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STABILITY STUDY OF THE ALANINE-EPR DOSIMETRY SYSTEM AT IPEN/CNEN-SP

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ABSTRACT

The dosimetry system using alanine-EPR is a standard secondary calibration system for high doses. IPEN's High Doses Dosimetry Laboratory (LDA) has an Electron Paramagnetic Resonance equipment operating in the X-band which performs high-dose dosimetry service for electron and X-ray fields for the dose range of 10Gy to 200kGy. IPEN has established a dosimetry system based on an alanine dosimeter developed at the institute. The system is composed of pure DL-alanine encapsulated in a polyethylene microtube, which allows estimated doses of 10Gy to 200kGy. The advantages of this system are the low signal fading over a long period of time (over 90 days) and dose measurements above 150kGy. The main disadvantage is the difficulty in measures below 10Gy. In order to improve quality assurance services delivered in radiotherapy, commercial alanine dosimeters are being tested and compared with the already established system for measurements with time intervals longer than 90 days. The present work is an evaluation of the commercial L-alanine dosimeter signal compared to the alanine dosimeter produced in IPEN. The dosimeters were irradiated with X-ray and E-beam and doses of 1, 10 and 20Gy. All measurements were performed following the same laboratory protocol based in ISO/ASTM guidelines. Environmental effects such as temperature, sensitivity to light and air humidity, and other storage conditions were evaluated. The results show that the decay of commercial dosimeters over 36 months was 11% higher than that observed in the dosimeter developed in IPEN, indicating the need for a correction factor for the comparison of dosimetry systems.

1. INTRODUCTION

The alanine-EPR is a standard secondary calibration system for measuring the absorbed dose in photon and electron radiation processing dose levels. Electron paramagnetic resonance (EPR) spectroscopy is a method for studying materials with free radicals (unpaired electrons). The system is based on the EPR quantification of free radicals formed in the irradiated alanine. The alanine dosimetry is a robust and consolidated technic and has been accepted for applications in transfer and high dose dosimetry, covered the range of 10-10^5Gy[1]. The advantages of the alanine dosimetry system are: tissue-equivalent properties; nondestructive readout; no effects of the absorbed dose rate and radiation energy and free radical stability[1,2].

IPEN has established a dosimetry system based on an alanine dosimeter developed at the institute. The system is composed of 120mg of DL-alanine encapsulated in a 30mm length polyethylene microtube, which allows estimated doses of 10Gy to 200kGy[2]. The advantages of this system are the low signal fading over a long period of time (over 90 days)

and dose measurements above 150kGy. The main disadvantage is the difficulty in measures below 10Gy.

In order to improve quality assurance services delivered in radiotherapy, commercial alanine dosimeters are being tested and compared with the already established system for measurements with time intervals longer than 90 days. The study was divided into 2 distinct experiments. The first experiment involved the irradiation of commercial L-alanine and DL-alanine dosimeters produced by IPEN and irradiation follow-up for a period of approximately 36 months. The second experiment was to evaluate the background signal of non-irradiated commercial alanine pellets. Commercial pellets produced by Gamma-Service were purchased from Bruker BioSpin (batch no. T020604). Similar studies are being carried out by the world's leading laboratories to improve the quality of alanine dosimetry results[3-5].

2. MATERIAL AND METHODS

2.1. Alanine dosimetry

The alanine-epr dosimetry is based on the quantification of free radicals formed in the detector after irradiation. Figure 1 shows the spectrum of a 20Gy irradiated alanine of Co-60. The peak-to-peak height (*hpp*) of the main spectrum feature is evaluated and associated with the radiation dose.

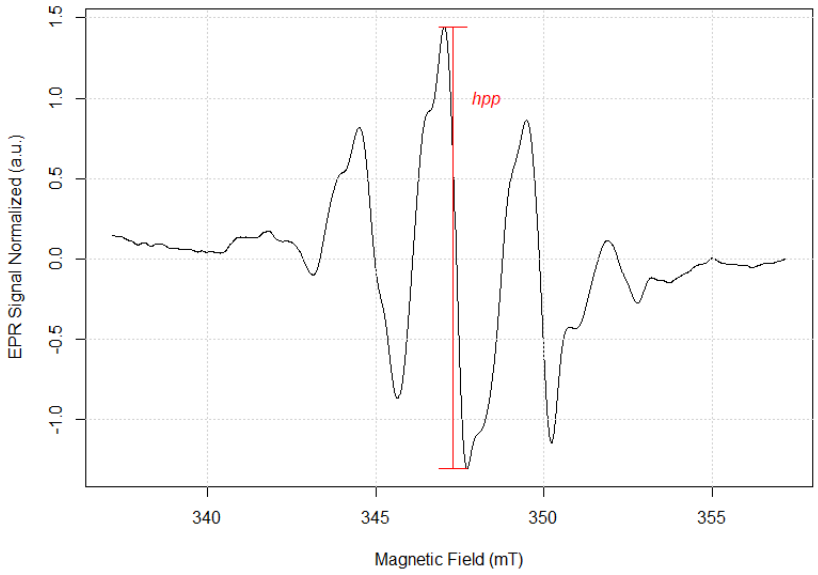

Figure 1: EPR spectrum of alanine with a dose of 20Gy.

In this study, two types of dosimeters were monitored, those produced at IPEN (DLA) and those purchased from Bruker BioSpin (AGS). The dosimeters produced at IPEN consist of approximately 120mg DL-alanine packed in a 30mm polyethylene microtube paraffin sealed. The AGS dosimeters are 64.5g mass (approximately 62g of L-alanine), packed with an aggregate material in the form of a pellet of 3mm height and 4.8mm diameter. The DLA

and AGS dosimeters were packed in a PMMA sample holder to ensure the electron equilibrium condition for the Co-60. AGS dosimeters are made up of 4 stacked pellets.

2.2. Irradiation

The dosimeters were irradiated in IPEN Co-60 sources (CTR and LCI laboratories) in sample holder for electron equilibrium conditions. Temperatures during radiation do not exceed 35^{o}C.

2.3. EPR readout

EPR measurements were performed using Bruker EMX PLUS spectrometer equipment operating in the X-band, under ambient laboratory conditions, with room temperatures between 20 and 22^{o}C and relative air humidity between 50 and 70%. For all measurements in the EPR, the standard sample provided by Bruker called the strong pitch (SP) was used. The SP was measured at the beginning and end of measurements. The protocol follows the recommendations of the ASTM standard, with adaptations for the experiment. Table 1 presents the main parameters used to perform the measurements[5].

Table 1: EPR parameters settings.

Parameter	Value
Frequency Modulation	100kHz
Modulation Amplitude	0.4mT
Sweep Width	20mT
Microwave Power	2.0mW
Sweep	10
Conversion Time	16.12ms
Sweep Time	20.15s
Time Constant	81.92ms
Resolution (points)	1250

Results were normalized by the alanine mass of each DLA or AGS dosimeter and by measurements with the standard SP. The 4 AGS pellets were measured one at a time, being rotated 3 times (1 measurement every 120°). The final dosimeter result was the average of these measurements.

3. RESULTS AND DISCUSSION

3.1. Alanine post-irradiated study

The 28 dosimeters were divided into 2 groups and were monitored for 36 months. The first group of 16 dosimeters produced at IPEN (DLA dosimeters) was manufactured and divided into two subgroups: 8 dosimeters were stored without additional protections besides the polyethylene microtube (that is part of the dosimeter), and 8 were irradiated with 10Gy and stored under the same conditions as the non-irradiated subgroup. The detectors were

measured monthly. Figure 2 presents the results of normalized measurements according to the established protocol.

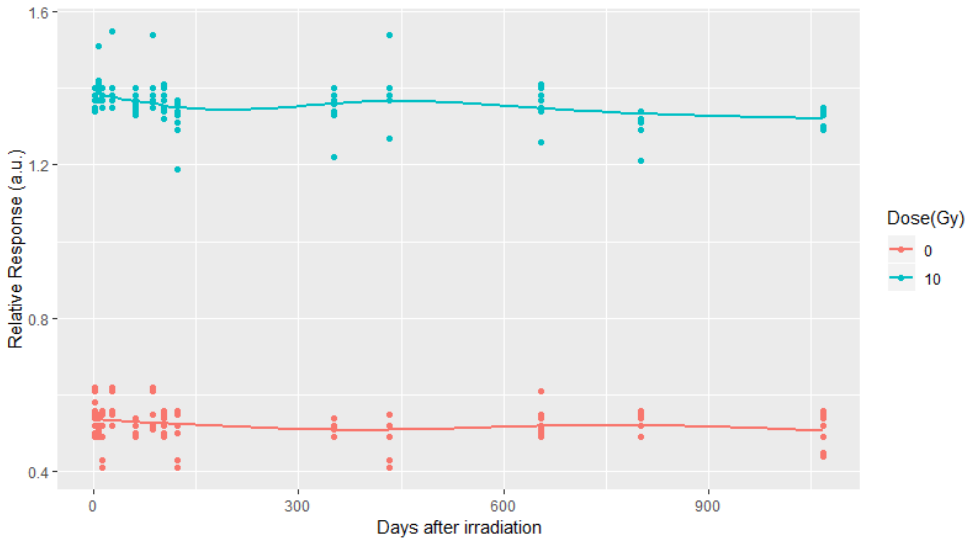

Figure 2: Relative Response DLA dosimeter.

The second group of 12 AGS dosimeters (4 pellets per dosimeter) was measured before irradiation for the establishment of the batch background signal, irradiated with doses of 10, 20 and 50 Gy in Co-60, and monitored over 36 months. The dosimeter storage followed the same conditions as the previous DLA dosimeter group. Figure 3 presents the results of normalized measurements according to the established protocol.

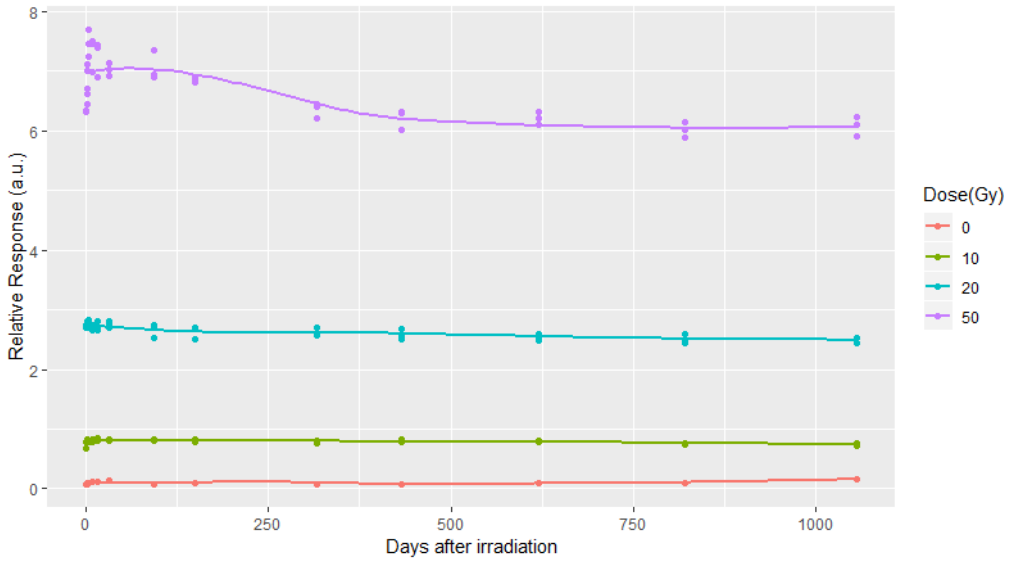

Figure 3: Response relative AGS dosimeter.

As it can be seen in Figure 2, DLA dosimeters have good stability over time, but the accuracy of measurements is affected by the difficulty in manufacturing dosimeters. This results in greater dispersion of results. Figure 3 shows that dosimeters composed of AGS pellets showed good stability. Only the 50Gy irradiated set had a signal fading of about 11% higher

than that observed in the dosimeter developed in IPEN, due to the interaction of the dosimeter with the environment, since the alanine in these dosimeters is not confined.

3.2. Alanine Pellet Long-Term Response

For the second experiment, 4 AGS alanine pellets were selected. Two pellets were packaged in a clear polypropylene bag and left in the office's temperature and lighting conditions without additional protections. Two pellets were stored in light-protected box in eppendorf tubes and stored under laboratory conditions. These pellets were followed for about 3.5 years, with measurements every 3-4 month intervals.
Figure 4 shows the behavior of AGS pellets during the test for both conditions: **exp** for pellets stored in polypropylene bag and placed in the office without lighting, temperature and humidity control and **lab** for pellets stored under controlled laboratory conditions. The confidence interval around curve fitting is show in gray band.

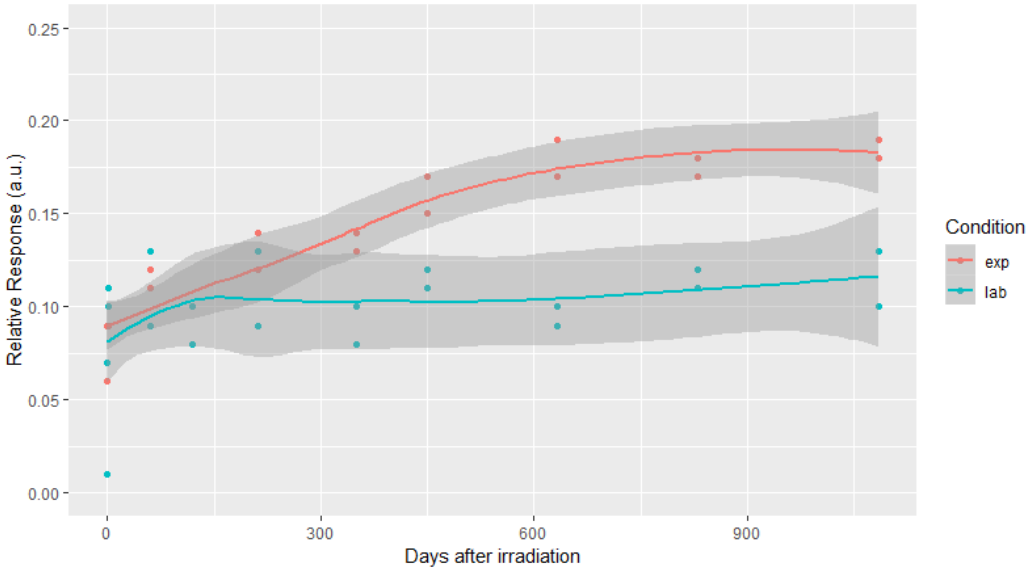

Figure 4: Long term response of non-irradiated AGS pellets.

Analysis of the impact of storage conditions indicates that it is possible to store non-irradiated lots for a long period of time without significant impact on the results. An additional precaution to guarantee the quality of the results of the stored samples is to take measurements of the non-irradiated AGS alanine, in order to establish the batch background with each new use.

3. CONCLUSIONS

The study of AGS alanine pellets indicated good performance over time comparable to the DLA dosimeter developed at IPEN. This study is important to advance in improving the lower dose limit for radiotherapy applications.

ACKNOWLEDGMENTS

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