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Mass attenuation coefficients of several bio-adhesive based oil palm particleboards at 16.59-25.26 keV photon energies

U A Abdu Mustapa[1], M F Mohd Yusof[2], P N K Abd Hamid[4], R Hashim[3], M Z Ahmad[1], M Z Abd Aziz[1]

[1]Advanced Medical and Dental Institute, Universiti Sains Malaysia, 13200 Penang, Malaysia
[2]School of Health Sciences, Universiti Sains Malaysia, 16150 Kota Bharu, Kelantan, Malaysia
[3]School of Industrial Technology, Universiti Sains Malaysia, 11800 Penang, Malaysia
[4]School of Physics, Universiti Sains Malaysia, 11800 Penang, Malaysia

umiatulasma@student.usm.my

Abstract. Particleboards made of oil palm with addition of polylactic acid (PLA), starch, and fish oil were fabricated with target density of 1.0 g/cm^3. The mass attenuation coefficients of the particleboards were measured using x-ray fluorescence (XRF) configuration in conjunction with niobium, molybdenum, palladium and tin metal plates that provided $K_{\alpha 1}$ photon energies between 16.59 and 25.26 keV. The results were compared to the calculated value of water using XCOM. The results showed that all particleboards having mass attenuation coefficients near to the value of water with the mass attenuation coefficient different less than 0.25. The method of fabrication did not give significant different to the mass attenuation coefficients of the particleboards. The results had indicated the potential of bio-adhesive based palm oil particleboards to be developed as phantoms for low energy photons.

1. Introduction

Increasing demand for wood products in many countries is creating certain amount problem for raw material supply. Declining of timbers from the natural forests has also pressured the wood-based industry to find alternative sources for consistent raw material supply. An alternative to solid wood products, various types of panel such as laminated veneer lumber, plywood, medium density fiberboard and particleboard have been developed in past. Oil palm (*Elaeis guineensis*) which is native species from Africa has the largest plantation land among other agricultural crops in Malaysia. It has a significant commercial value in the form of oil that can be produced from the mesocarp of the fruit. Currently Malaysia is one of the largest producers of palm oil in the world. Increasing land area of oil palm plantation has been leaving substantial amount of residue in harvesting sites.

The potential use of raw and natural materials in the development of binderless particleboard production successfully discovered by many researchers [6][7][8][9]. Binderless particleboard offer a significant effect towards ecological problem. Thus, in this study, the mass attenuation coefficient of such type of board was determined to be used as phantom material. Phantom is a simulated system that has been used in medical field for quality control (QC), quality assurance (QA), radiation protection, calibration and testing purpose. Polylactic acid (PLA) is biodegradable thermoplastic aliphatic polyester derived from renewable resources such as corn starch, tapioca roots, chips, starch or sugarcane. PLA basic chemical formula is $(C_3H_4O_2)n$. Starch is a carbohydrate abundantly present in various plant species, such as potato, wheat, sago, rice and corn. It is soft, white and tasteless powder that is insoluble in cold water, alcohol, or other solvents. The basic chemical formula of the starch molecule is $(C_6H_{10}O_5)n$.

Starch is a polysaccharide comprising glucose monomers joined in α 1,4 linkages. The simplest form of starch is the linear polymer amylose; amylopectin is the branched form.

Fish oil is in the form of liquid at room temperature but generally solidify below 150-100 C [13]. Fish oil supplements are now the third most frequently used supplements following multivitamin-minerals and calcium-containing supplements. Throughout the world, medical scientists are encouraging people to eat more fish as fish oil is the only major source of the polyunsaturated omega-3 fatty acids, eicosapentaenoic acids (EPA) and docosahexaenoic acids (DHA). In medical, fish oil is not only being used as medicine but also be used in different methods such as a markers in MRI. The objective of this study was to fabricate oil palm trunk particleboards added Polylactic acid (PLA), starch and fish oil respectively with a target density of 1.0 g/cm^3, which were similar with the density of water. The mass attenuation coefficients of the oil palm trunk particleboards produced were determined at energy range of 16.59, 17.47, 21.21 and 25.26 keV.

2. Material and Methods

2.1. Sample Preparation

Oil palm trunks were chipped using a hammer mill machine to convert from wood chip into wood particle. In the next step, the wood particles were grounded to fine material with particle size ranges of 149 - 250 μm in length in average. The moisture content of the wood particle has been measure and should reach a value less than 10%. The binderless particleboard was manually formed and pre-pressed into a mold of dimension 20.5 cm x 20.5 cm with target thickness of 0.5 cm. Polylactic acid (PLA) and starch, in the form of powder were added at rates of 10% each and mixed manually to formed the different particleboard. As for fish oil, in the formed of liquid, four different particleboard were formed which were divided at rates of 10 %, 20 %, 30% and 50% treatment levels. The particleboards were fabricated using hot pressing machine at of 160°C pressing temperature for 20 minutes and target density of 1.0 g/cm^3. The density of the particleboards were measured based on the external dimensions of the particleboard samples.

2.2. Measurement of Mass Attenuation Coefficients

The mass attenuation coefficient was measured using X-ray fluorescent (XRF) configuration based on the study by Marashdeh *et al*. [11] as shown in figure 1. An annular ^{241}Am source was used in conjunction with Niobium (Nb), Molybdenum (Mo), Palladium (Pd) and Tin (Sn) metal plate that provided $K_{\alpha 1}$ photons of 16.59 keV, 17.47 keV, 21.21 keV and 25.26 keV energies respectively. A low-energy Germanium detector (LEGe) was used to measured the transmitted photons from the sample. Multichannel analyzer (MCA) was used to determined the signal collected from spectroscopy amplifier corresponding to the peak energy. The mass attenuation coefficients of the particleboard samples were measured based on the transmitted photons according to the Beer-Lambert law given by the equation:

$$I = I_{\circ}\, e^{-\mu x} \tag{1}$$

with $I_{\circ}$ and I is the intensity of initial and transmitted photons across the thickness, μ is the linear attenuation coefficient of sample in cm^{-1} and x is the thickness of the material in cm. . The value of linear attenuation coefficient is calculated using the equation

$$\mu = \frac{1}{\chi} \ln\left(\frac{I_{\circ}}{I}\right) \tag{2}$$

The mass attenuation coefficients, μ/ρ of the particleboard samples were measured by dividing the value of linear attenuation coefficients to the density of the particleboard samples.The values of mass attenuation coefficients of the samples were compared to the calculated value of water using photon cross section database (XCOM) [10].

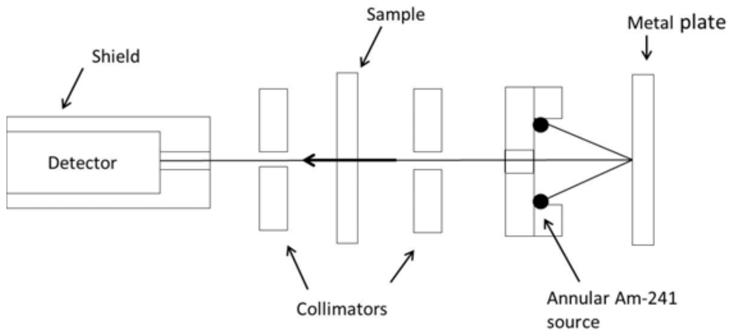

Figure 1. The experimental set-up used for the linear attenuation coefficient measurement of the fabricated oil palm trunk particleboards using an X-ray fluorescence (XRF) configuration.

3. Results and Discussions

The measured density of the oil palm particleboards using gravimetric method is presented in table 1. The results showed that the density of fabricated oil palm particleboards were close to the values of water

Table 1. The measured density of oil palm trunk particleboards measured using gravimetric methods based on the external dimensions of the particleboards.

Sample	Density (g/cm^3)			% difference to water
	Average	Max	Min	
A	0.978	1.099	0.884	2.2
B	1.050	1.103	1.004	5.0
C	1.075	1.094	1.035	7.5
D	1.214	1.233	1.189	21.4
E	1.080	1.098	1.057	8.0
F	1.082	1.113	1.057	8.2
G	0.997	1.049	0.987	0.3

(A) binderless oil palm trunk particleboard, (B) PLA added oil palm trunk particleboard, (C) starch added oil palm trunk particleboard, (D) 10% fish oil added oil palm trunk particleboard, (E) 20% fish oil added oil palm trunk particleboard, (F) 30% fish oil added oil palm trunk particleboard and (G) 50% fish oil added oil palm trunk particleboard.

The measured mass attenuation coefficients of oil palm trunk particleboards measured using the XRF configuration in comparison to the XCOM values of water is illustrated in figure 2. The detail of linear and mass attenuation coefficients of the particleboards is presented in table 2. The results showed that the mass attenuation coefficients of all oil palm trunk particleboards were close to the values of water at all XRF photon energies. The results were in good agreement to the study by Baskaran *et al.* [7] and the previous works on the fabrication of particleboards as phantom [11][14][2][1]. A paired sample t-test was performed to compare the mass attenuation coefficients of water to the oil palm trunk particleboards and presented in table 3. The results showed that the method of fabrication of the oil palm trunk particleboards did not significantly influenced the mass attenuation coefficients of the particleboards in comparison to water. The results were in good agreement to the study by Abuarra *et al*. [2]. The overall results had indicated the similarity of attenuation coefficients of oil palm trunk particleboards to water indicating their potential use as phantoms for low energy photons.

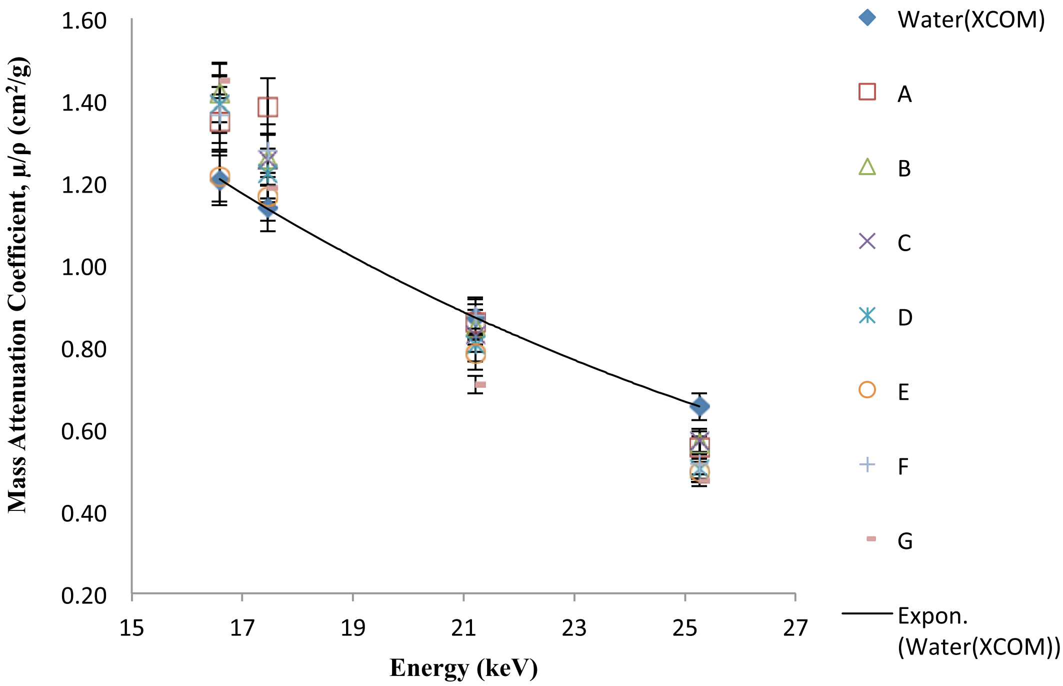

Figure 2. The mass attenuation coefficients of oil palm trunk particleboards in comparison to water (XCOM) at XRF photon energies between 16.59 and 25.26 keV.

Table 2. The mass attenuation coefficients of oil palm trunk particleboards measured using X-ray fluorescence (XRF) configuration.

Sample	**16.59keV**		**17.46 keV**		**21.21 keV**		**25.26 keV**	
	μ(cm^{-1})	μ/ρ (cm^2g^{-1})	μ(cm^{-1})	μ/ρ (cm^2g^{-1})	μ(cm^{-1})	μ/ρ (cm^2g^{-1})	μ(cm^{-1})	μ/ρ (cm^2g^{-1})
W	-	1.205	-	1.138	-	0.872	-	0.654
A	1.317	1.347	1.354	1.384	0.841	0.860	0.542	0.554
B	1.488	1.417	1.319	1.256	0.890	0.848	0.594	0.566
C	1.493	1.389	1.349	1.255	0.891	0.829	0.615	0.572
D	1.689	1.391	1.482	1.221	0.976	0.804	0.611	0.503
E	1.311	1.214	1.258	1.165	0.845	0.783	0.534	0.495
F	1.476	1.364	1.382	1.277	0.948	0.876	0.557	0.515
G	1.443	1.448	1.183	1.187	0.705	0.707	0.473	0.474

(A) binderless oil palm trunk particleboard, (B) PLA added oil palm trunk particleboard, (C) starch added oil palm trunk particleboard, (D) 10% fish oil added oil palm trunk particleboard, (E) 20% fish oil added oil palm trunk particleboard, (F) 30% fish oil added oil palm trunk particleboard and (G) 50% fish oil added oil palm trunk particleboard.

Table 3. The paired sample t-test of mass attenuation coefficients between water and oil palm trunk particleboards.

Standard	*p*-value of sample-standard pair						
	A	**B**	**C**	**D**	**E**	**F**	**G**
Water-sample	0.2178	0.2401	0.2689	0.4364	0.1557	0.2974	0.4530

4. Conclusion

The density of fabricated oil palm trunk particleboard with 50% of fish oil were nearly achieved the target density of water of 1.0 g cm^{-3} with the density value of 0.987 g cm^{-3} and differentation percentage density of 0.3 percent. Therefore, sample with 50% of fish oil is suitable as a water equivalent. The mass attenuation coefficient of the oil palm trunk particleboard is successfully determine. The mass attenuation coefficient of binderless, PLA, starch and fish oil added oil palm trunk particleboards were found closer to the value of calculated water by XCOM in the range of photon energy 16.59 keV – 25.26 keV. Therefore, it can be conclude that oil palm trunk binderless particleboard, added PLA,starch and fish oil particleboards were appropriate to be use as water equivalent material at 16.59 keV – 25.26 keV photon energy and developed as phantom of low energy photon.

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