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Evaluation of image quality and recovery coefficient of corn starch-bonded *Rhizophora* spp. particleboards as phantom for SPECT/CT imaging

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Abstract. The aim of this study was to evaluate the performance of corn starch-bonded *Rhizophora* spp. particleboards as phantom for SPECT/CT including the image contrast, source dimension ratio and recovery coefficient values. Phantom set made of the *Rhizophora* spp. particleboards was constructed according to the Jaszczak phantom commonly used in SPECT/CT with external dimension of 22 and 18 cm diameter and length respectively. Cylindrical vials with different diameter sizes filled with ^{99m}Tc unsealed source were inserted in drilled holes of the constructed particleboards phantom. The particleboards phantom was scanned by using SPECT/CT scanning mode and the SPECT images were reconstructed using clinical protocol. The results showed that the contrast value, source dimension ratio and recovery coefficient of *Rhizophora* spp. particleboards in good agreement with Jaszczak phantom. The overall results showed an excellent agreement of performance between corn starch-bonded *Rhizophora* spp. particleboards to the Jaszczak (water) as standard phantom material. The overall results indicated that the corn starch-bonded *Rhizophora* spp. can be highly recommended to be used as tissue-equivalent phantom material for Quality Assurance and dosimetry works in SPECT/CT imaging.

1. Introduction

Nuclear medicine images are formed based on the localization of radionuclide in the target organ. The reconstruction of tomographic images by detecting the gamma energies around the patient body using the gamma camera is known as single photon emission computed tomography (SPECT). The hybrid between SPECT and computed tomography (CT) known as SPECT/CT system increased the sensitivity and specificity of nuclear medicine studies.

Water has been used as standard tissue equivalent material had been widely used as phantom for dosimetric studies and quality control (QC) involving ionizing radiations [1]. Several solid-type materials made of water equivalent such as acrylic and Perspex® had been introduced as phantom material to replace water in many diagnostic imaging procedures but still failed to give accurate dosimetry in comparison to water and soft tissues.

Previous studies indicated the suitability of particleboards made of *Rhizophora* spp. as phantoms in many applications in medical physics [2-4]. However, there is a limited data on the potential of the



Rhizophora spp. particleboards for *in-vivo* detection of ionizing radiations such as in the nuclear imaging [5]. Therefore, this study focused on the evaluation of SPECT/CT images in the *Rhizophora* spp. particleboards in comparison to the standard phantom material.

2. Methodology

2.1. Preparation of Phantom for SPECT Imaging

A total of eighteen pieces of *Rhizophora* spp. particleboards were fabricated based on the study by Abd Hamid *et al.* [6][7]. A total of two sets of 6 cylindrical-shaped vials made of acrylic with 6 cm length and different diameters of 1.3, 1.6, 1.9, 2.5, 3.0 and 3.5 cm were constructed for the Jaszczak and the particleboards phantoms as shown in Figure 1 [7].

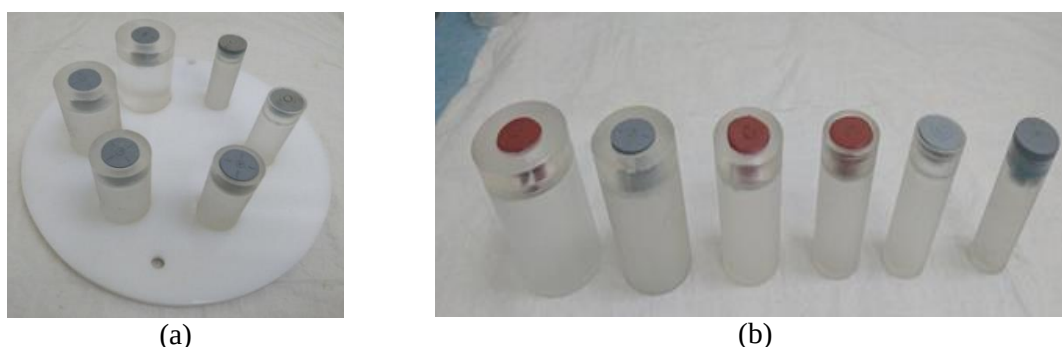


Figure 1. Two sets of constructed radionuclide vials for (a) Jaszczak phantom and (b) for corn starch-bonded *Rhizophora* spp. particleboards phantom.

A ^{99m}Tc unsealed source with approximate activity concentration of 59 200 Bq/ml was injected into vials using a syringe to prevent the presence of air bubbles. The vials containing ^{99m}Tc radionuclide were positioned in its inserts within the particleboards phantom as shown in Figure 2(a). A number of eighteen pieces of particleboards were stacked to form the cylindrical SPECT/CT phantom with the diameter of 22 cm and thickness of 18 cm. Four plastic rods were used to fix and align the particleboards together and the extended rods at the top surface of particleboard were fixed with plastic screws to minimize the air gaps between the particleboard pieces as shown in Figure 2(b). Another set of radiopharmaceutical vials were positioned in the Jaszczak phantom filled with water to simulate the attenuation of human soft tissues as shown in Figure 2(c).

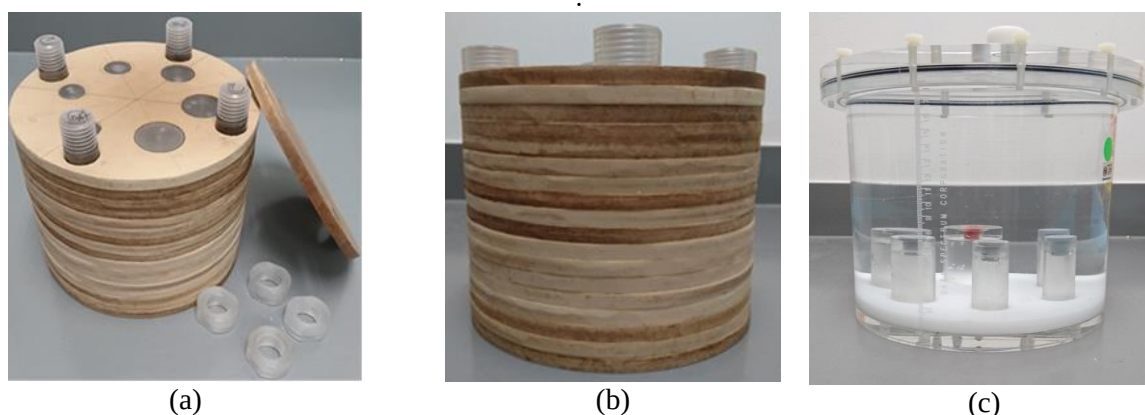


Figure 2. (a) The cylindrical vials were positioned in the inserts of the constructed corn starch-bonded *Rhizophora* spp. particleboards, (b) the 18 pieces of *Rhizophora* spp. particleboards were stacked together and (c) the Jaszczak phantom inserted with its set of radiopharmaceutical vials.

2.2 Image Quality Study of SPECT Images

The regions of interest (ROI) were drawn at the centre of the ‘hot spot’ area within the circular regions of vial on the SPECT images defined by using the CT images. Another ROI with similar size was also drawn on the background region that outside the region of vial images in the middle region of the phantom. The similar area size of ROI for each vial was used on all image slices. The image contrast of each vial was calculated by using equation [8]:

$$\text{Contrast} = \frac{C_{cyl} - C_{bgd}}{C_{bgd}} \quad (1)$$

with C_{cyl} is the average count per pixels in the cylindrical region and C_{bgd} is the average count per pixels in the background region. The apparent source dimension was evaluated by measuring the full width at half maximum from the plotted intensity profiles of radionuclide distributions.

The apparent source dimension was calculated by multiplying the measured full width half maximum (FWHM) with scale factor (mm/pixel) given by the gamma camera manufacturer as equation:

$$\text{Apparent Source Dimension, } d = FWHM \times SF \quad (2)$$

with SF is the scale factor given by the gamma camera manufacturer with the value of 4.42 mm/pixel. The ratio between the measured apparent source dimensions in the SPECT/CT image to the actual dimension given by the inner diameter of the vials containing the radionuclide was calculated by using equation:

$$\text{Ratio of source dimension} = \frac{d}{D} \quad (3)$$

with d and D is the measured apparent and actual dimension of the radionuclide respectively.

2.3 Analysis of Recovery Coefficient Values

The SPECT images of *Rhizophora* spp. particleboards and Jaszczak phantoms were reconstructed using Butterworth filter with scatter and attenuation correction applied. An ROI was drawn over the area of radionuclide distribution of each vial in the SPECT image and the average counts per pixel were measured. The activity concentration of apparent image were calculated by using following equation 3.25 [9]:

$$\text{Apparent Activity Concentration, } A_a = \frac{R_{ROI}}{S_{vol}} \times \frac{VS}{T_{acq}} \quad (4)$$

with R_{ROI} is the count per pixel (counts/pixel) in drawn ROI, VS is the voxel size with the values of $4.42 \times 4.42 \times 4.42 \text{ mm}^3$ given by the manufacturer and T_{acq} is the total scanning time (s). The actual activity of ^{99m}Tc source was calculated according radioactive decay law by using equation:

$$\text{True Activity Concentration, } A_t = A_0 e^{-\lambda t} \quad (5)$$

with A_t and A_0 is the current and initial activity of the radionuclide source (Bq) respectively, λ is decay constant of the radionuclide with the value of $3.21 \times 10^{-5} \text{ s}^{-1}$ and t is the time elapsed from the initial activity (s). Therefore, the recovery coefficient (RC) values of SPECT images of the radionuclide measured in the constructed corn starch-bonded *Rhizophora* spp. particleboards phantom was calculated by using following equation [8]:

$$\text{Recovery Coefficient, } RC = \frac{A_a}{A_t} \quad (6)$$

3. Results and Discussions

3.1 Evaluation of SPECT Image Contrast

The contrast evaluation of SPECT images of the phantoms scanned at 10 s, 20 s and 30 s per projection are illustrated in Figures 3. The images contrast of corn starch-bonded *Rhizophora* spp. particleboards shows a consistency to the contrast of images by Jaszczak phantom at 10 s, 20 s and 30 s scan time per projection.

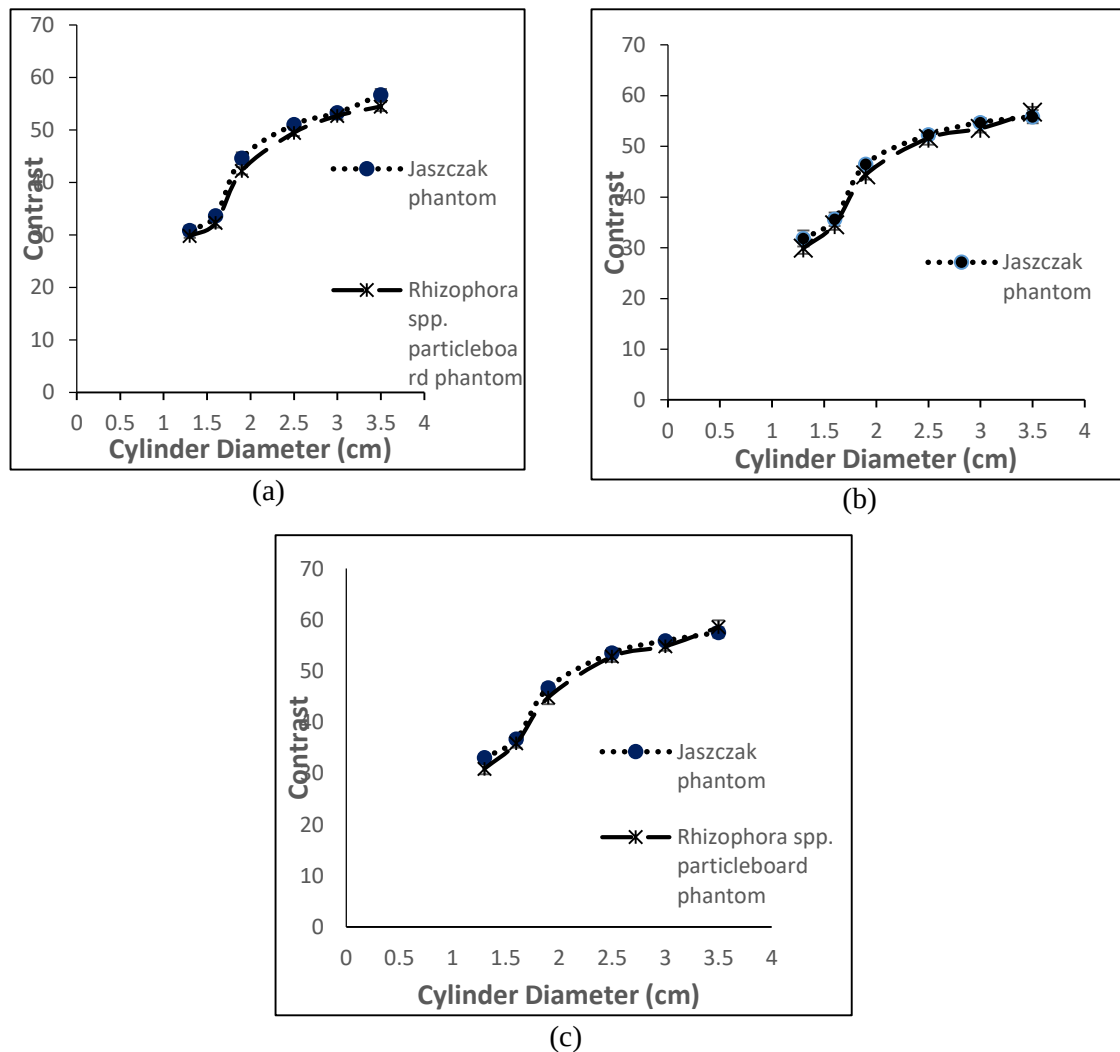


Figure 3. The contrast of the SPECT images for corn starch-bonded *Rhizophora* spp. particleboards in comparison to Jaszczak phantom at (a) 10 s/projection, (b) 20 s/projection and, (c) 30 s/projection of time setting.

The p -values obtained from paired sample t -test for pair of Jaszczak – *Rhizophora* spp. particleboards phantom as shown in Table 1. There are no significant difference between image contrast of Jaszczak phantom and corn starch-bonded *Rhizophora* spp. particleboards scanned at 20 s and 30 s time per projection shown by the p -values 0.079 and 0.113 respectively.

Table 1. The result of paired sample *t*-test for SPECT image contrast between Jaszczak phantom and corn starch-bonded *Rhizophora* spp. particleboards.

Time per projection (s)	Paired Differences		df	t	p-value (2-tailed)
	Means	St. Deviation			
10	1.537	0.697	5	5.400	0.003
20	0.978	1.090	5	2.198	0.079
30	0.755	0.965	5	1.916	0.113

3.2. Evaluation of Source Dimension Ratio

Table 2 shows the ratio of apparent diameter to actual diameter of cylinder size for corn starch-bonded *Rhizophora* spp. particleboards and Jaszczak phantom. The nearest apparent size to actual size was obtained by 2.5 cm of cylinder diameter shown by the lowest value of ratio 1.35 and 1.41 for Jaszczak phantom and *Rhizophora* spp. particleboards respectively followed by cylinder diameter with 3.0 cm. The ratio of dimension for corn starch-bonded *Rhizophora* spp. particleboards was in agreement to values of Jaszczak phantom within 4.44% of percentage differences.

Table 2. The ratio apparent to actual source dimension for each cylinder diameter for corn starch-bonded *Rhizophora* spp. particleboards and Jaszczak phantoms.

Cylinder Diameter (cm)	Jaszczak Phantom	<i>Rhizophora</i> spp. Particleboards	Difference ($\pm$ %)
1.3	2.05	2.11	2.93
1.6	1.68	1.74	3.57
1.9	1.49	1.54	3.36
2.5	1.35	1.41	4.44
3.0	1.38	1.42	2.90
3.5	1.51	1.51	0

3.3. Evaluation of Recovery Coefficient

The recovery coefficient (RC) is the ratio of the apparent activity concentration to the true activity concentration of a region of interest. The similar pattern of RC curves can be observed for Jaszczak phantom and *Rhizophora* spp. particleboards as illustrated in Figure 4. The result showed the rapidly improvement of RC to the value of 1.0 at increasing diameter of cylinder between 1.3 and 2.5 cm. The RC of the SPECT images at cylindrical diameter sizes of 2.5, 3.0 and 3.5 cm on the other hand were greater than 1.0 for both phantoms. The ideal value of RC would be close to 1.0 [10]. In some situation, RC values can be greater than 1.0 due to spill-over effect or spill-in effect. Spill-over effect occurred due to contamination of activity from the neighbouring tissue or spot to these hot areas [8].

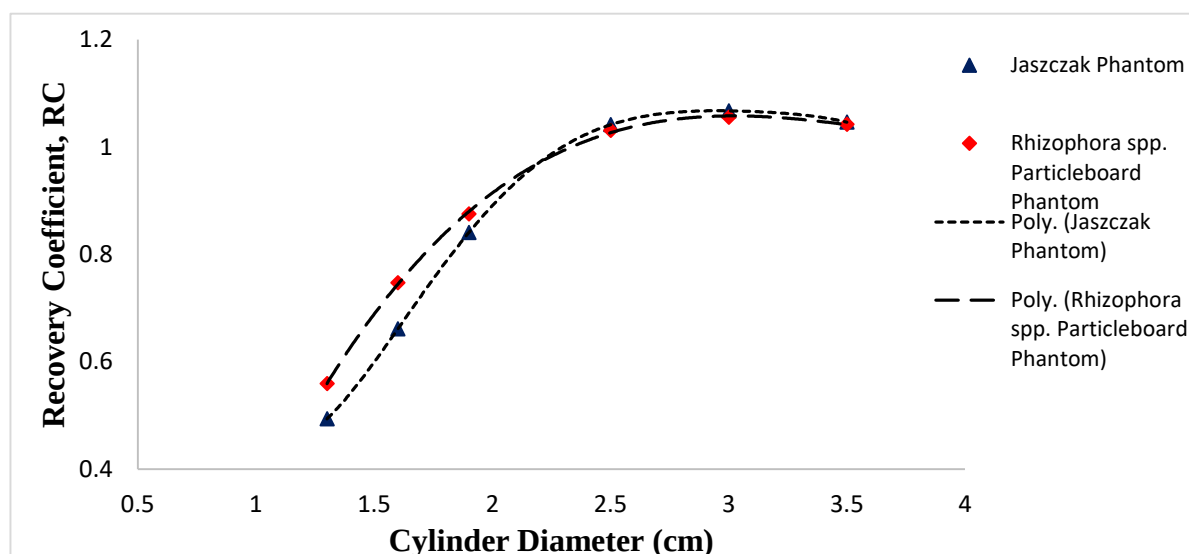


Figure 4. The recovery coefficient curves of Jaszczak and *Rhizophora* spp. particleboard phantoms at different diameter of radionuclide vial sizes.

4. Conclusion

The contrast values of SPECT image by the corn starch-bonded *Rhizophora* spp. particleboards were consistent with the Jaszczak phantom. The calculation of ratio between apparent and actual source dimension for corn starch-bonded *Rhizophora* spp. particleboards were consistent to the Jaszczak phantom. The evaluation of RC show an excellent agreement of RC curves between corn starch-bonded *Rhizophora* spp. particleboards to Jaszczak phantom with RC values close to ideal values of 1.0. The RC curve of the corn starch-bonded *Rhizophora* spp. particleboards was also consistent to the Jaszczak phantom. The overall results indicated that the corn starch-bonded *Rhizophora* spp. can be highly recommended to be used as new phantom material for Quality Assurance and dosimetry works in SPECT/CT. imaging.

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