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STUDY OF REPRODUCIBILITY AND DOSE RESPONSE OF ALANINE GEL DOSIMETER FOR CLINICAL ELECTRON BEAMS

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ABSTRACT

The Alanine is an amino acid tissue equivalent for the radiation interaction with matter, is stable and of low cost. The working principle of this dosimeter is the difference between Fe^{2+} presents in the solution and Fe^{3+} ions radiation induced concentration, which can be measured through spectrophotometric technique. The DL-Alanine ($C_3H_7NO_2$) improves the ferric ions (Fe^{3+}) production when the solution containing ferrous ions (Fe^{2+}) is irradiated. The signal response presents linear behavior in the studied electron dose range, between 5 and 40 Gy, and the intra-batch and inter-batch reproducibility to electron radiation are 4% and 5%, respectively. The obtained results indicates that the alanine gel solution presents good performance as radiation dosimeter and could be used us a alternative dosimeter for application in 3D clinical Gel Dosimetry.

1. INTRODUCTION

In current days, the three-dimensional mapping of the absorbed dose distribution in the volume of interest has become a very important tool to check if the radiation treatment was applied properly. Among of these instruments is the Gel Dosimetry. The Gel dosimetry was born in 1984, when Gore [1] proposed combining the Fricke system in a matrix in the form of a gel with the technique of Magnetic Resonance Imaging (MRI).

Many gel dosimeters were developed with different compositions, such as the combination of the polymerization of the monomers acrylamide and N, N'-methylene-bis-acrylamide (bis) with an aqueous agarose matrix [2], known by the acronym BANANA. In 2006, Mizuno [3] developed a new material in the form of a gel, which showed a significant improvement on previous Alanine solution system developed by Costa [4].

All dosimeters must have favorable dosimetric characteristics to be used successfully in the Radiation Dosimetry. Among of them the main features are the signal response linearity, good stability and high reproducibility. There are also external influences such as environmental conditions, dose rate and incident energy dependence response. Therefore, it evaluating theses dosimetric characteristics through to 2D technique can indicate the use of this solution in application in 3D dosimetry.

The Alanine ($C_3H_7NO_2$) is an amino acid tissue equivalent for the radiation interaction with matter, is stable, of low cost, and used as dosimetric material in secondary standard EPR dosimetry, so the choice of this compound to develop a new gel dosimetric material.

The working principle of this dosimeter is the difference between Fe^{2+} presents in the solution and Fe^{3+} ions radiation induced concentration, which can be measured through spectrophotometric technique (2D dosimetry). This technique permits to compare the two wavelengths, 457 nm band that corresponds to ferrous ions concentration and 588 nm band that corresponds to ferric ions concentration. The DL-Alanine improves the production of ferric ions (Fe^{3+}) when the solution containing ferrous ions (Fe^{2+}) is irradiated.

This work aims to study the reproducibility and signal response of the Alanine gel solution produced at IPEN as a function of clinical electron radiation dose using spectrophotometric technique.

2. MATERIALS AND METHODS

2.1. Alanine Gel Solution

The gel solutions were prepared according to Mizuno (2007), conditioned in cuvettes 1 cm x 1 cm x 4.5 cm and optical path of 10^{-2} m and maintained at low temperature during 24 h to solidification. Before irradiation the samples were maintained during 1 h at room temperature. The chemical composition of the dosimetric system is shown in table 1:

Table 1. Chemical composition of Alanine gel solution.

Compound	Concentration (mol/L)
Ferrous Ammonium Sulfate	0.001
Xylenol	0.0002
Sulfuric Acid	0.2375
DL-Alanine	0.6735
Tri-distilled water	5.55
Gelatin (300 Bloom)	10 % of the tri- distilled water volume

2.2. Acrylic Support

The samples were always positioned on a specially designed acrylic support with solid water plates RW3 positioned on and under the acrylic support for guaranteeing the desired depth and backscattering conditions, presented in Figure 1.

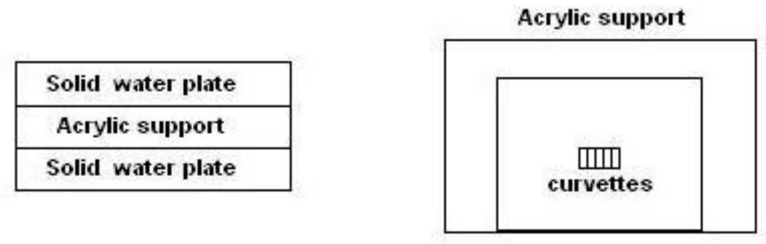

Figure 1 – Irradiation set up used to electrons irradiations

2.3. Electron Irradiation

The electron irradiations were performed using a Varian 2100 C Medical Linear Accelerator of the Radiotherapy Department of the Hospital das Clínicas of the University of Sao Paulo with doses between 1 and 40 Gy and radiation field of 10 x 10 cm^2 and electron energy of 6 MeV.

Each batch was composed of 35 cuvettes filled with gel solution, shared in 7 groups; each group was irradiated with one different dose, except one that was not irradiated, considered as background.

2.4. Spectrophotometric Evaluation

The optical response (absorbance) was measured using a Shimadzu UV-2101 PC spectrophotometer using the following set up parameters, see the table 2:

Table 2. Spectrophotometer set up parameters.

Parameters	
Wavelength range (nm)	400 - 700
Light source	Tungsten and Deuterium
Slit width (nm)	2
Absorbance (%)	-9.999 - +9.999
Transmittance (%)	-999.9 - +999.9
Scan speed (nm/min)	1600 (fast and 2nm interval)
Precision (nm)	0.1

2.5. Lower Detectable Limit (*LDL*)

The lower detectable limit was calculated through equation 1:

$$LDL = (DQ_{(0)} + 3\sigma_{DQ(0)}).b \qquad (1)$$

Where:

$DQ_{(0)}$: Mean optical density of non-irradiated dosimeters;

$\sigma_{DQ(0)}$: Standard deviation of the mean of non-irradiated dosimeters;

b : calibration factor - angular coefficient.

The angular coefficient/factor calibration was determined through to fit linear of electron dose response curve of Alanine Gel solution.

3. RESULTS AND DISCUSSION

3.1. Dose Response

The Alanine gel dose response curve is showed in figure 2. In the studied dose range, between 5 and 40 Gy, the signal response presents a linear behavior.

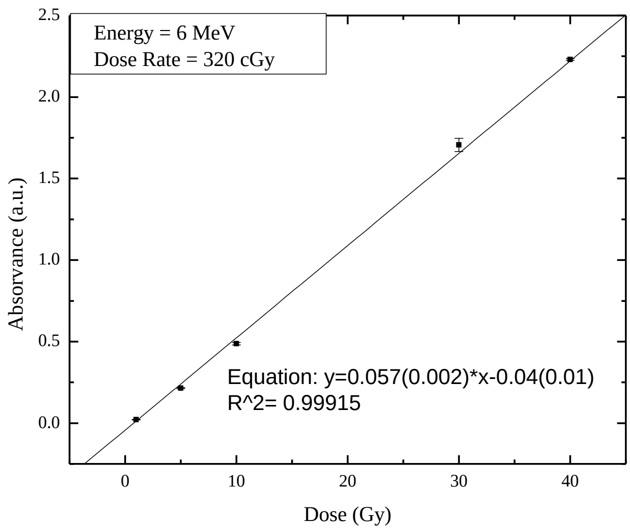

Figure 2. Electron dose response curve of Alanine Gel Solution.

3.2. Reproducibility

The intra-batch Alanine gel solution signal reproducibility to electron radiation was evaluated taking the standard deviation (1σ) of the mean of 5 different samples obtained from the same batch irradiated with doses between 5 and 40 Gy. The optical response presents intra-batch reproducibility better than 4%, presented figure 3. What it imply this dosimeter can be used in medical area.

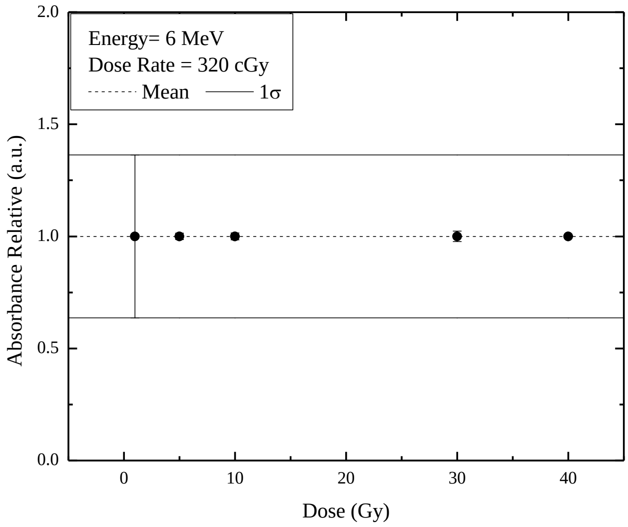

Figure 3. Intra-batch reproducibility of Alanine Gel Solution for electron radiation.

The inter-batches reproducibility was evaluated taking the standard deviation (1σ) of the mean of 5 different solution batches irradiated with doses between 5 and 40 Gy. The optical response presents also inter-batches reproducibility better than 5%, presented in figure 4.

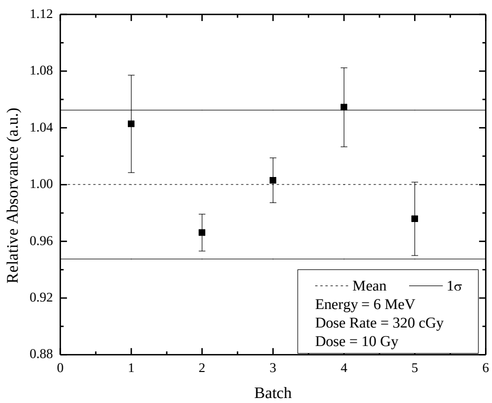

Figure 4. Inter-batches reproducibility of Alanine Gel Solution for electron radiation.

3.3. Lower Detectable Limit

According to table 3, the lower detectable limit of Alanine gel system for 6 MeV electron radiation is approximately 0.04 Gy.

Table 3. Lower detectable limit of Alanine gel system.

$DQ(0)$ (adm)	$\sigma_{DQ(0)}$ (adm)	b (Gy^{-1})	LDL (Gy)
0.700	0.002	0.057	0.040

4. CONCLUSIONS

According to the obtained results, Alanine Gel solution can be used as an alternative dosimeter with good precision in the dose range studied and could be used for application using the MRI technique for 3D dose distribution evaluation.

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REFERENCES

1. J. C. Gore, Y. S. Yang, and R. I. Schulz, "Measurement of Irradiation Dose distribution by Nuclear Magnetic Resonance (NMR) Imaging", *Physical Medical and Biology*,**Vol. 29**, pp 1189-1197 (1984).
2. M. J. Maryanski, R. J. Schultz, G. S. Ibbott, J. C. Gatenby, J. Xie, D. Horton and J. C. Gore, "Magnetic resonance imaging of radiation dose distributions using a polymer-gel dosimeter", *Physics Medical and Biology*, **Vol. 39**, pp 1437-1455 (1994).
3. E. Y. Mizuno, "Desenvolvimento e caracterização de um gel de alanina para aplicação na medida da distribuição da dose de radiação usando a técnica de espectrofotometria, Dissertação (Mestrado) –IPEN/CNEN-SP, São Paulo, 2007.
4. Z. M. Costa, "Desenvolvimento de Sistemas de DL-Alanina para dosimetria da Radiação Gama de Elétron", Dissertação (Mestrado) – IPEN/CNEN-SP, São Paulo, 1994.