ORIGINAL ARTICLE

Dosimetric Study of Rhizophora Spp. Particle Board Using Gafchromic XRQA2 Film

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ABSTRACT

Introduction: Various phantom with varied materials has been proposed to replace the human body. Besides, there is always a demand to use the local material as a phantom material, which is readily available and inexpensive. Wood is usually preferred because it is multifunction, environmentally friendly, low in toxic, inexpensive, as well as easy to use and prepare. Previous studies have found that Rhizophora spp. is a suitable natural source material and has been suggested due to its comparable dosimetric properties to commercial phantom. **Methods:** In this study, fabricated Rhizophora spp. particleboards phantom was opted as a solid-equivalent phantom medium at low energy photon beams using Gafchromic film x-ray quality assurance 2 (XRQA2). Additionally, the characteristics of XRQA2 film in the diagnostic energy range were generated. **Results:** Interestingly, the density of the fabricated Rhizophora spp particleboards was observed to have the same density with the water equivalent material (ρ= 1.00 g.cm^{-3}) and has shown to have loosened agreement with PDD of water phantom at approximately 25% of the dose error. Also, further analysis using XRQA 2 film showed that energy was independent at different ranges. **Conclusion:** The analysis of fabricated Rhizophora spp particleboards undertaken here has extended our knowledge of the possibility of manufacturing cost-effective water equivalent phantom by using binder-less particleboard from Rhizophora spp. Therefore, a definite need for smaller interspacing particles should be considered to elevate the potential of Rhizophora spp particle boards as water equivalent materials.

Keywords: Rhizophora Spp., Particle Board, kVp Beam Energy, Gafchromic XRQA2 Film

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INTRODUCTION

A phantom is a physical model made from tissue-equivalent materials to mimic the characteristics of the biological tissue and dose distribution in the human body (1, 2). Many phantoms with different materials have been proposed to replace the biological tissues in a human body. The density and effective atomic number of materials have a significant influence on the probabilities of photon interactions (3). Water equivalent materials such as polystyrene and acrylic made from patented materials that are clinically utilized for dosimetry purposes, are suitable to be used as phantom even though there are uncertainties in terms of their dosimetry properties (3).

Moreover, there is always a demand to use local materials which are readily available and inexpensive as a phantom material. Wood is usually preferred because it is a natural source, environmentally friendly, low in toxic, inexpensive, as well as easy to use and prepare. Moreover, Rhizophora spp. also has a closely similar density of water as standard phantom material (4). Previous studies have found that Rhizophora spp. is a suitable source material and has shown some similarities in its dosimetry properties with other standard phantom materials (5,6,7). It should be noted that numerous studies have been attempted to explain the radiation interaction with Rhizophora spp. wood (5,6,7).

Binderless particleboard is fabricated by pressing the particle wood without using any adhesive. The Rhizophora spp. particles should be small and compressed into particleboards with a high-pressure system. This type of particleboard has been studied by Marashdeh (2011) (5) in the mammography energy range. In his work, the effect of physical characterization of particle size on fabricated Rhizophora spp. wood into binderless particleboard was studied. Commercially available solid water phantom is costly. In this study, the water equivalent phantom made up from a suitable and inexpensive Malaysian mangrove tree was developed and needed to be evaluated in terms of its diagnostic energy ranges.

Meanwhile, the film dosimetry is one of the dosimetry methods used since Wilhelm Conrad Rцntgen discovered x-rays. This method has become a method of choice since many dosimetric devices are not suitable to be used with water or liquid. Some dosimetric device is an electronic-based system which is not waterproof and can damage the device. In this study, fabricated Rhizophora spp. particleboards phantom was evaluated as a solid-equivalent phantom medium at low energy photon beams using Gafchromic film x-ray quality assurance 2 (XRQA2).

Additionally, the characteristics of XRQA2 film in the diagnostic energy range were generated. By studying and analyzing the data, the potential, and suitability of the Rhizophora spp. particle board can be further explored and understood.

MATERIALS AND METHODS

Preparation of Rhizophora spp. particleboard

The Rhizophora spp. tree trunks were collected at Kuala Sepetang, Perak, Malaysia. The trunk was fabricated horizontally into approximately equal thickness by Formahero FH-600 BS saw. All the wood planks were carefully processed using the surface planner machine (Holy Tek HP 20, Taiwan) to reduce the trunk size. The Rhizophora spp. chips resulting from this process were gathered and grounded into a smaller particles using a Retch grinder. A horizontal screening machine was used to isolate the oversized particles, while particles with 210 µm in size were chosen. Only particles with 210 µm in size were chose to study the potential of large particle size of particleboards (8).

The moisture content produced by the Rhizophora spp. particles was determined using a moisture analyzer. The calculation of the mass of wood is shown in equation 1 (3).

$$m_w = vp\,(1 + mc_w\,\%) \quad \text{(eq. 1)}$$

Where m_w, mc_w, and vp are masses of wood, the percentage of moisture content, and volume of fabricated particleboard, respectively. In this study, the target density of the fabricated particleboard is 1 $g.cm^{-3}$.

The 0.5 cm Rhizophora spp particleboards were assembled to create a total 10 cm thickness for the experiments. All particleboards were manually prepared using a stainless-steel mold. The particles were spread uniformly on a square shaped stainless steel plate. Then, the particles were pressed using a cold-pressing method for 3 minutes. After that, the Rhizophora spp. particles were compressed using a hot-pressing method with a hydraulic press machine. The pressure was maintained at 200 kg/cm^2 at 200°C and was gradually decreased after 20 minutes because the water steam produced can damage the fabricated particleboard surface. The particleboards were then transferred and kept under the stainless-steel mold to prevent bloating. Next, the particleboards were cut into 20 x 20 cm2 sizes at a low thermal degree.

Quality Control Test

A set of tests were conducted to determine the performance of the x-ray machine to avoid discrepancy of data due to problems coming from the generator and the x-ray machine. A few tests of QC were performed; accuracy of kVp test, accuracy of exposure time test, dose linearity test, and collimation. All of the tests showed that the machine was in an optimal condition.

Gafchromic XRQA2 film Calibration curve

This procedure was conducted to determine the calibration curve of Gafchromic XRQA 2 film using batch number. In this study, calibration on air was conducted using Unfors solid-state detector as a reference detector to calibrate the film. Unfors detector is capable to measure the air kerma-rate in a positive value as the ionization chamber (9). This setup is achieved by arranging a film as shown in figure 1. The set up was energized with 81 kVp, 60 mAs, and 50 cm distance between a Styrofoam and an x-ray tube. A shorter source to surface distance was chosen in this experiment to reduce unnecessary tube loading. Parameters applied were maintained for a higher dose rate, and the dose received by the film is dependent on the fraction of exposures used for the particular film. The dose applied to the film was assumed to be identical for every exposure conducted on film calibration. After 24 hours, Gafchromic XRQA2 films were scanned using the Epson flatbed scanner and analyzed using FilmCal software. The exposed films were scanned and transferred to the FilmCal software to determine and observe the dose distribution in the XRQA 2 film. The software can generate the pixel value and it is important to convert it into optical density (OD). The pixel value was then converted into optical density

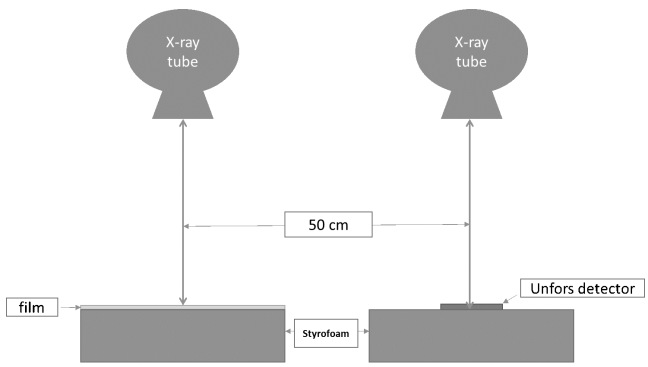

Figure 1: Arrangement of film and Unfors solid-state detector for the cross-calibration procedure

value using equation 2 (10), and finally, the calibration curve was plotted.

$$\text{Optical density} = \log_{10}\left(\frac{\text{unexposed pixel}}{\text{exposed pixel}}\right) \qquad \text{(eq. 2)}$$

Gafchromic XRQA 2 film energy dependent
The energy dependence test was carried out to evaluate the dependency of XRQA 2 films at different energy ranges. The experiment was started by placing the solid-state based detector on the couch at 50 cm distance between the couch and x-ray tube. Tube current, mA, and time, ms were manipulated to give the same dose reading by the detector. For this experiment, 81 kVp, 300 mA, and 200 ms were chosen as a reference parameter (clinically practiced) to get the reference dose on the detector. These average doses of three readings were calculated. Then, the average dose was used as a reference dose value.

The exposure of 40 – 117 kVp and 90 to 560 ms exposure time were used to provide various energy choices to reproduce the reference dose value (approx. 13.1 mGy) to evaluate the XRQA2 film. The film was placed on the Styrofoam at 50 cm distance between the Styrofoam and x-ray tube. Further, the film was exposed to two fractions for a total dose of 26.2 mGy and 5 fractions for 65.5 mGy of the total dose. After 24 hours, the XRQA 2 film was scanned and analyzed. The Verisoft software was utilized the calibration curve was obtained. The dose of a film was also estimated. Next, the energy-dependent graph was plotted to observe the dependency of both films from 40 – 117 kVp energy range.

Comparison of percentage Depth Dose curve in Rhizophora spp particleboard and Solid water Phantom
The percentage depth dose curve was constructed to study the dose received at different depth in both fabricated Rhizophora spp. particleboard phantom and solid water phantom. PDD was measured by placing a phantom parallel to the beam to get the depth dose in every depth using a single exposure. This experiment was conducted on both Rhizophora spp. particleboards and water phantom. The phantom was placed perpendicular to the couch, as illustrated in Figure 2. The exposure energy chosen for these experiments was 81 kVp, 300 mA, and 200 ms for 5 fractions with 10 x 10 cm^2 field size at the surface of the phantom.

After 24 hours, Gafchromic XRQA2 films were scanned using a Flatbed Scanner and analyzed using FilmCal Software. The FilmCal Software used the calibration curve obtained previously to calculate the dose value. Then, the dose value of the fabricated Rhizophora spp. Particleboard was compared with the water phantom.

RESULTS

Gafchromic XRQA2 film Calibration curve
In conducting this experiment, 81 kVp, 60 mAs, and

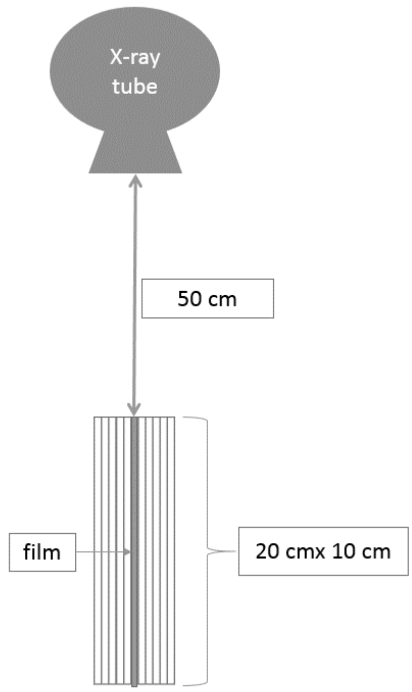

Figure 2: Arrangement of film at the center of the phantom and placed vertically to the X-ray beam

50 cm distance of the x-ray tube to the film were used. Optical density (OD) is a parameter used in film dosimetry to explain the amount of radiation deposited on the film. The changes in the mAs value was found to be proportional on the OD of the film. The decrease in OD happens when mAs decrease by half. The amount of radiation represented by the film is an effect of the radiation exposure that the film has received. High radiation exposure to the film caused the optical density of the film to become darker, and the underexposed film did not contain enough details on the resultant film. The calibration curve was prepared to enable the conversion of the pixel value to the dose in mGy. Figure 3 shows a calibration curve of Gafcromic XRQA2 film in the selected dose range of 0 to 250 mGy. This dose range was selected because it is more relevant to diagnostic radiology.

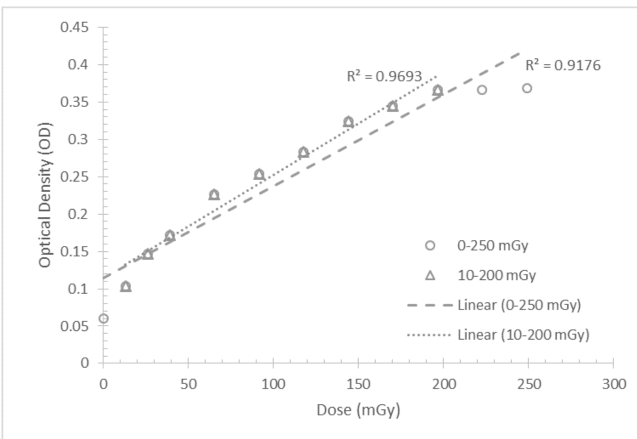

Figure 3: Characteristic curve of Gafchromic XRQA2 from 0 to 250 mGy

Energy-dependent of the Gafchromic XRQA 2 film

This test was conducted to study the linearity of XRQA2 in different effective energy of photons, mainly in the diagnostic energy range. Table I shows the response of XRQA2 film from the range of 25.2 keV to 40.4 keV effective energy.

Table I: Gafchromic XRQA2 dose respond on a different effective energy of x-rays. 1, 2- and 5-times exposures were made to evaluate the energy-dependent effect on Gafchromic XRQA2

kVp	HVL (mm Al)	Effective energy (keV)	1 x exposure	2 x exposures	5 x exposures
40	1.42	25.2	13.18	23.224	63.09
50	2.04	28.7	13.07	23.83	61.40
60	2.34	30.4	13.19	25.13	69.70
70	2.66	31.9	12.97	25.06	69.58
81	3.11	34.00	13.03	24.17	65.03
90	3.52	35.8	13.15	23.80	68.08
102	4.04	38.00	12.96	24.33	61.93
117	4.63	40.4	12.99	22.50	63.42
		Average	13.06	24.00	65.28
		Av. dose diff	-0.03	-2.19	-0.21
		St. Dev	0.09	0.88	3.38

Comparison of Depth Dose curve in Rhizophora spp particleboard and Solid water Phantom

This test was conducted to evaluate the performance of Rhizophora spp phantom with commercial solid water phantom. The evaluation was performed by comparing PDD of Rhizophora spp phantom with a solid water phantom. The XRQA film was irradiated, as shown in figure 2, and the PDD curve was plotted, as shown in figure 4. Both curves show a similar trend for Rhizophora spp. particleboard and water phantom; initial dose was increased and gradually dropped after reaching the maximum dose.

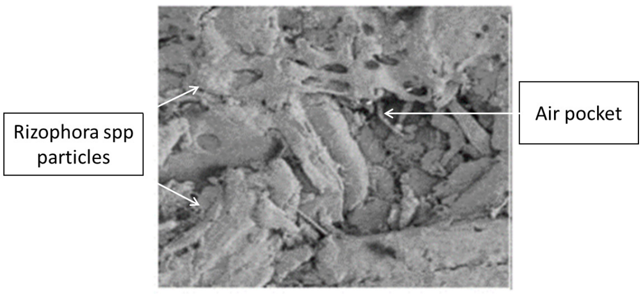

Figure 4: Graph of absorbed dose against length in Gafchromic XRQA2 film

DISCUSSION

Physical properties of Rhizophora spp. particleboard

The average moisture content calculated for this study is 6.09% (Table II). The calculation of the mass of wood used to produce the particleboard phantom is shown in equation 1 (3) and the density of the particleboard was calculated using equation 3.

Table II: Table of percentage moisture content in wood

Reading	Mass of wood (g)	Moisture content (%)
1	0.125	6.35
2	0.125	5.56
3	0.125	6.35
Average	0.125	6.09

m_w=(21 x 21 x 0.5) x (1+ 6.09%)

m_w=233.93 g

where, m_w, mc_w,and vp are mass of wood, percentage of moisture content, and volume of fabricated particleboard respectively.

$$\rho = \frac{m}{v} \qquad \text{(eq. 3)}$$

$$\rho = \frac{4000 \text{ g}}{0.5 \text{ cm x } 20 \text{ x } 20 \text{ cm x } 20 \text{ cm}}$$

ρ = 1.00 g.cm^{-3}

where, ρ, m, and v, are density of the particleboard, mass of the particleboard, and volume of the particleboard respectively. Density calculated in equation 3 verified the density as targeted (1.0 g.cm-3).

Gafchromic XRQA2 film calibration curve

Figure 3 shows a directly proportional relation between OD and dose of XRQA2 from 10 - 200 mGy as R2 value was closer to 1. As the dose increased, the OD value was also observed to increase. The region of 0 - 10 mGy is known as the insensitive part of XRQA2, where OD of the film does not correlate with the amount of dose. After 200 mGy, the OD of XRQA2 film was observed to be saturated with an increment of dose (9). This saturation point shows that the XRQA 2 film responded to the radiation increase until the threshold response was reached, and became saturated. Both regions contributed to the reduction of the R2 value of the XRQA 0-250 mGy curve.

Energy-dependent of Gafchromic XRQA 2 film

Generally, the response of the XRQA2 film is independent of the effect of energy because it can reproduce the same dose at different diagnostic energy range (9). The average dose difference and standard deviation data also reported a small dose of uncertainty (approx. 2 mGy).

Comparison of Depth Dose curve in Rhizophora spp particleboard and Solid water Phantom

In Rhizophora spp particleboard after reaching the dmax (depth 4 cm to 12 cm), the agreement with commercial solid water was observed to loosen as shown in figure 4. A possible explanation could be due to the presence of the incomplete binding of the fabricated phantom which allowed the contribution of air pockets. In this region, PDD error as high as 25% was observed. Air pockets in the Rhizophora spp particleboard were suspected as the reasons for PPD error in this region. These air pockets are illustrated in figure 5, where the arrangement of the Rhizophora spp particles developed interspacing air pockets, which caused an error due to dose perturbation effect in dosimetry and irradiation condition of PDD (11). Furthermore, the amount of backscatter radiations that contributed to the dose were also reduced at depth 4 to 12 cm. (12). In the future, the interspacing filling materials can be suggested to reduce this effect so it can provide comparable data with commercial solid water phantom.

CONCLUSION

This study was designed to determine the characteristics of fabricated Rhizophora spp. particleboard with 210 μm particle size and 1 gcm^(-3) target density. The results of this study indicates the possibility of manufacturing cost-effective water equivalent phantom using binder-less particleboard from Rhizophora spp. wood. The particleboard has been evaluated using Gafchromic film, XRQA2. The results show that Rhizophora spp. particleboard is a potential water equivalent material for general x-ray dosimetry. However, this study also found some limitations of Rhizophora spp. Particleboard thus, improvements in future studies are suggested. Interspacing air pockets caused limitations in the particleboards. Therefore, smaller interspacing particles should be considered to elevate the potential of Rhizophora spp particle boards as water equivalent materials.

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