Asian Journal of Healthy and Science
p-ISSN: 2980-4302
e-ISSN: 2980-4310
Vol. 3 No. 3 March 2024

EFFECT OF BOLUS THICKNESS-BASED BASE EICHHORNIA CRASSIPES POWDER (WATER HYACINTH) ON RADIOTHERAPY BOLUS HOMOGENEITY

Muslimah Putri Utami[1], Sugiyanto[2], Gatot Murti Wibowo[3], Ari Suwondo[4], Yeti Kartikasari[5], Mohamad Hidayatullah[6]

[1,2,3,4,5]Politeknik Kesehatan Kemenkes Semarang, Indonesia
[6] Ken Saras Hospital Semarang, Indonesia
Email: mputriutami28@gmail.com

Abstract

Bolus radiotherapy aims to make the radiation dose more homogeneous, and increase the surface dose to the skin. Exploration of alternative materials for substitute mixtures that are relatively safer is needed to reduce the weaknesses in the use of plasticine mixtures. To develop the basic ingredients for making bolus using biopolymers in water hyacinth (Eichhornia crassipes). This research was conducted using the method of Research and Development. The suitability of the physical characteristics of the bolus (homogeneity judged by CT number; Relative Electron Density is calculated by a formula ρb;% surface dose is obtained from TPS (Treatment Planning System) in the test and the 3 variations of the thickness (0.5 cm, 1.0 cm and 1.5 cm). The feasibility of the bolus product was determined based on the flexibility of the texture and resistance to cold temperatures. Result: Water hyacinth (Eichhornia crassipes) can be used as a reference for alternative bolus materials in radiotherapy due to the response of water hyacinth (Eichhornia crassipes) to radiation Water hyacinth (Eichhornia crassipes-based bolus has same RED (Relative Electron Density) value as soft and solid tissue in all thickness variations and has a surface dose value of ±100% for all thickness variations. Water hyacinth (Eichhornia crassipes) based bolus is homogeneous against radiation and can increase the dose surface so that water hyacinth (Eichhornia crassipes) has benefits and can be used as an alternative bolus material in radiotherapy.

Keywords: Bolus, Relative Electron Density, Eichhornia crassipes

INTRODUCTION

Radiotherapy or radiation therapy is a treatment for tumors using ionizing rays. This type of ionizing rays can be in the form of x-rays and gamma rays, alpha and beta, as well as from several groups of particles such as electrons and neutrons. One of the radiotherapy modalities that is widely used is LINAC (Linear Accelerator) (Dewang *et al.*, 2015). The electron beam provides a uniform radiation dose within the target volume tumor (TV) superficial and can minimize radiation dose to deeper tissues (Fairuzdzah *et al.*, 2015). However, there are still obstacles to optimizing the absorbed dose at the target volume to achieve homogeneity of the radiation dose distribution because the influence of the irradiated surface contour varies (Jaya & Sutanto, 2018). For example, in LINAC radiotherapy patients with breast tumors post-mastectomy, the surface contour of the organ is not flat (flat) will affect the distribution of the effective dose of surface irradiation on the TV (Kudchadker *et al.*, 2022; Ordonez-Sanz *et al.*, 2014). As a result, there was an increase in the absorbed dose precisely at locations deeper than the layer area where the superficial tumor was located, which in turn reduced the effectiveness of dose distribution in the TV while damage to healthy tissue in deeper locations occurred (Montaseri *et al.*, 2012). To overcome this problem, a radiotherapy facility known as a bolus is needed (Adamson *et al.*, 2017). The use of a bolus will provide a more homogeneous and higher dose to the skin as optimization of treatment if without the use of a bolus it will cause damage to the skin because 95% of the absorbed dose is on the skin and using a bolus dose of the skin is <75% (Guhan *et al.*, 2003; Kermode *et al.*, 2005).

The main goal of bolus radiotherapy is to disguise the patient's irregular contours and provide a flat surface for normal radiation (R.Oberoia *et al.*, 2019). Therefore, a bolus consists of a tissue-equivalent material that is placed directly on the surface of the skin. The second bolus aims to treat lesions near the skin surface which can be achieved by increasing the skin surface dose (Montaseri *et al.*, 2012; Khan and Gibbons, 2010; Khan, 2003)

The content of the bolus material must have components that have the characteristics of homogeneously attenuating radiation beams, although the use of natural base mixtures has been studied and applied, but the use of mixed materials from the water hyacinth plant (*Eichhornia crassipes*) has not been studied in depth (Cherry and Duxbury, 2019; Ordonez-Sanz *et al.*, 2014). Water hyacinth (*Eichhornia crassipes*) has high fiber content and low protein content, and water hyacinth (*Eichhornia crassipes*) is a plant that contains high cellulose as a biopolymer so that it has the potential to be used as a base for bolus mixtures because besides this plant species it is easily available in nature (Heriyanto *et al.*, 2015). Tropical geography such as Indonesia, also meets the requirements for bolus radiotherapy (Fitasari, 2009; IAEA, 2005; Sutanto *et al.*, 2019).

For this reason, this research will conduct radiotherapy boluses based on water hyacinth powder (*Eichhornia crassipes*) with bolus thicknesses of 0.5 cm, 1 cm and 1.5 cm. Water hyacinth powder is (*Eichhornia crassipes*) expected to be a new substrate in the manufacture of radiotherapy boluses. The bolus will be analyzed using CT Scan and LINAC to determine the value of Relative Electron Density (RED) and the percentage of surface dose using 6 MV of energy (Wong *et al.*, 2020). This study aimed to was to develop the basic ingredients for making bolus using biopolymers in water hyacinth (*Eichhornia crassipes*).

RESEARCH METHODS

The research method used is research and development (Research & Development) which is a research method to produce certain products, and test the effectiveness of these products. The development and research model used in this study is the development model Borg and Gall which consists of ten implementation steps including (1) research and information collecting, (2) planning, (3) develop preliminary form of product, (4) preliminary field testing, (5) main product revision, (6) main field testing, (7) operational product revision, (8) operational field testing, (9) final product revision, and (10) dissemination and implementation. To shorten the time of research and development in this research is limited to a few stages. These stages include: a) problems and potentials; b) product design; c) expert validation; d) product trial; e) product feasibility test; f) preparation of reports (Margono, 2005; Borg and Gall, 1983)

The population in this study is an infinite population because the researchers used samples in the form of inanimate objects, namely radiotherapy boluses with variations in thickness of 0.5 cm, 1 cm, and 1.5 cm. Meanwhile, the sample in this study was a type of radiotherapy bolus made from Eichornia Crassipes, Water Hyacinth Powder, and Plasticine Bolus given irradiation simulation using the same energy 6 MV.

In this study, researchers collected data by explaining the procedures for processing and analyzing data according to the approach taken. This study uses a closed assessment questionnaire to provide criticism and suggestions as well as product improvements. The results of this descriptive analysis are quantitative data and qualitative data. Quantitative data is obtained from the calculation value using the formula for determining the relative value of electron density and the percentage of surface dose and the value of the validator, while the qualitative data is in the form of a descriptive explanation of the research results and validation results (Tampubolon *et al.*, 2019; Metcalfe *et al.*, 2007)

RESULT AND DISCUSSION

The results of the stages of product development for water hyacinth bolus *(Eichornia Crassipes)* will be described as follows:

Problems and Potential

Research can begin with the emergence of problems with plasticine boluses, namely boluses used today, made from paraffin or wax that do not last long in cold temperatures and will harden if left for a while and the material used is not organic. Therefore, the potential that can be raised is to make radiotherapy boluses made of organic material by utilizing biopolymers in water hyacinth *(Eichornnia Crassipes)* (Ratnani *et al.*, 2011; Rorong and Suryanto, 2010).

Product design

This study used water hyacinth *(Eichornnia Crassipes)* as the base material for radiotherapy bolus because it contains high cellulose, which is the main constituent of plants composed of D-glucose subunits and is a linear biopolymer of anhydroglucopyranose molecule (Zimmels *et al.*, 2006). Tests were conducted on water hyacinth *(Eichornnia Crassipes)* which had been powdered with a weight variation of 5 gr ; 7.5 gr ; and 11 gr to determine the response to radiation. The test was carried out using a CT-Scan to find out the CT Number value to calculate the RED value and simulated irradiation on the linac at the TPS. The CT scan energy used is 120 KV and 240 mA can be seen in the Table !below for the test results.

Table 1. Value of CT Number and value of Relative Electron Density (RED) water hyacinth

No	Water hyacinth		
	5.0 gr	**7.5 gr**	**11.0 gr**
1	-849.3	-880	-886
2	-854.5	-881.3	-878.9
3	-857	-879.1	-880.6
4	-858	-877.6	-878.6
Average	-854.7	-879.5	-881.026
RED	0.1453	0.1205	0.1189

In the Table 1 it can be explained that the RED value of water hyacinth powder *(Eichornnia Crassipes)* is below the solid and soft tissues. However, water hyacinth powder *(Eichornnia Crassipes)* has the opportunity to be used as a bolus in radiotherapy because the fibers contained in water hyacinth powder *(Eichornnia Crassipes)* are able to absorb radiation and spread radiation evenly. significant. Water hyacinth contains organic polymer bonds in its cellulose, namely (C6H10O5).

Table 2. Radiation absorption dose of water hyacinth with energy 6 MV

Depth	Without bolus	Water hyacinth		
		5 gr	**7,5 gr**	**11 gr**
Surface	51.9	66.8	68.4	72.9
0,5 cm	89.4	91.1	91.2	92.3
1 cm	99.7	99.6	99.8	99.2
1,5 cm	100.6	99.8	99.8	99.1
2 cm	99.3	98.5	98.5	97.7
% surface dose	51.59%	66.40%	67.99%	72.46%

In Table 2, it can be concluded that water hyacinth (*Eichornia crassipes*) can increase the surface dose as one of the bolus requirements. Water hyacinth (*Eichornia crassipes*) can distribute radiation well seen from the value of the absorbed dose at each depth.

The deficiency in water hyacinth *(Eichornia crassipes)* is due to the absence of density which affects the density and reduces the RED value and the percentage of surface dose. Gluten in wheat flour also has benefits as a viscoelastic bolus material that is able to make the bolus more elastic and can be shaped according to the needs of treatment in radiotherapy.

Several references, researchers determine olive oil as a lubricant because the concentration of squalene in olive oil is higher than in other types of oil. Due to the basic ingredients and mixed ingredients of water hyacinth bolus (Eichornia crassipes) made of organic materials, an antifungal agent is needed in the form of Sodium Tetraborate Decahydrate which is able to form complexes with various biomolecules such as glucose, protein and fat contained in wheat flour and water hyacinth powder *(Eichornia crassipes)* (Damat *et al.*, 2020)

The right composition for variations in the thickness of 0.5 cm, 1 cm and 1.5 cm is (42:10:2:2) tbsp. Due to the different density of wheat flour and water hyacinth powder, it cannot be measured using a weighing scale. The process of making water hyacinth bolus *(Eichornia Crassipes)* sodium tetraborate decahydrate must be dissolved first, and burned using distilled water or water at a rate of 0.2 gr: 100 ml, and stirred until dissolved. Water hyacinth powder, wheat flour, olive oil and a solution of sodium tetraborate decahydrate were placed in a bowl that had been prepared with the dose that the researchers had managed to get, namely 42 tbs. water hyacinth powder 10 tbsp wheat flour 2 tbsp olive oil 2 tbs solution sodium tetraborate decahydrate. From this dose, 3 types of water hyacinth bolus can be made with variations in thickness of 0.5 cm, 1 cm, and 1.5 cm. After the dough is mixed and gets the right texture, the bolus can be in the form of a square with a field area commonly used for boluses, which is 10x10 cm. If you want to make boluses one at a time, the required dose is 14 tbs of water hyacinth powder, 2 tbs of wheat flour, 1.5 tbs of olive oil and 1.5 tbs of solution sodium tetraborate decahydrate apply in multiples of 2 to make a bolus of the desired thickness.

Validation

Validation (Table 3 and Table 4) was carried out by distributing an assessment questionnaire on the water hyacinthbolus *(Eichornia crassipes).* carried out by: 1) a competent material expert in the field of radiotherapy physics; and 2) a competent radiotherapist.

Table 3. Validation of **water hyacinthbasic ingredients (*Eichornia crassipes*) by material expert who is competent in the field of radiotherapy physics**

No	Description	Water Hyacinth Validation			
		1	2	3	4
1	Water hyacinth bolus characteristics		v		
2	Homogeneity to radiation		v		
3	Bolus response to radiation with variations in thickness			v	
4	Percentage of surface dose		v		
5	Development of organic bolus				v
6	Effectiveness cost of manufacture				v
7	Effectiveness of making bolus				
8	Availability of bolus material			v	

Table 4. Validation of water hyacinthbase material (*Eichornia crassipes*) by competent radiotherapist

No	Description	Validation			
		1	2	3	4
1	Water hyacinth bolus characteristics		v		
2	Homogeneity to radiation		v		
3	Bolus response to radiation with variations in thickness				v
4	Percentage of surface dose			v	
5	Development of organic bolus				v
6	Effectiveness cost of manufacture				v
7	Effectiveness of making bolus				v
8	Availability of bolus material		v		

Based on the validation results, it can be concluded that water hyacinth *(Eichornia crassipes)* can be used as the basis for making a good radiotherapy bolus. This can be proven by the score on the validation questionnaire.

Table 5. Water hyacinth bolus validation *(Eichornia crassipes)* by material expert who is competent in radiotherapy physics

No	Description	Mixed EG Bolus Validation			
		1	2	3	4
1	Characteristics of bolus to tissue			v	
2	Homogeneity to bolus			v	
3	Response to radiation with variations in thickness				v
4	Percentage of surface dose on bolus			v	
5	Development of organic bolus			v	
6	Effectiveness cost of manufacture				v
7	Effectiveness of making bolus				v
8	Availability of bolus material			v	

The results of product validation (Table 5) by a competent material expert in the field of radiotherapy physics show the results of scores of 3 and 4 with a percentage >50% for all questions in the "good" and "very good".

Table 6. Water hyacinth bolus validation *(Eichornia* crassipes) radiotherapist

No	Description	Validation			
		1	2	3	4
1	Characteristics of bolus to tissue			v	
2	Homogeneity to bolus				v
3	Response to radiation with variations in thickness				v
4	Percentage of surface dose on bolus				v
5	Development of organic bolus				v
6	Effectiveness cost of manufacture				v
7	Effectiveness of making bolus				v
8	Availability of bolus material				v

The results of product validation (Table 6) by a competent radiotherapist showed an overall score of 4 with a percentage of 100% in the "very good" category. For product characteristics, it shows a value of 3 with a percentage of 75% in the "good" category.

Product

Trial the trial was carried out at Ken Saras Hospital, Semarang. Variations in bolus thickness of water hyacinth *(Eichornia crassipes)* 0.5 cm, 1 cm and 1.5 cm with an energy of 120 kV 240 mA on CT Scan, energy 6 MV on LINAC. To determine the effectiveness of a water hyacinth bolus compared to a routine bolus, namely a plasticine bolus. Then the plasticine bolus was measured and compared with the water hyacinthbolus *(Eichornia crassipes).*

Table 7. CT Number Value and Relative Electron Density (RED) Water Hyacinth Bolus and Plasticine Bolus

No	Water hyacinth Bolus			Plasticine Bolus		
	0.5 gr	**1.0 gr**	**1.5 gr**	**0.5 gr**	**1.0 gr**	**1.5 gr**
1	64.8	77.6	82.1	95.8	112.8	119.8
2	67.6	74.9	66.1	107.6	97.5	118.7
3	75.6	77.8	73.3	100.1	102	118.7
4	71.1	63.8	66.6	109.5	99.6	112.2
Average value	69.775	73.525	72.025	103.25	102.975	117.35
RED	1.0854	1.0872	1.0865	1.1015	1.1014	1.1083

Table 7 explains that the water hyacinth bolus has a value equivalent to soft tissue (muscle and breast) and solid tissue (solid bone) and has a RED value that is almost the same as a routine bolus, namely a plasticine bolus.

Table 8. Radiation Absorption Dose Value of 6 MV on Water Hyacinth Bolus and Plasticine Bolus

n	Without	Water hyacinth Bolus			Plasticine Bolus		
		0.5 gr	**1.0 gr**	**1.5 gr**	**0.5 gr**	**1.0 gr**	**1.5 gr**
Surface	51.9	98.8	101	101.7	98.5	100.7	101.3
0.5 cm	89.4	100.5	102.1	100.2	101.7	100.3	98
1 cm	99.7	99.7	100.7	98.1	101.6	98.9	96.8
1.5 cm	100.6	97.7	98.6	95.7	99.1	96.9	94.4
2 cm	99.3	95.6	96.3	93.4	97	94.3	92
% surface dose	52.26%	99.49%	101.71%	102.41%	99.19%	101%	102%

In Table 8 it can be explained that the higher the radiation energy used, the percentage of surface dose without the use of a bolus the increase is due to the difference in scattering (scattering) that occurs when the radiation particles pass through the medium (solid phantom) (Montaseri *et al.*, 2012). Water hyacinth bolus *(Eichornia crassipes)* has a higher percentage of surface dose compared to routine bolus, namely plasticine bolus because water hyacinth powder *(Eichornia crassipes)* and wheat flour have elastic and non-elastic collisions which cause the release of secondary electrons as a result of the ionization process, so that These secondary electrons can penetrate deeper into the position of maximum dose depth (Dmax).

Product feasibility test

The feasibility test is carried out by looking at the results of product validation and by looking at the bolus with the naked eye the results of the bolus s can be seen in Figure 1.

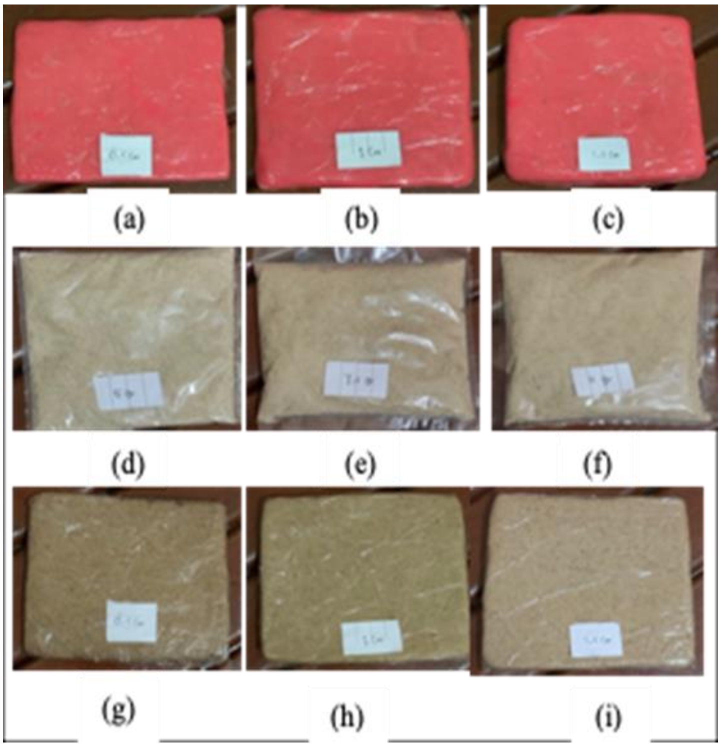

Figure 1 Plasticine bolus, water hyacinth powder, water hyacinth powder ((a) 0.5 cm plasticine bolus, (b) 1 cm plasticine bolus, (c) 1.5 cm plasticine bolus, (d) water hyacinth powder 5 gr, (e) water hyacinth powder 7.5 gr, (f) water hyacinth powder 11 gr, (g) water hyacinth bolus 0.5 cm, (h) water hyacinth bolus 1 cm, (i) water hyacinth bolus 1.5 cm)

In Figure 1 it can be seen the color difference of each bolus according to the color of the basic ingredients used. Water hyacinth boluses (*Eichhornia crassipes*) have a more elastic texture than plasticine boluses so that water hyacinth boluses (*Eichhornia crassipes*) can be more easily shaped according to needs in both cold and normal temperatures. And the elasticity level of the water hyacinth bolus is better when compared to the plasticine bolus which will harden at a certain time and have an influence on the radiation dose that will be transmitted to the target. Thus, it can be concluded that the water hyacinth bolus (*Eichhornia crassipes*) has advantages for users in terms of texture and bolus resistance.

This research and development was carried out with reference to the research and development stages of Borg & Gall which explained that there were ten stages in research and development, but in this study the ten steps were simplified into six steps. The factors that underlie the simplification are: time constraints, limited costs, similarity in stages, and opinions according to Borg & Gall.

The bolus characteristics of water hyacinth (*Eichhornia crassipes*) can be seen from the Relative Electron Density (RED) value and the percentage of surface dose. It can be seen from Table 1 and Table 2 which states that the water hyacinth bolus (*Eichhornia crassipes*) has the same RED value as the routine bolus, namely the plasticine bolus and has a higher surface dose percentage value than the plasticine routine bolus. Therefore, it can be concluded that the water hyacinth bolus (*Eichhornia crassipes*) has the potential to be used as an organic- based radiotherapy bolus.

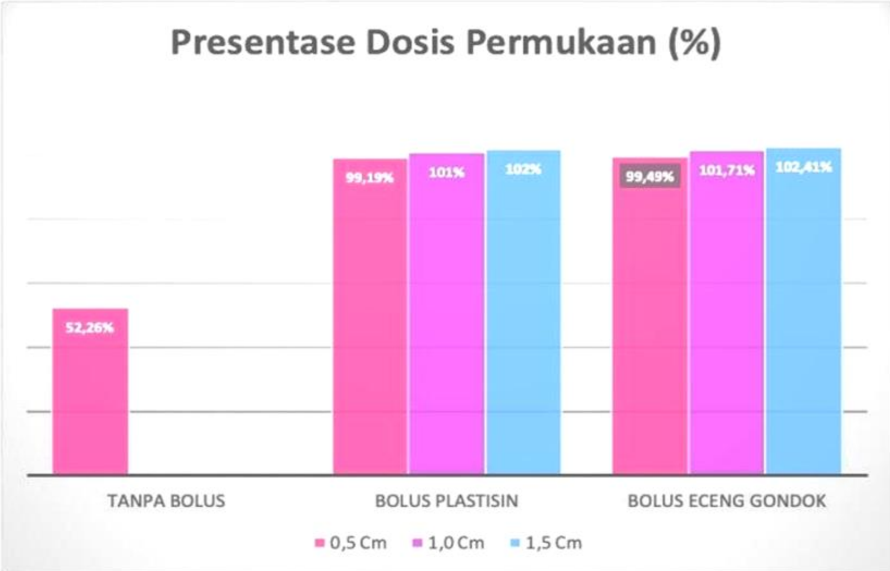

Figure 2. Percentage of surface dose using 6 MV energy

Based on Figure 2, it can be explained graphically the percentage value of the surface dose of water hyacinth bolus (*Eichhornia crassipes*) has a higher value of all thickness variations when compared to routine plasticine boluses.

Variations in the thickness of the radiotherapy bolus greatly affect the homogeneity of the bolus due to the ability of the absorption dose of radiotherapy waves when high energy electron particles pass through the bolus, interactions occur with the bolus constituent particles, in the water hyacinth bolus, namely water hyacinth powder and wheat flour, elastic and non-elastic collisions occur which cause the release of secondary electrons as a result of the ionization process, so that these secondary electrons can penetrate deeper into the position of maximum dose depth (dmaks). A bolus with a small thickness causes the beam to scatter more easily than a bolus with a larger thickness. So the percentage value of the resulting surface dose increases with increasing radiation energy.

Based on the results of measurements and validation by radiotherapy physicists and radiotherapy experts validation, it can be stated that the water hyacinth bolus (*Eichhornia crassipes*) deserves to be used as an organic radiotherapy bolus

CONCLUSION

Based on the results of the development of bolus radiotherapy based on water hyacinth (Eichhornia crassipes) fortified with wheat flour, olive oil, and sodium tetraborate decahydrate with the deposition method of mixing the ingredients. The measurement results indicate that the bolus characteristics of water hyacinth (Eichornia crassipes) have met the radiotherapy bolus standard and were declared eligible for radiotherapy bolus..

BIBLIOGRAPHY

Adamson, J. D., Cooney, T., Demehri, F., Stalnecker, A., Georgas, D., Yin, F.-F., Kirkpatrick, J., Adamson, J. D., Cooney, T., Demehri, F., Stalnecker, A., Georgas, D., Yin, F.-F., & Kirkpatrick, J. (2017). Characterization of Water-Clear Polymeric Gels for Use as Radiotherapy Bolus. *Technology in Cancer Research and*

Treatment, *Vol.16(6)*(6), Pp. 923-929. https://doi.org/doi.org/10.1177/1533034617710579
Borg, W. R., & Gall, M. D. (1983). *Educational Research: An Introduction*. Longman.
Cherry, P., & Duxbury, A. M. (2019). *Pratical Radiotherapy Physics and Equipment* (3 rd). Wiley-Blackwell.
Damat, D., Pratiwi, Y. S., Prastyowati, I., Hidayati, M. N., Antika, R. B., Oktaviani, L. D., Shoukat, N., & Ahmed, K. (2020). The Effect of Borax as A Food Additive on Energy Metabolism. *Annals of TropicalMedicine and Health*, *Vol.23(8)*(8), Pp. 1317-1323.
Dewang, S., Tahir, D., & Asrisal, R. (2015). Electron Beam of Linear Accelerator Have Been Verified with Energy of Water Phantom was Varied. *Physics, Medicine*, Pp. 1-6.
Fairuzdzah, A. L., Mustafa, I. S., Yahaya, Z. S., & Ishak, S. A. (2015). To Study the Durian Seed As a New Substrate for Bolus in Radiotherapy. *Conference: Proceedings of Sixteenth TheIIER International Conference*, Pp. 110-113.
Fitasari, E. (2009). Pengaruh Tingkat Penambahan Tepung Terigu terhadap Kadar Air, Kadar Lemak, Kadar Protein, Mikrostruktur, dan Mutu Organoleptik Keju Gouda Olahan. *Jurnal Ilmu Dan Teknologi Hasil Ternak*, *Vol.4(2)*(2), Pp. 17-29.
Guhan, B., Kemikler, G., & Koca, A. (2003). Determination of Surface Dose and The Effect of Bolus to Surface Dose in Electron Beams. *Medical Dosimetry: Official Journal of The American Association of Medical Dosimetrists*, *Vol.28(3)*(3), Pp. 193-198. https://doi.org/doi.org/10.1016/S0958-3947(03)00072-4
Heriyanto, H., Firdaus, I., & Destiani, A. F. (2015). Pengaruh Penambahan Selulosa dari Tanaman Eceng Gondok (Eichornia crassipes) dalam Pembuatan Biopolimer Superabsorben. *Jurnal Integrasi Proses*, *Vol.5(2)*(2), Pp. 88-93. https://doi.org/dx.doi.org/10.36055/jip.v5i2.203
IAEA. (2005). *Radiation Oncology Students, A Handbook for Teachers and Student*. Sales and Promotion Unit.
Jaya, G. W., & Sutanto, H. (2018). Fabrication and Characterization of Bolus Material Using Polydimethyl-Siloxane. *Materials Research Express*, *Vol.5(1)*(1). https://doi.org/doi.org/10.1088/2053-1591/aaa447
Kermode, M., Jolley, D., Langkham, B., Thomas, M. S., Holmes, W., & Gifford, S. M. (2005). Compliance with Universal/Standard Precautions among Health Care Workers in Rural North India. *American Journal of Infection Control*, *33*(1), Pp. 27-33. https://doi.org/doi.org/10.1016/j.ajic.2004.07.014
Khan, F. M. (2003). *The Physics of Radiation Therapy* (3 rd). Lippincott Wiliiams & Wilkins.
Khan, F. M., & Gibbons, J. P. (2010). *The Physics of Radiation Therapy*. Lippincott Wiliiams & Wilkins.
Kudchadker, R. J., Hogstrom, K. R., Garden, A. S., McNeese, M. D., Boyd, R. A., & Antolak, J. A. (2022). Electron Conformal Radiotherapy using Bolus and Intensity Modulation. *International Journal of Radiation Oncology, Biology, Physic*, *Vol.53(4)*(4), Pp. 1023-1037. https://doi.org/doi.org/10.1016/s0360-3016(02)02811-0
Margono, S. (2005). *Metodologi Penelitian Pendidikan*. Rineka Cipta.
Metcalfe, P., Kro, T., & Hoban, P. (2007). *The Physics of Radiotherapy X-Ray and Electrons* (1 st). Medical Physics Pub Corp.
Montaseri, A., Alinaghizadeh, M. R., & Mahdavi, S. R. (2012). Physical Properties of

Ethyl Methacrylate as a Bolus in Radiotherapy. *Iranian Journal of Medical Physics*, *Vol.9(2)*(2), Pp. 127-134. https://doi.org/doi.org/10.22038/ijmp.2012.318

Ordonez-Sanz, C., Bowles, S., Hirst, A., & MacDougall, N. D. (2014). A Single Plan Solution to Chest Wall Radiotherapy with Bolus? *The Bristish Journal of Radiology*, *Vol.87(103*(1037). https://doi.org/doi.org/10.1259/bjr.20140035

R.Oberoia, P., B.Maurya, C., & A.Mahanwar, P. (2019). Study The Effect of Control Radiation on Optical and Structural Properties of Polymeric Gel Dosimeter. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, *Vol.455*, Pp. 21-27. https://doi.org/doi.org/10.1016/j.nimb.2019.06.019

Ratnani, R. D., Hartati, I., & Kurniasari, L. (2011). Pemanfaatan Eceng Gondok (Eichornia Crassipes) untuk Menurunkan Kandungan Cod (Chemical Oxygen Demond), Ph , Bau ,dan Warna pada Limbah Cair Tahu. *Jurnal Momentum UNWAHAS*, Pp. 41-47. https://doi.org/doi.org/10.36499/jim.v7i1.296

Rorong, J. A., & Suryanto, E. (2010). Analisis Fitokimia Enceng Gondok (Eichhornia Crassipes) dan Efeknya Sebagai Agen Photoreduksi Fe 3+. *Chemistry Progress*, *Vol.3(1)*(1), Pp. 33-41. https://doi.org/doi.org/10.35799/cp.3.1.2010.72

Sutanto, H., Hidayanto, E., Jaya, G. W., & Supratman, A. S. (2019). *Bolus Berbahan Silicone dan Natural Rubber*. UNDIP Press.

Tampubolon, H., Tarigan, K., & Sembiring, T. (2019). *Pembuatan dan Penentuan Absorben Bolus Radioterapi Berbahan Alginat Menggunakan Energi 8 MeV dan 10 MeV*. Institusi Universitas Sumatera Utara.

Wong, G., Lam, E., Bosnic, S., Karam, I., Drost, L., Yee, C., Ariello, K., Chow, E., & Wronski, M. (2020). Quantitative Effect of Bolus on Skin Dose in Postmastectomy Radiation Therapy. *Journal of Medical Imaging and Radiation Science*, *Vol.51(3)*(3), Pp. 462-469. https://doi.org/doi.org/10.1016/j.jmir.2020.06.006

Zimmels, Y., Kirzhner, F., & Malkovskaja, A. (2006). Application of Eichhornia Crassipes and Pistia Stratiotes for Treatment of Urban SAewage in Israel. *Journal of Environmental Management*, *Vol.81(4)*(4), Pp. 20-28. https://doi.org/doi..org/10.1016/j.jenvman.2005.11.014