TO STUDY THE DURIAN SEED AS A NEW SUBSTRATE FOR BOLUS IN RADIOTHERAPY

[1]FAIRUZDZAH AHMAD LOTHFY, [2]ISKANDAR SHAHRIM MUSTAFA, [3]ZARY SHARIMAN YAHYA, [4]SITI ATIKAH ISHAK, [5]NORFATAHA MOHD DAUD

[1,2,3,4,5]Universiti Sains Malaysia, Universiti Teknologi Mara
E-mail: azza_840609@yahoo.com, iskandarshah@usm.my, zary@usm.my, sitiatiqah.ishak@gmail.com, nfataha@usm.my

Abstract- Bolus which have tissues characteristics properties is used for equate the irregular patient contour and increasing the skin dose of patient. Durian seed gum is an organic substance used as new material for fabricating the bolus in radiotherapy. The durian seed gum was blended with polyvinyl alcohol, glycerol and formalin in order to prepare the bolus. The major objective of this study was to assess the feasibility of using durian seed gum as a bolus in radiotherapy and evaluate the dosimetric properties such as mass density, relative electron density, and transmission factors by using Computed tomography and linear accelerator. Evaluation of the results assessed showed that the dosimetric properties of fabricated bolus have a good similarity to water. Referring to the results of this study and other properties such as flexibility and harmlessness, it is proposed that durian seed gum is a suitable substance to be used as bolus in radiotherapy.

Keywords- Bolus, Durian seed gum, Dosimetric properties, Radiotherapy.

I. INTRODUCTION

In radiotherapy, with megavoltage photon, such as gamma rays or x-rays causes DNA devastation of cell in target area. The most familiar radiation treatment used is external radiation from the machine outside out f the patient's body such as a linear accelerator [1]. By destroying the genetic material that controls how the cells develop and divide, the radiation is able to trigger cell injury and devastation. By using the higher energy radiation, both healthy and malignant cells are destructed [2].

Megavoltage photon radiotherapy penetrates the skin to irradiate deep-seated tumors, with skin-sparing property. Consequently, one must be a layer of scattering material to act as the skin surface as purpose to treat superficial lesions. Hence, bolus are used in order to deliver the full prescribed dose to the skin surface and underlying tissue [3]. Others, bolus is applied to the surface of a patient for purpose to compensate irregular patient contour, negating skin sparing, and extra attenuating.

Bolus is a soft and resilient material with tissue-equivalent properties which is used in direct contact to patient skin [4]. Bolus is position closely to human contact to correct the distribution of absorbed dose in radiotherapy. The standard bolus should not sag during treatment. Basically, bolus should have good plasticity, flexibility, and adhesion to a living body besides free from air bubble [5], [6].

Durio zibethinus, commonly called as 'Durian' is favorable tropical fruit in some Asean countries. Fruit Crop Statictic 2012 inform that the durian is the main fruit which plant in Malaysia [7]. Durian seed consist roughly 20% to 25% of the total fruit mass [8]. The biopolymer from durian seed consist of a heteropolysaccharide-protein structure [9]. Natural biopolymer from plant sources provide variety of functional properties and has more advantages rather than synthetic polymer. It is due to biocompatibility, non-toxic, and inexpensive [10].

The aim of this work is to study and investigate the durian seed as a new substrate for bolus in radiotherapy. By using the Durio zibethinus seed which is natural biopolymer, it can replace the current material used as bolus. Eventually, it will reduce the cost of producing the bolus at mass production. Others, the natural organic polymers will preserve the petrochemical resources and reducing environmental impact.

II. METHODS AND MATERIALS

The process for producing the bolus starts with weighting the 70g of purified durian seed gum and 30g of PVA. Subsequently, 200ml of distilled water was added into PVA and stirred for three hours at 900 C. Promptly, 10ml glycerol and 10ml formalin was gradually added into the prepared PVA solution. Next, the mixtures were heated for 4 hours. It is followed by mixing the mixtures into 70g durian seed gum. As a purpose to remove access bubbles, all the prepared mixtures were heated the in a vacuum oven at 600 C, more than-25mmH for half an hour. In the subsequent stage, the blended durian seed gum/PVA is casted in glass plate. The dimension of prepared sample was 4cmx4cmx0.5cm. Finally the samples were irradiated with electron beam with dosage of 25kGy. The mass

density, relative electron density, and transmission factors were then assessed for fabricated bolus.

A. Mass density and Relative electron density

To measure the mass density and relative electron density of the sample, it was calculated based on Computer Tomography (CT) numbers acquired from the computed tomography images of the sample (by Siemens Somatom Definition AS+ CT Scanner Siemens Healthcare Germany - 128 slice) under various protocols and electron density phantom. Starting with setting for the tissue characterization phantom such that the internal computer tomography laser passed through the centre of the phantom. The exposure was performed by using Table 1 protocols with 5-mm slice thickness used.

At the next stage, arrange all the samples and take the reading for five times for each protocol. Henceforth, the calibration curve were plotted which are the mean of CT number value was plotted against the density of the tissue insert and mean of CT number value was plotted against the relative electron density of the tissue insert [11]. Densities of water and the sample of durian seed bolus were calculated using the plotted graph.

Table 1: Protocols used for computer tomography images were acquired as a guide to develop calibration curve

Protocol	kV	140	120	120	120	100	80	80	80
	mA	448	232	290	448	448	232	290	448

Table 2: Tissues density obtained from tissue electron density phantom.

Materials	Physical densities (gcm^{-3})	Relative electron densities
Dense bone 800 mg/ml HA	1.610	1.512
Lung (inhale)	0.200	0.190
Breast	0.990	0.976
Trabecular bone	1.160	1.117
Muscle	1.060	1.043
Lung (exhale)	0.500	0.489
Liver	1.070	1.052
Adipose	0.970	0.952

B. Transmission factor

Commence with calibrate EBT3 film irradiated with energy at 6MV at a different dose value which are 50MU, 100MU, 150MU, 200MU, and 250MU. The field size and Source Image Distance (SID) calibration setup used are 10cm x 10cm and 100cm, respectively. EBT3 film size use for calibration procedure is are 3cm x 3cm. The film was positioned at 15 mm depth of the slab phantom. The film was change optical density for every MU, monitoring unit given. After that, all the film was scanned in red mode (48 bit RGB) at a scanning resolution of 400 dpi in transmission mode.

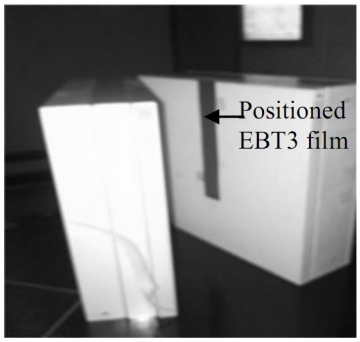
Where $PV_{unirradiated}$ = mean pixel value of unirradiated film, and $PV_{after\ irradiation}$ = mean pixel value of film after irradiation [12]

Calculate dose by using (2).

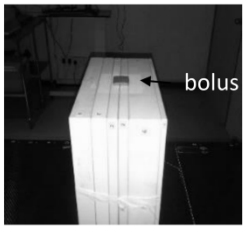
$$Calculated\ dose = \frac{MU\ x \frac{depth\ dose}{100}}{FSCF} \quad (2)$$

Where FSCF is the field size correction factor found from the physics beam data, and MU is monitoring unit [12].

After that, the calibration curve which is calculated doses(cGy) versus Net Optical Density was plotted [12]. Next, EBT3 film with dimension area 3cm x 10cm is positioned on the slab surface such as in fig. 1 (a). Bolus sample was placed on slab phantom fig. 1 (b). The exposure about 200MU was given for the bolus. The exposures were repeated without sample and using commercial bolus.



(a)



(b)

Fig 1: (a) EBT3 film 3cm x 10cm pasted between slab phantom and (b) bolus sample place on the slab phantom

III. RESULTS AND DISCUSSION

Density (gcm-3) is a very significant to discriminate property of tissue especially in lung tissue, bone, fat, and linear attenuation coefficient, μ, tracks linearly with density [13]. To achieve tissue-equivalent properties, a density can be obtained to water. Thus,

for instance, the density of bolus material can be about 1gcm-3. The mass density of created bolus calculated from eight Computer Tomography scan protocols which had different kV and mA, are shown in Table 1 along with the results obtained from the calibration curve. Densities are calculated in term of Housefield units (HU), then the density of all created bolus was measured. The kVp and mA chosen should be the typical values used in scanning protocols for radiotherapy patients.

The calibration curve created by referring to the electron density phantom which excluded density value of water as fig 2. Density value of water is used as purpose to compare with created bolus density with different protocols.

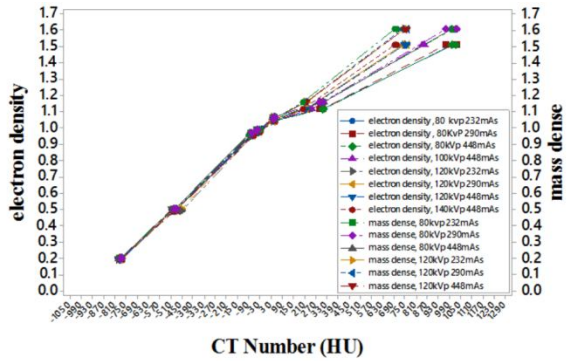


Fig 2: Calibration curve for relative electron density versus HU unit and mass density versus HU unit created from data obtained from tissue characteristics phantom.

Table 3: Density of water and bolus for different imaging protocol.

kVp	mA	Mass density water	Mass density fabricated bolus
80	448	1.00367 ± 0.00197	1.00375 ± 0.010061
80	290	1.00200 ± 0.00190	1.00429 ± 0.00535
80	232	1.00267 ± 0.00175	1.00429 ± 0.00535
100	448	1.00400 ± 0.00089	1.00429 ± 0.00535
120	448	1.00400 ± 0.00089	1.00857 ± 0.00378
120	290	1.00400 ± 0.00110	1.00500 ± 0.00756
120	232	1.00267 ± 0.00175	1.00375 ± 0.00518
140	448	1.00317 ± 0.00075	1.00250 ± 0.00463

```
Two-sample T for Water vs Bolus

             N      Mean     StDev  SE Mean
Water        8  1.003439  0.000760  0.00027
Bolus        8   1.00455   0.00177  0.00063


Difference = mu (Water) - mu (Bolus)
Estimate for difference:  -0.001116
95% CI for difference:  (-0.002660, 0.000428)
T-Test of difference = 0 (vs not =): T-Value = -1.64
P-Value = 0.136  DF = 9
```

Fig 3: Two-sample T test results for comparison density of bolus and water.

From fig 3, the mean density value for bolus is 1.00455 ± 0.00117 gcm-3. P-value of bolus is greater than commonly chosen a-levels, which are 0.136 there is no significant difference between these types of bolus with water. The calibration curve created by referring to tissue characteristics phantom which excluded relative electron density value of water. The relative electron density value of water is used as purpose to compare with created bolus relative electron density at different protocols.

Table 4: Relative electron density of water and bolus for different imaging protocol.

kVp	mA	Relative electron density of water	Relative electron density of fabricated bolus
80	448	1.00117 ± 0.00075	1.00000 ± 0.00577
80	290	1.00083 ± 0.00098	1.00429 ± 0.00535
80	232	1.00133 ± 0.00082	1.00000 ± 0.00816
100	448	1.00150 ± 0.00043	1.00714 ± 0.00756
120	448	1.00100 ± 0.00089	1.00000 ± 0.00900
120	290	1.00233 ± 0.00103	1.00143 ± 0.00900
120	232	1.00133 ± 0.00121	0.99714 ± 0.00488
140	448	1.00150 ± 0.00105	1.00286 ± 0.00488

```
Two-sample T for water. vs Bolus

             N      Mean     StDev  SE Mean
water.       8  1.001374  0.000452  0.00016
Bolus        8   1.00161   0.00310   0.0011


Difference = mu (water.) - mu (Bolus )
Estimate for difference:  -0.00023
95% CI for difference:  (-0.00285, 0.00238)
T-Test of difference = 0 (vs not =): T-Value =-0.21
P-Value = 0.839  DF = 7
```

Fig 4: Two-sample T test comparison relative electron densities for bolus and water.

From fig 4 indicate that the mean relative electron density value for bolus is 1.00161 ± 0.00310 gcm-3 P-value of bolus greater than commonly chosen a-levels, which are 0.839 . There is no significant difference between these types of bolus with water.

The measurement transmission factor of photons produced from linear accelerator in a phantom are of great importance in the field of radiotherapy. The transmission probability for a gamma ray through any material is characterized by its linear attenuation coefficient, μ which depend on the photon energy, the atomic number of the material (tissue) through which it passes, and tissue density [14].

The calibration curve was created from different doses which had different MU, are illustrated in fig 5. Depth dose are calculated in term of cGy which obtained from calibration curve, are shown as mean value plus/minus standard deviation of two measurements.

Fig 6 shows the graph illustrating that the commercial bolus and all types of created bolus at 5mm causes a shift of 5mm. This maximum value of depth dose is achieved for the depth of 10mm, then the curve

decrease rapidly. One of the purposes of using bolus is to adjust the isodose curves closer to the patient's skin, delivering more dose closer to the surface. The shifted occurred about 5mm, gives a good agreement of using bolus during treatment [15]

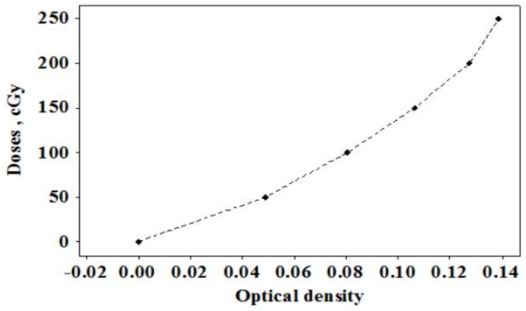


Fig 5: The dose plotted as a function of net optical density.

The transmission factors which were calculated for fabricated bolus with the standard bolus taken from Pantai Hospital, Penang at energy 6MV by using linear accelerator were similar. Fig 7 shows that p-value for standard bolus and bolus is 0.762. Its can conclude that, no significant difference in transmission values between all created bolus and standard bolus.

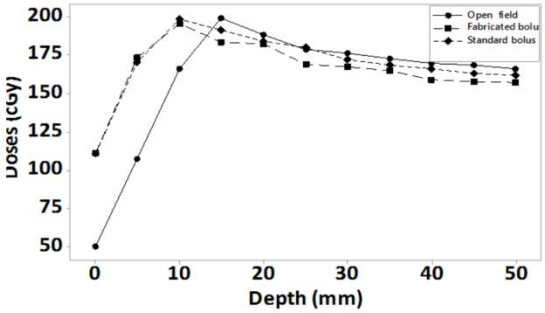


Fig 6: Three efficiencies curves as a function of depth of penetration of gamma ray for the source of 6 MeV for fabricated bolus, standard bolus and open field.

```
Two-sample T for Depth dose at 10mm

Sample            N     Mean   St Dev  SE Mean
Bolus 3:7         2  199.500   0.707     0.50
Standard bolus    2   198.50    3.54      2.5


Difference = mu (Bolus 3:7) - mu (Standard bolus)
Estimate for difference:  1.00
95% CI for difference:  (-31.39, 33.39)
T-Test of difference = 0 (vs not =): T-Value = 0.39 P-Value
= 0.762  DF = 1
```

Fig 7: Two-Sample T test results by comparing standard bolus with bolus.

REFERENCES

[1] J. P. Kirkpatrick, F. R. Demehri, S. E. Johnston, A. M. Stalnecker, and T. M. Cooney, "Bolus Materials For Radiation Therapy And Methods of Making And Using The Same," 29-Oct-2007.

[2] S. American Cancer, "The Science Behind Radiation Therapy," 2014. [Online]. Available: http://www.cancer.org/acs/groups/cid/documents/webcontent/003019-pdf.pdf. [Accessed: 23-Jan-2015].

[3] V. Vyas, L. Palmer, R. Mudge, R. Jiang, A. Fleck, B. Schaly, E. Osei, and P. Charland, "On bolus for megavoltage photon and electron radiation therapy.," Med. Dosim., vol. 38, pp. 268–73, Jan. 2013.

[4] A. Montaseri, M. Alinaghizadeh, and S. R. Mahdavi, "Physical Properties of Ethyl Methacrylate as a Bolus in Radiotherapy," vol. 9, no. 2, pp. 127–134, 2012.

[5] T. Cooney and S. Johnston, "Development of a Novel Bolus Material," 2006.

[6] S. Izeki, K. Hatakeyama, F. Ebihara, Y. Koga, and all of K. (JP), "Bolus for radiotherapy," US 6,231858 B1, 14-Jul-1999.

[7] M. Agriculture Department, "Perangkaan Tanaman Buah-Buahan Fruit Crop Statistics," 2012.

[8] B. T. Amid, H. Mirhosseini, and S. Kostadinovi¿, "Chemical composition and molecular structure of polysaccharide-protein biopolymer from Durio zibethinus seed: extraction and purification process," Chemistry Central Journal, vol. 6, no. 1. p. 117, 2012.

[9] B. T. Amid and H. Mirhosseini, "Effect of different purification techniques on the characteristics of heteropolysaccharide-protein biopolymer from durian (Durio zibethinus) seed.," Molecules, vol. 17, no. 9, pp. 10875–92, Jan. 2012.

[10] N. S.B and N. N.H.N.T, "Determination of Suitability of Durian (Durio Zebethinus) Seed Gum Extract in Replacing of Xantan Gum in Fruit Nectar," Int. J. Sci. Eng. Res., vol. 2, no. 1, pp. 2347–3878, 2014.

[11] C. B. Saw, A. Loper, K. Komanduri, T. Combine, S. Huq, and C. Scicutella, "Determination of CT-to-density conversion relationship for image-based treatment planning systems.," Med. Dosim., vol. 30, no. 3, pp. 145–8, Jan. 2005.

[12] G. Sim, J. Wong, and K. Ng, "The use of radiochromic EBT2 film for the quality assurance and dosimetric verification of 3D conformal radiotherapy using Microtek ScanMaker 9800XL flatbed scanner," Journal of Applied Clinical Medical Physics, vol. 14, no. 4. 08-Jul-2013.

[13] J. T. Bushberg, J. A. Seibert, E. M. Leidholdt, and J. J. M. Boone, The Essential Physics of Medical Imaging. USA: Lippincott Williams & Wilkins, 2002, p. 933. [14] R. N. Bryan, Introduction to the Science of Medical Imaging, vol. 19. United State of America: Cambridge University Press, 2009, p. 326.

[15] J. C. Bryan, Introduction to Nuclear Science, Second Edition. United State: CRC Press Taylor & Francis Group, 2013, p. 420.

★★★