ICMP2011
April 17-20 · Porto Alegre - RS - Brazil

Optical Response and Energy Dependent Response of the Alanine Gel Solution Produced at IPEN to Clinical Photons and Electrons Beams

Cléber Feijó Silva[1,2] and Letícia Lucente Campos[2]

[1] Faculdade Método de São Paulo – FAMESP / Radiologia, Sao Paulo, Brazil
[2] Instituto de Pesquisas Energéticas e Nucleares –IPEN / CNEN/SP, Sao Paulo, Brazil

Abstract— **The DL-Alanine ($C_3H_7NO_2$) is an amino acid tissue equivalent traditionally used as standard dosimetric material in EPR dosimetry. Recently it has been studied to be applied in gel dosimetry, considering that the addition of alanine in the Fricke gel solution improves the radiation induced ferric ions production. The spectrophotomety evaluation technique can be used comparing the two spectrum wavelengths bands: 457 nm band that corresponds to ferrous ions and 588 nm band that corresponds to ferric ions concentration to evaluate the dosimetric properties of this material. The performance of the Alanine gel solution developed at IPEN has been firstly studied using spectrophotomety technique aiming to apply this material to 3D clinical doses evaluations using MRI technique. In this work the optical response and energy dependent response of this solution submitted to clinical photons and electrons beams were studied.**

Different batches of gel solutions were prepared according to Mizuno (2007) and maintained at low temperature during 12 h to solidification. Before irradiation the samples were maintained during 1 h at room temperature. The photons and electrons irradiations were carried out using a Varian 2100 C Medical Linear Accelerator of the Radiotherapy Department of the Hospital das Clínicas of the University of São Paulo with absorbed doses between 1 and 40 Gy; radiation field of 10 x 10 cm^2; photon energies of 6 MeV and 15 MeV and electron with energies between 6 and 15 MeV.

The obtained results indicate that signal response dependence for clinical photons and electrons beams, to the same doses, for Alanine gel dosimeter is better than 3.6 % (1σ) and the energy dependence response, to the same doses, is better 3% (1σ) for both beams. These results indicate that the same calibration factor can be used and the optical response is energy independent in the studied dose range and clinical photons and electrons beams energies.

Keywords— **Alanine, 3D gel dosimetry, clinical beams, instrumentation, optical response.**

I. Introduction

Nowadays, 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, considering the absorbed dose delivered to the tumor, since with a lower dose the treatment has no effect, and a larger dose puts at risk who are healthy tissues around the tumor. It is therefore extremely important to create techniques that can be used to check the distribution of absorbed dose to the tumor and tissue around it. Among these radiation dosimetry techniques the Gel Dosimetry has been largely studied.

The first publication in Gel Dosimetry area was in 1984 by Gore et al [1], when the Fricke solution was incorporated into a gel matrix and this system was combined with magnetic resonance imaging to make possible three-dimensional radiation dosimetry. Therewith it was born the modern gel dosimetry [2]. Gel dosimeters have been studied using different compositions of the dosimetric solution and gel materials such as organic gels or polymer gels [3, 4]. The High Dose Laboratory of IPEN developed a alanine gel dosimeter based on the alanine dosimetric solution proposed by Costa (1994) [5] using spectrophotometry and electronic paramagnetic resonance – EPR evaluation techniques and improved by Mizuno (2007) [6] with the addition of gelatin at the dosimetric solution and using spectrophotometry as evaluation technique aiming to obtain a gel dosimeter enable to evaluate 3D dose distribution using MRI technique. The DL-Alanine ($C_3H_7NO_2$) is an amino acid tissue equivalent that improves the radiation induced ferric ions production, which can be estimated through spectrophotometry technique to measure the ferric ions concentration aiming to evaluate the dosimetric properties of this material.

In this work the optical response and energy dependent response of this solution submitted to clinical photons and electrons beams were studied, considering that these dosimetric properties are of crucial importance for characterizing and standardizing a dosimetric system [7].

II. Materials and Methods

A. Alanine gel solution

The dosimetric solution was prepared following the method described by Mizuno (2007) using 300 Bloom gelatin. The solution was conditioned in cuvettes 1 cm x 1 cm x 4.5 cm with optical path of 10^{-2} m and maintained at low temperature during 12 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	C (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

B. Samples Irradiation

The samples were always positioned on a specially designed acrylic support in a solid water RW3 phantom that consists of 30 x 30 x 30 cm^3 plates positioned on and under the acrylic support for guaranteeing the desired depth and backscattering conditions, presented in Figure 1.

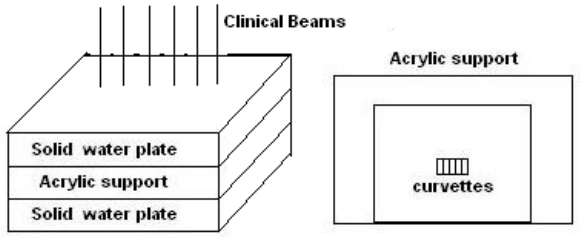

Fig. 1 Irradiation set up to photons and electrons irradiations

C. Photon and electron irradiations

The photons and electrons 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, radiation field of 10 x 10 cm^2, photon energies of 6 and 15 MeV, electron energies 6, 9 and 15 MeV, and dose rate of 320 cGy/min.

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.

D. 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

Each presented value is the average of 5 measures and the error bars the standard deviation of the mean.

III. Results

A. Absorbed Dose response

The Alanine gel dose response curves for clinical photon (6MeV) and electron (6MeV) beams are showed in figure 2 and 3, respectively.

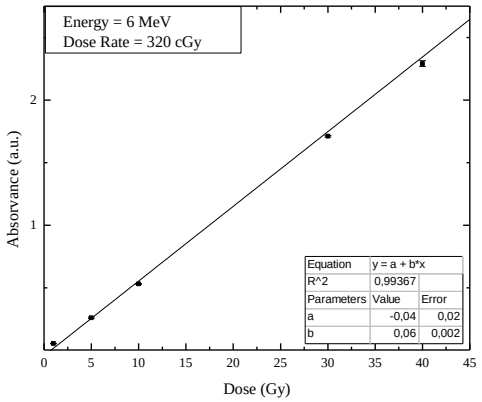

Fig. 2 Photon dose response curve of Alanine gel solution

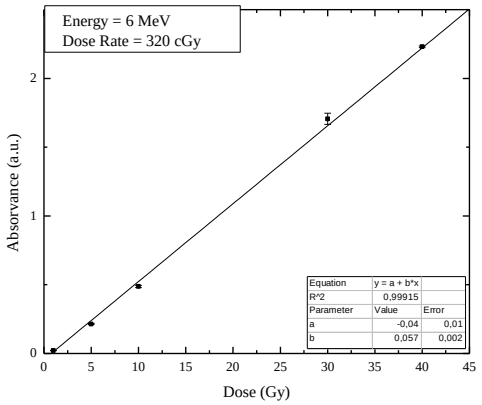

Fig. 3 Electron dose response curve of Alanine gel solution

B. Energy response

The Alanine gel energy response curves for clinical photons and electrons beams are showed in figure 4 and 5, respectively.

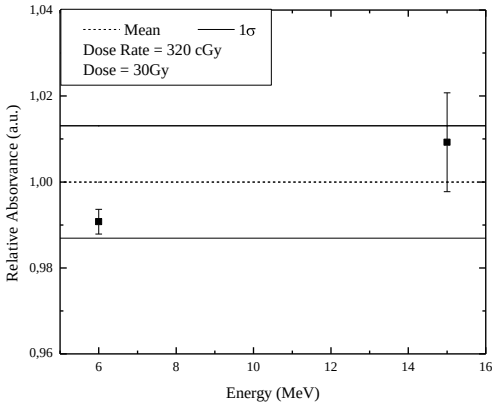

Fig. 4 Photon energy response curve of Alanine gel solution

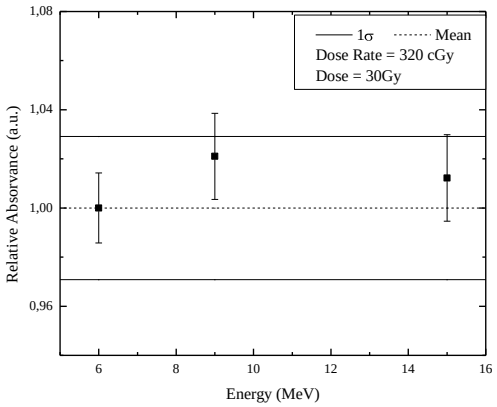

Fig. 5 Electron energy response curve of Alanine gel solution

IV. Discussion

A. Dose response

In the dose range studied, between 1 and 40 Gy, the optical response presents a linear behavior for both clinical beams. The optical response to the same doses of the Alanine gel solution for photons and electrons radiation is better than 3.6%, indicating that the sensitivity can be considered independent of the radiation type for the studied energies.

B. Energy response

The energy response of the Alanine gel solution to the same doses is better than 3% (1σ), indicating that the optical response can be considered independent of beam energy in the studied energy range.

V. Conclusions

The obtained results indicate that it is possible to evaluate the absorbed doses for both clinical photons and electrons radiation beams using the same calibration curve for different energies.

The obtained results indicate that the Alanine gel dosimeter presents good performance and can be useful as dosimeter in the radiotherapy area using MRI technique for 3D dose distribution evaluation.

Acknowledgment

The authors are thankful to Comissão Nacional de Energia Nuclear (CNEN), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and Faculdade Método de São Paulo (FAMESP) by the financial support, and to the Radiotherapy Department of the Hospital das Clínicas of the University of Sao Paulo for assistance during the samples irradiation.

References

1. Gore J C, Yang Y S, and Schulz R I (1984) Measurement of Irradiation Dose distribution by Nuclear Magnetic Resonance (NMR) Imaging. Med Phys 29:1189-1197
2. Baldock C Historical overview of the development of gel dosimetry a personal perspective. J Phys 56: 14-22
3. Uusi-Simola J,Sami Heikkinen S, Kotiluoto P, Serén T, Seppala T, Auterinen I, and Savolainen S (2007) MAGIC polymer gel for dimetric verification in boron neutron capture therapy. J.Appl Phys 8: 114-123
4. Guillerminet C, Gschwind R, Makovicka L, Spevacek V, Soukoup M, and Novotny J (2005) Comparative study for polyacrylamid gels and thermoluminescent dosimeters used in external radiotherapy. Rad Meas 39: 39-42
5. Costa Z M (1994) Desenvolvimento de sistemas de DL-Alanina para dosimetria da radiação Gama de Elétrons. Instituto de Pesquisas Energéticas e Nucleares, São Paulo
6. Mizuno E Y (2007) Desenvolvimento e caracterização de um gel de Alanina para aplicação na medida da distribuição da dose de radiação usando a trécnica de espectrofotometria. Instituto de Pesquisas Energéticas e Nucleares, São Paulo
7. Attix F H (1986) Introduction to radiological physics and radiation dosimetry. John Wiley and Sons, New York

CORRESPONDING AUTHOR:

Author: Cléber Feijó Silva
Institute: FAMESP
Street: Jabaquara Avenue, 1314 - Mirandópolis
City: Sao Paulo
Country: Brazil
Email: cfeijos@yahoo.com.br