© 2019 IJSRSET | Volume 6 | Issue 3 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology
DOI : https://doi.org/10.32628/IJSRSET196325

Manufacture and Determination of Absorbent in Bolus Radiotherapy Based On Alginate Using of 8 MeV and 10 MeV Energy

Hendra Tampubolon*, Kerista Tarigan, Timbangen Sembiring
Department of Physics, University of Sumatera Utara, Medan, Sumatera Utara, Indonesia

ABSTRACT

Bolus radiotherapy have been created by using material of mixture a silicone rubber as matrix and alginate powder as a filler through chemical solution deposition methods with variation of composition silicone rubber : alginate powder : catalyst (99 : 0 : 1)%wt, (80 : 19: 1)%wt, (80 : 18 : 2)%wt, (80 : 17: 3)%wt, (80 : 16 : 4)%wt and (80 : 15 : 5)%wt. The sample fabrication was done in two steps. The first step of alginate powder is mixed with a solution of rubber and catalyst silicon until homogeneous for 5 minutes with the wet mixing method. The second step of the powder which was homogeneously mixed was printed with glass mould measuring 11 x 11 x 1 cm^3 with variations in thickness of 5 mm, 10 mm and 15 mm then dried at 30^0. Each bolus sample is already to be characterized which includes: physical properties (density, porosity, and water absorption), mechanical properties (tensile strength, elongation and modulus young) and performance (CT Number and absorbency dose). The characterization results showed that alginate powder: optimum rubber silicon ie (80: 19) wt% at a thickness of 15 mm resulted in a density value of 2.091 x 10^3 kg/m^3, porosity of 9.82% and water absorption of 1.66%. Mechanical properties with tensile strength 3.37 MPa, elongation at 45.28% and modulus of elasticity of 0.816 MPa. Bolus radiotherapy performance properties relative electron density (RED) values or CT numbers of 1.25 resulted in surface absorbance doses of 8 MeV of 101% and 10 MeV of 108.01%. The results of bolus radiotherapy based on composite alginate powder reinforced by silicone rubber can be applied as a cancer therapy material to replace bolus from wax, and paraffin.

Keywords: Alginate, Bolus, Radiotherapy Absorption Dosage, Silicone Rubber

I. INTRODUCTION

Linear accelerator (Linac) is a radiotherapy device that consists of a number of discrete components that function to accelerate high-energy electrons by using RF waves before electrons reach the target to produce X-rays. Now linear accelerators can produce two differences of energis namely X-rays and electrons[22]. The most widely used electron energy circuit for clinical purposes is 20 MeV. In general, electron beam is used in the treatment of superficial cancer (depth <5cm)[15].

The American Association of Physicists in Medicine TG 25 recommends that the electron beam parameters consist of energy, the size of the radiation field and bolus chosen so that the target volume covers 90% of the prescribed dose. At present, skin cancer treatment is generally done by radiotherapy using a linear accelerator (Linac) using electron beams. In superficial cancer treatment using a linear accelerator component there is a possibility that electrons will hit normal tissue. Therefore a bolus-type material is needed as a radiation shield. Bolus is an equivalent body tissue material placed on the surface of the skin outside the irregular contour of the patient and thus provides a flat surface for radiation treatments[24].

Bolus material used in radiation therapy aim to manipulate doses in the tissue. Bolus material is also used to increase the dose in the skin in electron beam use[26]. Paraffin wax can be considered equivalent to body tissue and bolus paraffin is generally widely used in radiotherapy. However, activities in making paraffin bolus consist of several stages, making irregular surface molds in radiation treatment, making molds and heating paraffin wax into liquid can be time of consumses in the process[11]. In some hospitals in Indonesia the raw material that is generally utilized in making bolus radiotherapy is melamine. Melamine is an ingredient that easily changes its elasticity due to changes in temperature, the form of bolus made from melamine is easily changed if pressed and does not return to normal if pressed[12]. However, there are still air bubbles on the surface of the sample, where air bubbles produce empty space that affects sample density and when tensile strength testing is carried out, the sample does not receive the same tensile force.

Therefore, in this study a bolus radiotherapy will be carried out using a mixture of polydimethyl siloxane, catalyst and alginate (99 : 0 : 1)%wt, (80 : 19 : 1)%wt (80 : 18 : 2)%wt, (80 : 17 : 3)%wt, (80 : 16 : 4)%wt and (80 : 15 : 5)%wt also with bolus thickness of 5 mm, 10 mm and 15 mm. The mixture of polydimethyl siloxane, alginate and catalyst is expected to fill the empty bolus made from PDMS so that it has been more even density. Bolus will be analyzed using a CT scan to be able to determine the relative electron density (RED) values to match physical and mechanical properties, absorbency dose analysis using electrons 8 MeV and 10 MeV.

II. METHODS AND MATERIAL

A. Equipment and Materials Research

The equipments used are spatula, beaker glass, oven, caliper, digital balance, mould sample from acrylic, Universal Testing Machine, and linear accelerator (Linac) Siemens Primus brand, solid water phantom, computed tomography scanner (CT scanner) and chamber plan parallel. The material used is alginate, silicone rubber RTV 52 and bluesil catalist 60R

B. Research Variables

Research variables on the manufacture of bolus materials include raw material composition and characterization.

TABLE I
PERCENTAGE OF BOLUS BASED ON ALGINATE POWDER REINFORCED SILICONE RUBBER

Sample Code	Silicone Rubber (%wt)	Alginate (%wt)	Catalist (%wt)
A	99	0	1
B	80	19	1
C	80	18	2
D	80	17	3
E	80	16	4
F	80	15	5

As for the characterization of bolus materials include : physical properties (density, porosity, and water absorption), mechanical properties (tensile strength, modulus of elasticity and elongation break) and performance properties (absorbency dose, and relative electron density).

C. Research Procedures

- **Manufacture of Bolus Radiotherapy**

The raw material prepared in the form of liquid for silicone rubber type RTV52 as a matrix (adhesive), alginate powder as filler and 60R bluesil catalist was weighed beforehand with variations in composition with a system of complete random design seen in Table 1. Alginate powder mixed by silicone rubber then added 60R bluesil catalyst as a hardener using chemical solution deposition method which then stirred until homogeneous for 3 minutes using a mixer in beaker glass. After the ingredients are evenly mixed then the ingredients are poured into a glass mold that has been smeared with vaseline so that the dried sample is easy to remove with a mold size (11 x 11 x 1) cm. Then the sample is allowed to dry for 5 - 7 hours in the oven at 30°C. The sample has been removed from the mold using a small spatula and the sides are trimmed. The same has done with variations in the composition and thickness of the bolus radiotherapy which differed from 5 mm, 10 mm and 15 mm. Characterized bolus samples include physical properties and mechanical properties. And also the performance of bolus samples by analyzing absorbed doses using 8 MeV and 10 MeV energy and tomographic images were taken by using CT Scan to obtain CT-Number values to be able in analyzing relative electron density (RED).

III. RESULTS AND DISCUSSION

Bolus is a composite material that functions as a radiotherapy medium made of material that is equivalent to body tissue placed directly above the skin surface during the radiotherapy radiation process. In general, the bolus radiotherapy used is a hard bolus that comes from wax while the soft bolus comes from modified latex and paraffin material which is still has disadvantages including not durable in the condition of air conditioned rooms, more rigid and has a lot of porosity so that the dosage absorbed low[8]. Bolus based on composite alginate powder/silicone rubber a more elastic, dense and ecofriendly absorbent for X-ray therapy has been made using chemical solution deposition techniques.

A. Characterization of Physical Properties

- **Density**

Density is the mass measurement of each unit of material volume. It was performed by using Archimedes method by immersing the test sample into beaker glass for 24 hours and measured dry mass and wet mass[7].

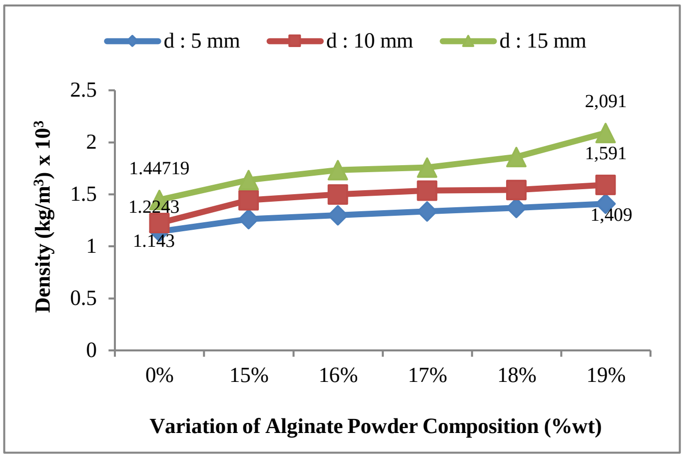

Figure 1 : Test result density of bolus radiotherapy based alginate/silicone rubber on various variations composition and thickness

Figure 1 shows that the increased density value is proportional to the addition of alginate powder composition. This is shown from the results of the research that the optimum condition of bolus radiotherapy was obtained at a thickness of 15 mm with variations in the composition of silicone rubber : alginate powder : catalyst (80 : 19 : 1)% wt. This composition is able to produces a density value of 2.09 x 10^3 kg/m^3. In the theory, silicon rubber has a density of 1.25 x 10^3 kg/m^3 while the density of alginate powder has 1.60 x 10^3 kg/m^3 so that the density of the silicon rubber/alginate powder composite based on the rule of mixture for the composition of silicone rubber : alginate powder (80 : 19)%wt at 15 mm thick at 1.30 x 10^3 kg/m^3, the density value of the theory is not much different from the practical density value. This is influenced by the geometry of the sample made, the mixing process and the amount of pressure applied[12].

- **Porosity**

Porosity is the number of pores contained in the pore material, where the pores are formed due to hole or crystal defects that make up the material[13].

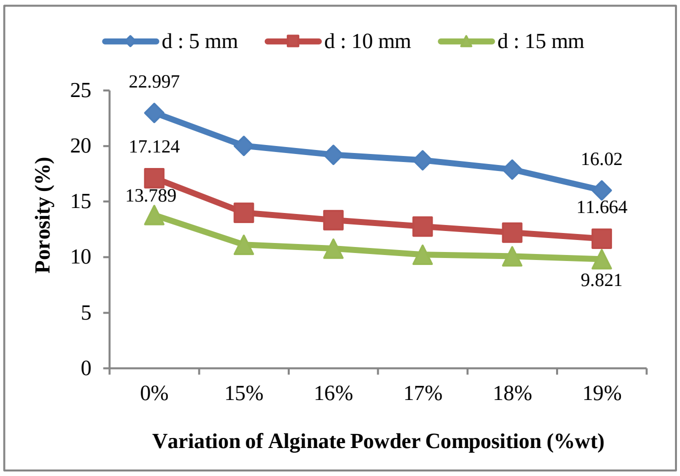

Figure 2 : Test result porosity of bolus radiotherapy based alginate/silicone rubber on various variations composition and thickness

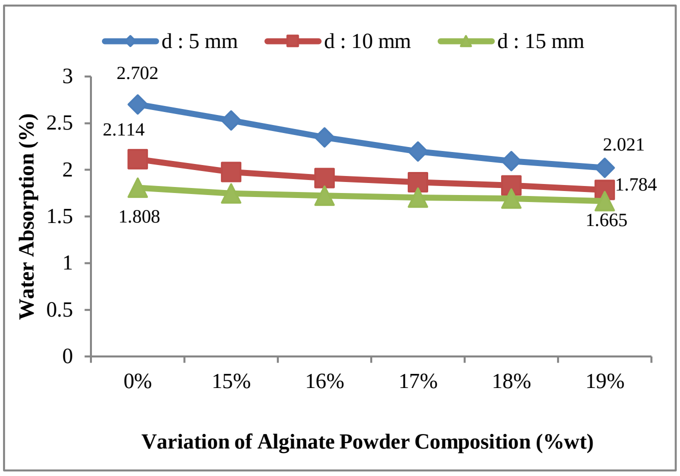

Figure 3 : Test result water absorption of bolus radiotherapy based alginate/silicone rubber on various variations composition and thickness

From the results of the observation in Figure 2, the optimum variation in the composition of the mixture has a small porosity in the composition (80: 19)% wt at 15 mm thick with porosity values ranging from 9.82%. This is due to the homogeneity of the mixture between the strength of the rubber silicone and the alginate powder which is not evenly distributed so that porosity occurs which gives rise to incoming oxygen or impurities in the material. In addition, the density with porosity is closely related, which is inversely proportional, where the higher the bolus density, the smaller the porosity produced, where high density can form a strong covalent bond[11].

- **Water Absorption**

Water absorption is the ability of the material to hold or absorb water on the bolus which is very important in absorbing doses of radiotherapy where moist conditions (air conditioned space) still produce the optimum absorbency dose[13].

From the picture it can be seen that the optimum absorption value of bolus water occurs in the composition of silicone rubber: alginate powder (80 : 19) wt% at 15 mm thick produces a value of water absorption of 1.66%. The value of water absorption in bolus radiotherapy material is inversely proportional to the thickness and composition of the alginate powder. This is because the low optimum composition has a silanol (Si-OH) group that has not been substituted so it is very sensitive to water eventhough the properties of silicone rubber are water resistant (hydrophobic) due to the siloxane group (Si-O-Si) formed from silanol (Si-OH) groups are polar[14].

B. **Characterization of Mechanical Properties**

- **Tensile Strength**

Tensile strength which is a test conducted to determine the ability of bolus radiotherapy in holding the load or mechanical force vertical given until the occurrence of broken[15].

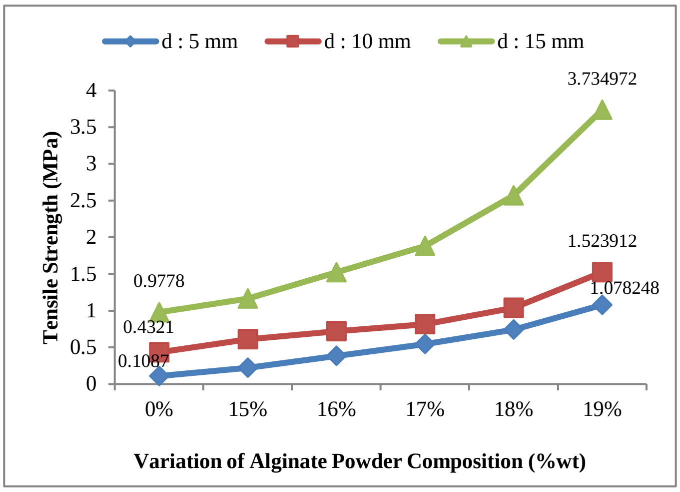

Figure 4 : Test result tensile strength of bolus radiotherapy based alginate/silicone rubber on various variations composition and thickness

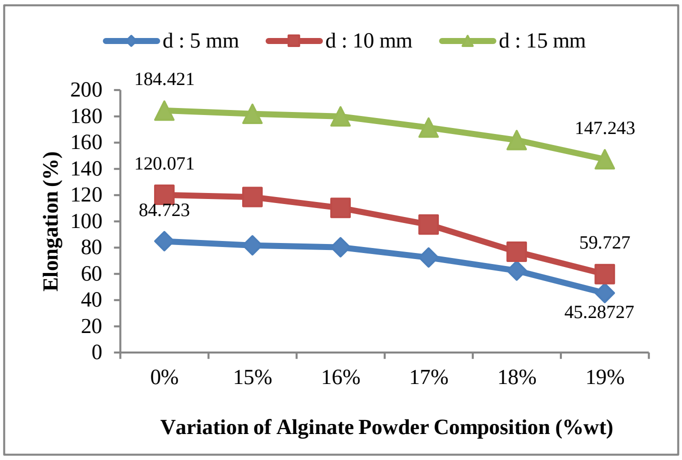

Figure 5 : Test result elongation break of bolus radiotherapy based alginate/silicone rubber on various variations composition and thickness

The results showed that the optimum conditions obtained tensile strength values on the composition of silicone rubber : alginate powder (80 : 19)% wt at a thickness of 15 mm ie 3.73 MPa. The value of tensile strength decreases when decreasing the filler mass of alginate powder which causes the formation of hydrogen (H_2) bonds and makes the distance between bolus polymer chains increasingly tenuous[15]. Where hydrogen bonds are very weak bonds, they are weaker than covalent bonds which cause increased velocity of viscoelastic response and molecular mobility of polymer chains in bolus constituents of radiotherapy[16].

- **Elongation of Break**

Elongation break test was performed to determine how long the bolus stretch after experiencing withdrawal forces before and after experiencing rupture.

The results showed that bolus radiotherapy which had the lowest percentage level of breakout was obtained in the composition of silicone rubber: alginate powder (80 : 19) wt% with a thickness of 5 mm which was 45.28%. Whereas the condition of variation which has the highest percentage of elongation of break on the composition of silicone rubber : alginate powder (80 : 15)%wt at 15 mm thickness of 181.74%. The decrease in elongation is caused by a decrease in the number of hydrogen bonds formed due to the non-optimal matrix in binding to the alginate filler causing the pores in the bolus to form easily, so that the viscoelasticity response decreases. Where the response causes the bolus to be slightly stiff, and less elastic. This is because silicon rubber forms the molecular interactions of polymer chains to increase viscoelastic speed and chain mobility in polymers[17].

- **Modulus of Elasticity**

Modulus of elasticity is a test that aim to determine how resistant a bolus material is to strain to elastic deformation when given vertically outside stress

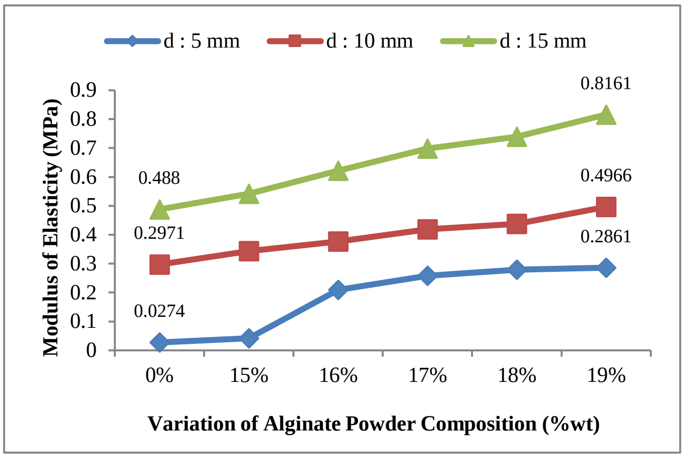

Figure 6 : Test result modulus elasticity of bolus radiotherapy based alginate/silicone rubber on various variations composition and thickness

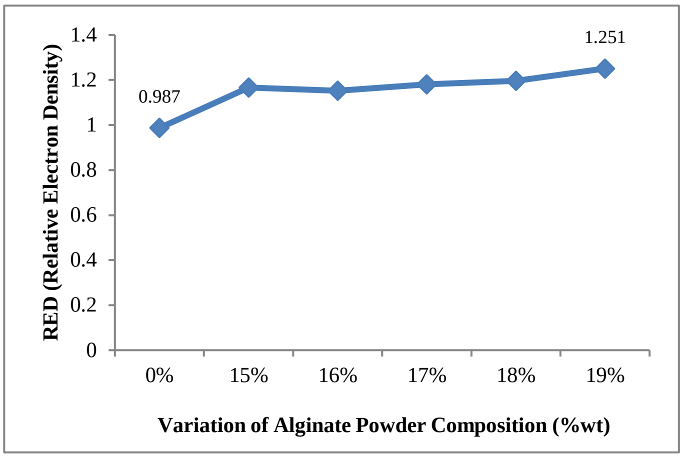

Figure 7 : Test result relative electron density of bolus radiotherapy based alginate/silicone rubber on various variations composition with thickness of 15 mm

The results showed that bolus which has the optimum modulus of elasticity in the composition of silicone rubber : alginate powder (80: 19)% wt at a thickness of 15 mm which is equal to 0.816 MPa. Modulus of elasticity is influenced by the addition of alginate powder and thickness which triggers a viscoelastic response and molecular mobility of siloxane chains (Si-O-Si) formed from silanol (Si-OH) silicon rubber groups causing bolus elasticity of radiotherapy to increase and the degree of bolus material stiffness decreases[18].

C. **Characterization of Performance Properties**

- **Relative Electron Density (RED)**

Where the RED bolus value has an important role when calculating the dose distribution when the patient uses bolus, so it can be known how much the estimated radiation dose received by the patient on the surface area of the skin and below the surface of the skin. to ensure the return of the match bolus with the type of tissue.

Figure 7 shows that the optimum condition obtained relative electron density value (RED) from the CT Scan results in the composition of silicone rubber: alginate powder (80: 19) wt% of 1,251 with the number CT Number 414,19 HU, while for bad conditions on the silicon composition rubber: alginate powder (80: 15) wt% with RED 1,167 with CT Number 241.4 HU. This increase in RED value is influenced by the composition of the alginate powder, in which inorganic polymeric bonds of silicon rubber are siloxane bonds consisting of silicon (Si) and oxygen (O) atoms and methyl bonds consisting of carbon (C) and hydrogen more optimum for binds to the alginate powder filler so that it is denser and stronger[19].

- **Percentage of Absorption Doses on the Surface**

Bolus radiotherapy is based on a composite of alginate powder which is reinforced by silicon rubber, each of which is tested using LINAC to find out how much percentage the surface dose is generated in the electron beam with an energy of 8 MeV and 10 MeV.

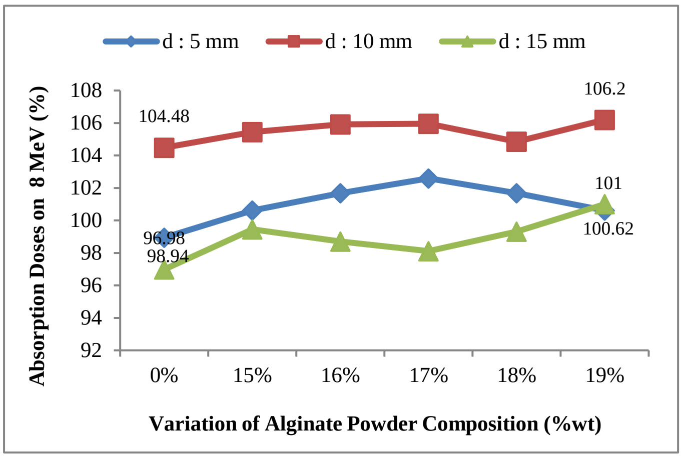

Figure 8 : Test result percentage of absorption doses 8 MeV of bolus radiotherapy based alginate/silicone rubber on various variations composition with thickness

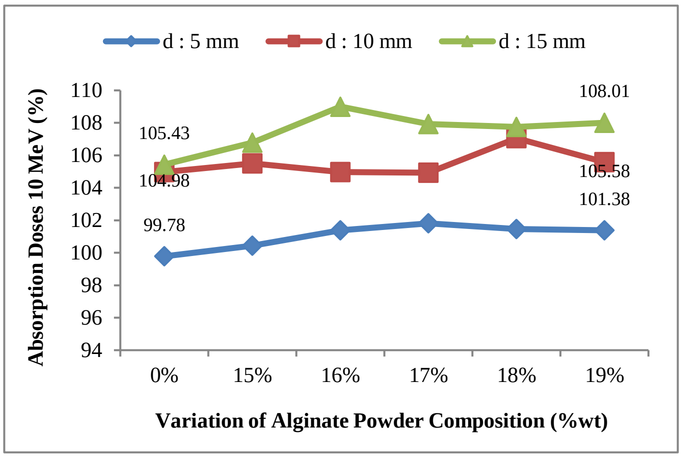

Figure 9 : Test result percentage of absorption doses 10 MeV of bolus radiotherapy based alginate/silicone rubber on various variations composition with thickness

From the results of the observation of the graphic above, it shows that the absorptive dose value increases in proportion to the increase in the composition of alginate powder and bolus thickness of radiotherapy. This is shown from the results of the research that the optimum condition obtained the absorbency dose value at 8 MeV which is good on the composition of silicone rubber : alginate powder (80 : 19) wt at a thickness of 10 mm at 106.2%, where the bolus absent dose is 93%. This increase in absorbency doses is due to scattering differences that occur when electron particles pass through a medium (solid phantom). For a beam of electrons with low energy, electrons are more easily scattered when interacting with a medium (solid phantom), consequently the fluence of electron beams increases because the scattering angle (ɵ) is larger[20].

From the results of the graphic above, the optimum conditions obtained for absorbing doses at 10 MeV were good for the composition of silicone rubber: alginate powder (80: 19)% wt at a thickness of 15 mm by 108.01%, which was 95% absent bolus. It can be concluded that the bolus thickness of radiotherapy greatly influences the absorption capacity of the wave radiotherapy because when high-energy electron particles pass through the bolus there is interaction with bolus-forming particles namely alginate powder and silicone rubber in the form of elastic and inelastic collisions which cause secondary electron release as a result of ionization so that the secondary electrons can penetrate deeper into the maximum dose depth (d_{max}) [21]

IV. CONCLUSION

In the research obtained by bolus radiotherapy composite-based alginate powder reinforced by silicone rubber produced the optimum composition, namely variations in the composition of silicone rubber: alginate powder: catalyst (80: 19: 1)% wt at 15 mm thickness having good physical properties with density values 2.09 x 10^3 kg/m^3, porosity 9.82% and water absorption 1.66%. Mechanical properties with tensile strength 3.37 MPa, elongation at 45.28% and modulus of elasticity of 0.816 MPa. Optimum composition variation is obtained, namely silicone rubber : alginate powder (80 : 19) wt% at 15 mm thickness has the density properties of CT numbers that meet tissue standards in phantom testing for therapeutic media with relative electron density (RED) values from CT Scans result on compositions of 1.251 produced surface absorbing doses of 8 MeV of 101% and 10 MeV of 108.1%.

V. REFERENCES

[1] AAPM. (1991). "*Clinical Electron-Beam Dosimetry: Reports of The AAPM Task Group No. 25*". American Association Physical in Medical

[2] Anusavice, Kenneth (2007), *"Philips Science of Dental Material"*, 11th Edition. Missouri: Elsevier.

[3] Barret A., Dobbs J., Morris S. & Roques T., (2009), *"Practical Radiotherapy Planning"*, 4th ed. UK Company, London.

[4] Blum, M. M., and John, H. 2011. *Historical perspective and modern applications of Attenuated Total Reflectance–Fourier Transform Infrared Spectroscopy (ATR-FTIR).* Article in Drug Testing and Analysis. 4, 298-302.

[5] Campbell, I. M., 1988, *Catalysis of Surfaces*, Chapman and Hall, New York, 154.

[6] Charles M. Washington and Dennis Leaver, (2010), *"Principles and Practice of Radiation Therapy"*, Mosby

[7] FURIA, T.E. (Editor). 1972. "*Handbook of food additives"*.2nd edition. CRC Press Inc., USA. 653 pp.

[8] Gede W.J. & Heri S. (2017). *"Fabrication and Characterization of Bolus Material Using Polydimethyl-Siloxane"*, (January 2018), 015307. https://doi.org/10.1088/2053-1591/aaa447.

[9] Gunham B., Kemikler G., and Koca A. 2003. *"Determination of Surface Dose and The Effect of Bolus To Surface Dose In Electron Beams"*. Medical Dosimetry 28, pp. 193-198.

[10] Heri Sutanto, Eko H., Gede Wiratma J., Santi Yuli A., and Astri Suppa S. 2018. *"Bolus Berbahan Silicone dan Natural Rubber"*. Smart Medical Research Center, Universitas Diponegoro.

[11] Humpries S.M., Boyd K., Patricia C. and Francis D.N., 1996. "*Comparison of Super Stuff and Paraffin Wax Bolus Therapy of Irreguler Surfaces*". Journal of Medical Dosimetry, 21, 155-157.

[12] Junaedi D., Setiawati E., Arifin Z. and ramantisa S., 2016. "*Analisis Penggunaan Polydimethyl Siloxane Sebagai Bolus Dalam Radioterapi Menggunakan Elektron 8 MeV Pada Linac*". Youngster Physics Journal, 5, 391-398.

[13] Kang, E.T., Neoh, K.G. and Tan, K.L., 1998. *Polyaniline: Polymer with Many Interseting Intrinsic Redox State*. Prog. Polym. Sci. Vol. 23, 277-324.

[14] Khan F.M. (2003), *"The Physic of Radiation Therapy"*, 3th ed. Lipincot Williams and Wilkins, Philadelphia, U.S.A.

[15] Khan F.M. (2014) , *"The Physic of Radiation Therapy"*, 5th ed. Lipincot Williams and Wilkins, Philadelphia, U.S.A.

[16] Khifitiyah M., Hidayanto E., dan Arifin Z, 2014. *"Analisa Kurva Percentage Depth Dose (PDD) dan Profile Dose Untuk Lapangan Radiasi Simetri dan Asimetri Pada Linear Accelerator (LINAC) 6 dan 10 MV".* Youngster Physic Journal 3, pp. 279-286.

[17] KIRK and OTHMER. 1994. "*Encyclopedia of chemical technology".* Fourth Edition. Volume 12. John Wiley & Sons, New York. 1091 pp.

[18] Metcalfe P., Kron T., and Hoban P. (2007). *"The Physics of Radiotherapy X-Rays and Electrons"*. Medical Physics Publishing.

[19] Muhammad A.I. and Ardyanata H., (2013). *"Pengaruh Jenis Katalis Terhadap Kekuatan Tarik dan Stabilitas Termal Polidimetilsiloksan*

(PDMS) untuk Lapisan Pelindung Baja AISI 1050", Jurnal Teknik Pomits, 2, 2337-3539.

[20] Nurhening Y., and Affandi A.N. 2012. *"Tinjauan Sifat Hidrofobik Bahan Isolasi Silicone Rubber".* Teknik Elektro Universitas Negeri Yogyakarta.

[21] Nurmaulita. 2010. *"Pengaruh Orietasi Serat Sabut Kelapa Dengan Resin Poliester Terhadap Karakteristik Papan Lembaran".* Tesis Magister Sains. Universitas Sumatera Utara : Medan

[22] Pam Cherry and Angela M, (2009). *"Practical Radiotherapy Physic and Equipment",* Blackwell Publishing, U.S.A.

[23] Park, J.W. and Yea, J.W., 2015. *"Three-Dimensional Customized Bolus for Intensity-Modulated Radiotherapy In a Patient With Kimura's Disease Involving The Auricle",* Cancer/Radiotherapie 20, pp. 205-209.

[24] Podgorsak, E.B. (2005). *"Radiation Oncology Physic: A Handbook for Teachers and Students",* International Atomic Energy Agency, Vienna, Austria.

[25] Segura T. and Burillo G., 2013. *"Radiation Modification of Silicone Rubber With Glycidymethacrylate",* Radiation Physics and Chemistry 91, pp.101-107.

[26] Visscher S. and Barnett E., 2016. "*Comparison of Bolus Materials to Highly Absorbent Polypropylene and Rayon Cloth".* Journal of Medical Imaging and Radiation Sciences, 1-6. doi: 10.1016/j.jmir.2016.08.003.

[27] Segura T. and Burillo G., 2013. *"Radiation Modification of Silicone Rubber With Glycidymethacrylate",* Radiation Physics and Chemistry 91, pp.101-107.

Cite this article as :

Hendra Tampubolon, Kerista Tarigan, Timbangen Sembiring, "Manufacture and Determination of Absorbent in Bolus Radiotherapy Based On Alginate Using of 8 MeV and 10 MeV Energy", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 6 Issue 3, pp. 123-131, May-June 2019. Available at doi : https://doi.org/10.32628/IJSRSET196325
Journal URL : http://ijsrset.com/IJSRSET196325