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# EPR study of dosimetric properties of glucose irradiated by X-photons and electrons: Analyse of storage effect on produced free radicals

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ABSTRACT

Electron Paramagnetic Resonance “EPR” measurements were undertaken on powder glucose irradiated by X photons and electrons in order to study its dosimetric properties and evaluate its spectral behaviour in the field of radiotherapy. Dose-response evolution and the impact of storage on irradiated samples were analysed using peak to peak amplitude and double integration method. The obtained measurable threshold dose is 2 Gy. The dependence of the EPR signal as function of the absorbed dose was found to be linear in the dose range 0 – 20 Gy for all used energies. An effect of the type of radiation on the sensitivity is observed, glucose seems to be slightly more sensitive to X photons irradiation than to electrons. The investigations of shape and intensity of EPR signals during storage period of twelve months revealed a consequent radical activity, probably due to two major free radicals produced by irradiation. The signal height of one of the EPR components increases significantly during the first two months after irradiation, and then stabilizes.

## 1. Introduction

Electron Paramagnetic Resonance spectrometry of several materials, in which stable free-radicals are created, has becomes a useful technique for dosimetry purposes over a vast dose range (McLaughlin and Desrosiers, 1995; Schauer et al., 2006). It provides absorbed dose measurements through the detection and evaluation of the free radicals in the sample under consideration (Regulla, 2000). This technique may detect unpaired electrons of free radicals and it can be considered fast, precise, applicable at large interval dose (few Gy - several kGy) and compared with other dosimetric methods such as thermo-luminescence and optical stimulated luminescence (Costa et al., 2010; Vestad et al., 2004; Jursinic, 2007) it is a non-destructive method that allows to reread the dosimeter if necessary. Thus, elaborated EPR studies of irradiated organic substances such as amino acid derivatives (Osmanoglu and Sütcü, 2017), alanine (Khoury et al., 2015; Marrale et al., 2016) and table sugar (Ghosne et al., 2011; Mikou et al., 2015), or inorganic ones such as formates, phenol, sulfanic acid and strontium sulphate (Aboelezz et al., 2015; Bartolotta et al., 2001; Maghraby and Tarek, 2006; Marrale et al., 2014; Nor et al., 2016; Rushdi et al., 2015; Waldeland et al., 2011) have revealed that EPR technique coupled with these materials can provide reliable dosimeters in radiotherapy and in radio-sterilization fields.

Glucose is another organic material, available, non-toxic and it is interesting to study its dosimetric properties. The previous works conducted on this irradiated material showed that probably two free radicals are produced at low temperature (Pauwels et al., 2006). Glucose exhibit linear EPR response in a large dose range (Mikou et al., 2014) and it is affected by storage time after irradiation (Hervé et al., 2006; Piroonpan et al., 2017; Yordanov and Georgieva, 2004). It should be noted that previous studies have not sufficiently analysed the effect of the nature of the irradiating particle on the dosimetry curves sensitivity. Similarly, the spectral evolution of glucose as a function of the storage time after irradiation has not been accurately treated.

The aim of this work is to analyse and compare the dosimetric properties of glucose irradiated by high energy X photons (6 and 18 MV) and accelerated electrons (6 and 18 MeV), using EPR spectroscopy measurements. Thus, the measurable threshold dose was determined and the variation of EPR signal intensity according to the absorbed dose up to 20 Gy for each new energy has been evaluated. For dosimetric considerations, it is essential to analyse the stability of the EPR signal during the storage period after irradiation. Given the complexity of the signal measured on irradiated glucose, a careful exploration of the storage effect after irradiation is performed on this material. This study was undertaken by regularly examining the spectral evolution of the EPR signal during twelve months of storage period.

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All these measurements have been processed by evaluating the peak-to-peak amplitudes of two main observed lines, and also by calculating the area under EPR absorption spectrum using the double integral method.

## 2. Materials and methods

### 2.1. Sample irradiation

Glucose from origin Rectapur-Prolabo France was irradiated by X-rays photons (X-6 and X-18) and electrons (E-6 and E-18) delivered by a linear accelerator Clinac 2300DHX (Varian Medical Systems, Inc., Palo Alto, CA, USA) used for radiotherapy at oncology hospital of Fez-Morocco. Several samples of 500 mg were irradiated to doses in the interval dose of 1–20 Gy. Irradiations were performed into a PMMA phantom at depth 1.4 cm for X-6, 3.3 cm for X-18, 1.2 cm for E-6 and 3 cm for E-18 corresponding to the maximal deposited dose for used energy. The irradiation field was $10 \times 10\ cm^2$, and the distance from irradiation source to phantom surface is 100 cm.

### 2.2. EPR measurements

EPR measurements and evaluation of free radicals produced by irradiation were undertaken using a Magnettech-MS400 (Berlin, Germany) spectrometer, operating in X band. $200 \pm 1$ mg of irradiated glucose was filled in quartz tubes with an inner diameter of 4 mm. EPR spectra were recorded using a microwave power of 1 mW, modulation amplitude of applied magnetic field of 0.5 mT, time constant of 0.1 ms, gain of 200 with a resolution of 4096 points. The temperature was fixed at about 23 °C in the outside of the spectrometer. These recording were optimised to acquire a good signal-to-noise ratio while avoiding saturation and distortion of the spectrum form (Mikou et al., 2014). For regular calibration of the EPR spectrometer, a calibration sample of 1,1-diphenyl-2-picrylhydrazyl DPPH (EPR resonant signal: microwave frequency of 9.43 GHz, g-factor = 2.0036) was daily used to check the stability of the magnetic field and the resonance frequency. This sample is also used to correct the intensity fluctuations of EPR measurements.

Using the optimal dosimetric parameters, we analysed the dose response of glucose samples after irradiation by X photons and electrons. EPR measurements were carried out several times (24 h, one month, three months and six months) after irradiation. For every irradiation dose, four samples were analysed to check the statistical reproducibility and to evaluate the measurement dispersion. The EPR measurements were treated by peak-to-peak and double-integration methods.

For the study of the stability of glucose irradiated by photons and electrons. Four lots of samples have been considered, two lots were irradiated by photons (X-6 and X-18) with doses 2, 6, 10, 15 and 20 Gy, while the other ones were irradiated by electrons (E-6 and E-18) with doses 3.5, 6, 10, 15 and 20 Gy. These twenty samples were stored in closed tubes at room temperature and protected from light and moisture. EPR measurements were started one day after irradiation and analysed at different times during a period of twelve months.

## 3. Results and discussion

### 3.1. EPR spectrum of glucose

As known, the primary spectrum obtained by EPR measurements is the first derivative of the absorption spectrum. The amplitude of this spectrum could be assessed by measuring the peak-to-peak height (HPP) as shown in Fig. 1; or carrying out its double integration to evaluate the area under the absorption spectrum. This second method takes into account the contribution of all radiation-induced species in glucose (Fig. 2).

Fig. 1 shows the EPR spectra of glucose measured one day after irradiation by 6 MV X photons (Dose: 1–6 Gy). The background signal measured on non-irradiated sample was subtracted from spectra

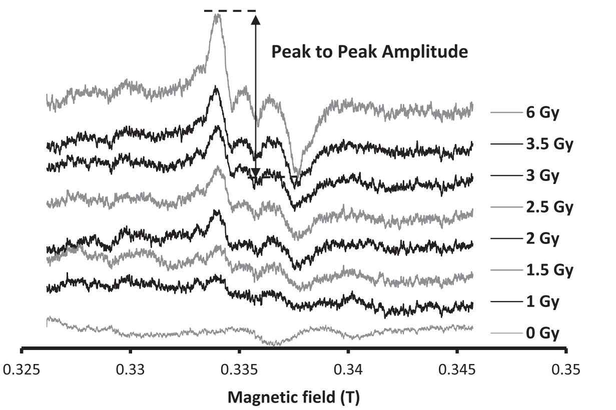


**Fig. 1.** EPR spectra of glucose irradiated to 6 MV X-ray, recorded with modulation amplitude of 0.5 mT and microwave power of 1 mW.

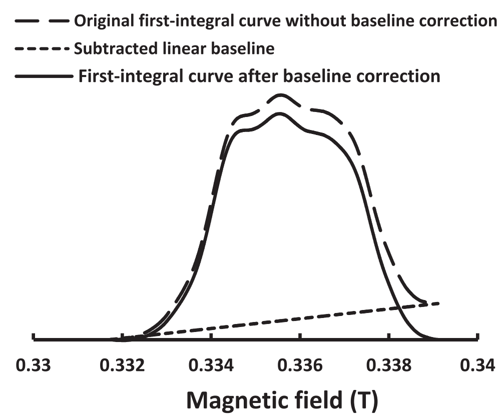


**Fig. 2.** First-integral curve of a 20 Gy EPR spectrum of glucose before and after baseline correction.

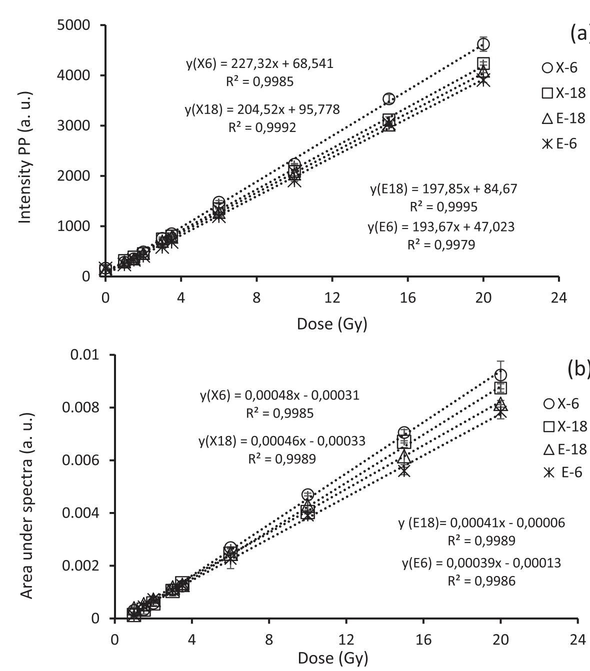


**Fig. 3.** EPR response of glucose versus absorbed dose measured at the same interval time after irradiation by X-photons and electrons using peak to peak method [a] and double integration method [b].