3 and 550 kg/m^3 . The particles and the resin were mixed approximately in the blender for 5 min to ensure that the particles are evenly mixed with the resin.

After the mixing process, the kenaf particles were brought out from the mixer and were scattered in a rectangular-shaped former with a dimension of 340×340 mm, which was first placed on a caul plate covered with a teflon fiber sheet. The furnish (kenaf particles + resin) was pre-pressed in the cold press at a pressure of 35 kg/cm^2 and subsequently pressed in the hot press machine model Taihei to 12 mm thickness at a temperature of 170°C for 6 min. And then, the particleboards were exposed to the surrounding to reduce the temperature of the pressed particleboard and encourage the resin to cure.

Two different diameters in a circle shape were cut from kenaf particleboard and used to cover the full frequency range. Sample with 100 mm diameter was used to measure the frequency range from 125-1600 Hz and 28 mm diameter was used to measure the frequency range of 1200-6000 Hz.



Figure 1: The circle shape of kenaf particleboard for NAC test

2.3 Testing procedures

All samples were kept in a conditioning room which was set at a temperature of $20 \pm 2^\circ\text{C}$ and $65 \pm 5\%$ RH for 3 days prior to the mechanical and acoustic tests. The conditioning was to ensure that the resin in the particleboards have cured uniformly.

To determine the acoustical property of the composites, the sound absorption coefficients were determined by the impedance tube method in accordance with ASTM E1050-98. The test was done by placing a loudspeaker at one end of an impedance tube and the other end of the tube was placed with the testing sample. The loudspeaker generates broadband, stationary random sound waves. The sound waves propagate within the tube strike between the sample and the sound source and they are reflected as standing wave interference pattern on the computer screen. The acoustic absorption coefficient (α) is defined as the ratio of the acoustic energy absorbed by the PB ($I_{\text{incident}} - I_{\text{reflected}}$) to the acoustic energy incident (I_{incident}) on the surface and it depends on the frequency range. The frequency range for testing was 125 – 6000 Hz. The equipment used for the test was as in Figure 1.



Figure 2: The impedance tube gadget for acoustic analysis

3. RESULT AND DISCUSSION

3.1 Effects of Resin Loading

The effects of the resin loading to the noise absorption coefficient (NAC) are stipulated in the Figure 3, 4 and 5. All figures showed the increase of mean NAC values at lower frequency range (125-1000 Hz) and reached the optimum mean NAC value at 3000 Hz and it decreased gradually after 3000 Hz until 6000 Hz. From the study, it was found that UF loading has given no effects to the NAC values as shown in Figure 3, 4 and 5. Board density of 550 kg/m³ at the frequency below 1000 Hz has revealed that the highest mean NAC value (0.054 - 0.15) was recorded from particleboards loaded with 10% UF loading (Figure 3).

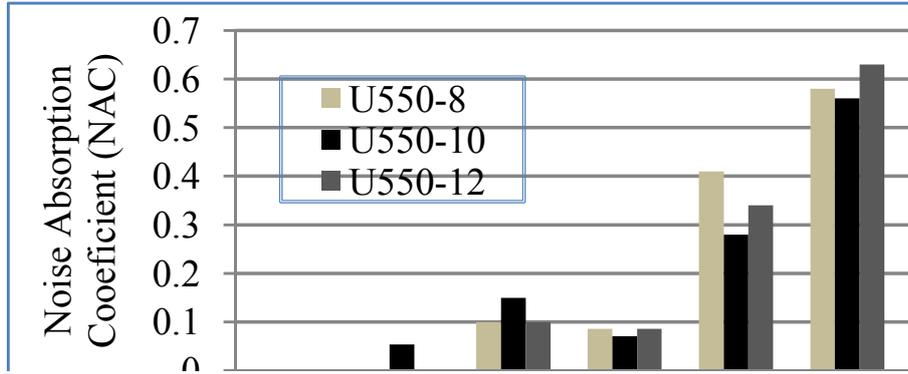


Figure 3: Sound Absorption Coefficient versus Frequency of Kenaf Core Particleboard at a Density of 550 kg/m³ with different UF loading

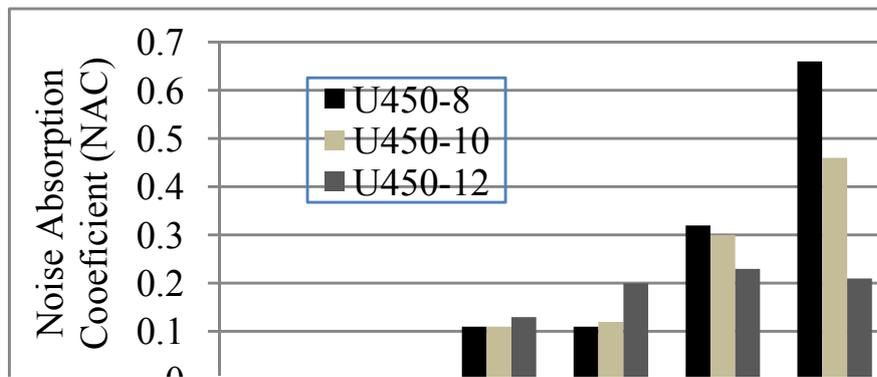


Figure 4: Sound Absorption Coefficient versus Frequency of Kenaf Core Particleboard at Density of 450 kg/m³ and Variable UF loading

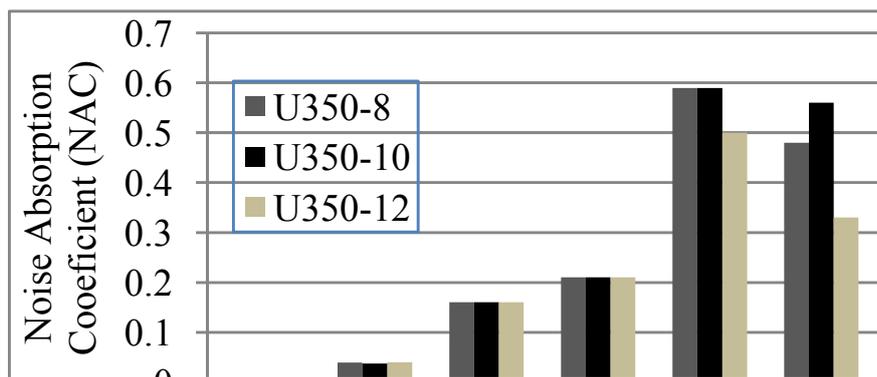


Figure 5: Sound Absorption Coefficient versus Frequency of Kenaf Core Particleboard at Density of 350 kg/m³ with different UF loading

UF loading at 8% showed the best NAC (0.41) compared to the other UF loading at the frequency of 2000 Hz. As for UF loading at 12%, the maximum mean NAC value (0.63) was reached at the frequency of 3000 Hz. Meanwhile, for 4000 Hz frequency, only boards fabricated with 10% UF loading were able to reach the highest mean NAC value (0.23-0.36). There was no mean NAC values recorded for all boards when the frequency was increased from 5000 to 6000 Hz.

Figure 4 demonstrated that the higher UF loading at 12% exhibited the higher NAC (0.1-0.2) in the lower frequency compared to the other UF loadings but then it became constant in the NAC range of 0.2-0.24 in the medium frequency (1000 Hz – 2000 Hz). Meanwhile, UF loading at 8% showed the optimum NAC (0.66) at the 3000 Hz and the mean NAC value remained high (0.29-0.37) at 4000 Hz until 6000 Hz.

There were same values revealed in the low frequency among the three UF loadings as in Figure 5. In the medium and high frequencies which are 2000 Hz until 6000 Hz, UF 10% gave the highest mean NAC value followed by UF 8% and UF 12%.

Kenaf fiber tested with NAC test was found to increase its NAC value from the low frequency (100 Hz – 800 Hz) until it reached the optimum NAC of 0.91 in the frequency range of 1000 Hz – 1600 Hz and later its NAC decreased and maintained around 0.83-0.84 in the range of 2000 Hz – 5000 Hz [3].

3.2 Effects of Kenaf Loading

The effects of kenaf core loading to the NAC value are presented in Figure 6, 7 and 8. Generally, Figure 6 (all boards manufactured with 8% UF loading) have exhibited that boards with the lower kenaf loading are the best noise absorbers. Both low and high frequencies have demonstrated that kenaf boards at 350 kg/m³ density was having the best mean NAC value compared to kenaf boards with densities at 450 kg/m³ or 550 kg/m³. Similar trend was observed in Figure 7 and 8 for boards of 10% and 12% UF loading, respectively.

Porous sound absorbing materials have good acoustic insulating properties over a wide frequency range. The larger the pores, the better the acoustic insulation. Kenaf boards at the densities of 400 kg/m³ and 600 kg/m³ have presented higher sound absorption coefficients than 800 kg/m³ in the 500-8000 Hz frequency range. These might due to the porosity of the lower density boards which was greater than denser boards. It is believed that in the boards with the density of 800 kg/m³, many of the pores (voids) are filled with the kenaf particles, thus have reduced the total pore volume of the board. Even though the mechanical properties of the boards have improved but reduction was observed on the sound absorption coefficient [20].

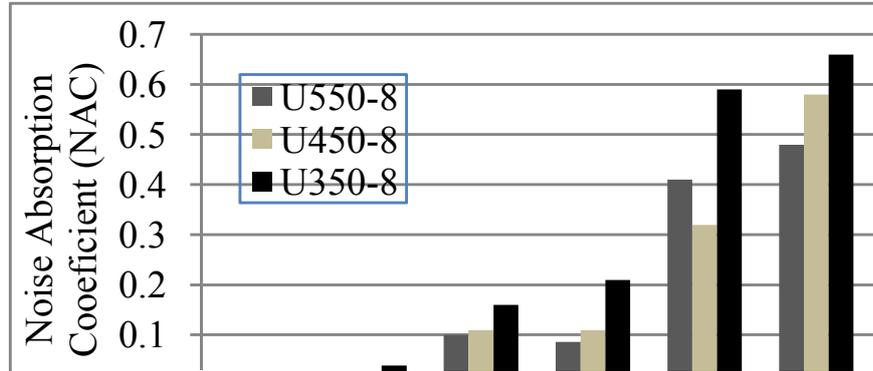


Figure 6: Sound Absorption Coefficient versus Frequency of Kenaf Core Particleboard at UF Loading of 8% and Variable Board Density

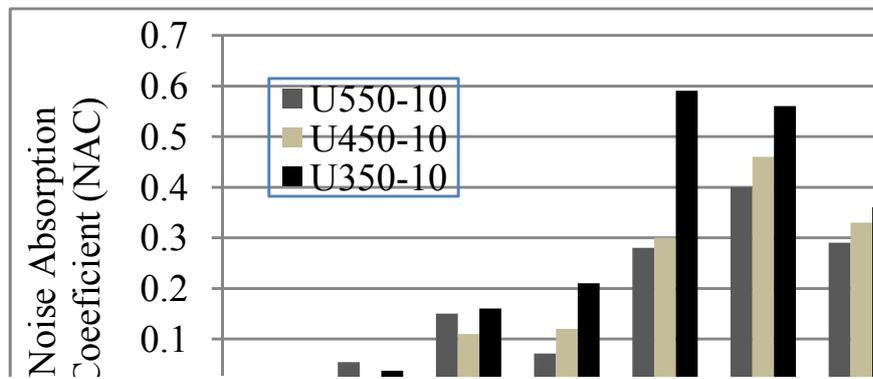


Figure 7: Sound Absorption Coefficient versus Frequency of Kenaf Core Particleboard at UF Loading of 10% and Variable Board Density

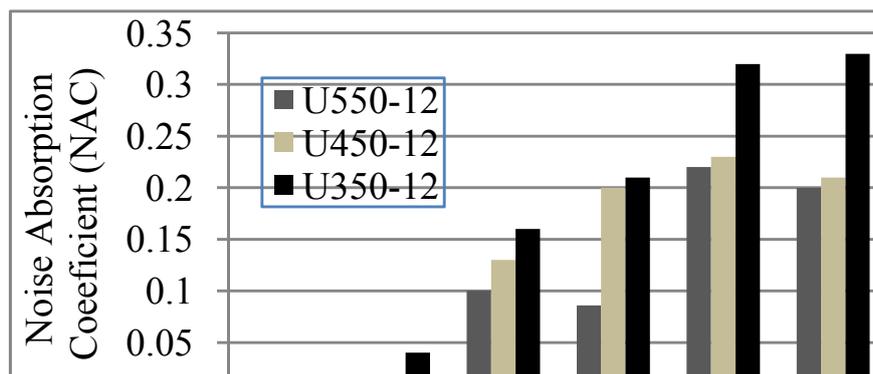


Figure 8: Sound Absorption Coefficient versus Frequency of Kenaf Core Particleboard at UF Loading of 12% and Variable Board Density

Fiberboard, particleboard and plywood have shown a decrease of NAC value as the frequency increased due to their specific characteristic of absorbing sound in the low frequency range but reflecting sound in the middle and high frequency ranges [20].

Commercial insulation materials are made of glass fiber, glass foam and others toxic materials which are noxious to human beings and cause environmental problem. Kenaf core PB can solve this problem. It was not noxious, product that can be renewable and biodegradable.

Sound absorption coefficient of rice straw – wood particle composite boards are higher than other wood – based materials in the 500-8000 Hz frequency range, which is caused by the low specific gravity of composite boards, which are more porous than other wood – based materials [20].

4. CONCLUSIONS

This study shows by using the impedance tube test method to determine noise absorption coefficients of kenaf core particleboards have been successfully carried out. Influence of UF adhesive and the kenaf content were detected on the boards. Results show the NAC of board containing of 8% and 10% are found the best noise absorber rather than 12% UF loading. It was found in the low, medium or even in the high noise frequencies. Board at the 350 kg/m³ density absorbed more noise might be due to its better porosity behavior which able to reduce noise interference

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