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Development of Sugar as Calibration Radiation Dosimeter with ESR Technique

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ABSTRACT

At the present, Red Perspex dosimeter, which is a common calibration radiation dosimeter, is very expensive. Instead of using Red Perspex dosimeter, a new technique for detection of radiation by using a new calibrator especially of various types of sugar and electron spin resonance spectroscopy (ESR) was challenged for the test. In the study, many types of sugar consisting of white sugar, icing sugar, and sucrose were tried as calibration radiation detectors by irradiation with gamma ray at 10 and 50 kGy and thus applying with electron spin resonance spectroscopy (ESR) technique at different microwave power from 0.02. In the detection by calibrating with sugar and further using ESR technique compared with the Red Perspex and UV spectroscopy, the average percentage errors of sucrose, icing sugar, and white sugar dose were 6.0, 8.0 and 25.0 respectively. In this case, sucrose and icing sugar, representing such low percentage errors, were tentatively a practical calibration radiation dosimeter together with ESR spectroscopy.

Key words: Sugar dosimeter, Icing sugar, sucrose, radical, ESR

INTRODUCTION

In general of calibration radiation dosimeters use many materials. Red Perspex is one of dosimeter that use wildly in this field. It has high accuracy and precision [3]. But the high cost has main disadvantage of Red Perspex. Office of Atom for Peace of Thailand is radiation quality control and calibrates radiation dosimeter. Then Office of Atom for Peace of Thailand use Red Perspex at about of many kilograms in daily. To overcome the disadvantage of Red Perspex, the new materials were find and research. Sugar has high crystallinlity and low price. Moreover it has been reported that sugar is one of the best dosimetric materials for use in emergency dosimetry [1]. Electron spin resonance is a physics method in study of free radical that is excited under a magnetic filed by microwave absorption to a high energy state. This absorption is measured as a function of magnetic field in ESR spectroscopy [4,2]. The ESR is applying to radiation dosimeter. In this study, ESR dosimetric characteristics of sugars are investigated in detail and reported, in the hope of using sugar and ESR technique as ESR dosimeter.

Materials and Methods

Materials:

In this work three types of sugar were selected and studied: white sugar was purchased from the local market in Bangkok of Thailand that made from united farmer and industrial company Co., Ltd., icing sugar was purchased from Imperials Royal Food Industry Company and sucrose was obtained from Ajax Finechem Pty Ltd.

Preparation of samples:

All the samples were grinded to less than 250 µm using agate mortar and pestle and preserved in an oven at 50 °C. The samples of 25 g weight placed in polyethylene bag and irradiated by γ-ray from a source of ^{60}Co at room temperature with doses 1 and 50 kGy for calculated microwave power of ESR read out. Moreover the sample irradiated with doses from 1 to 50 kGy for study on dose response.

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ESR test:

The ESR measurements were carried out with a Brucker spectrometer and operating in X band. All ESR measurements of the samples were obtained at room temperature and open in air. Sample of 1.0 g placed in a 3 mm internal diameter quart ESR tubes and centered in the cavity. Each sample was measured three times. An average of three such measurements was used for each data point. The spectrometer operating conditions adopted during the experiment were 352.5 mT central magnetic field; 20 mT scan range; 9.6 GHz microwave frequency and vary microwave power from 0.02 to 10.00 mW.

Results and Discussions

ESR spectra:

The samples of different sugar (white sugar, icing sugar and sucrose) used in this study were studies in parallel. Before irradiation all the studies samples were ESR silent. While ESR signal appears after grinding of sugar as show in Fig. 1. The shape and g-value (g = 2.0035 ± 0.0002) of this mechanically induced ESR spectrum fully coincide with gamma radiation induced one. The intensity of the mechanically induced EPR spectrum depends on the applied power of crystals crushing and can become equivalent to ca [6]. After radiation, ESR signals at 2.0035 due to free radical and a very weak [1].

Variations in ESR spectra with microwave power:

The sugar sample irradiated to a dose of 1.0 and 50.0 kGy were investigated in microwave power ranges of 0.02–10.00 mW. The signal intensity, peak to peak amplitude of the first derivative normalized by the weight of all the samples, as a function of microwave power is shown in Fig. 2. As it is seem from the figure, the behavior of all the samples with incident microwave power was similar [5]. The intensity increasing linearly with microwave power until 2.0 mW and be come to saturation. A microwave power of 4.0 mW was adopted throughout the experiment.

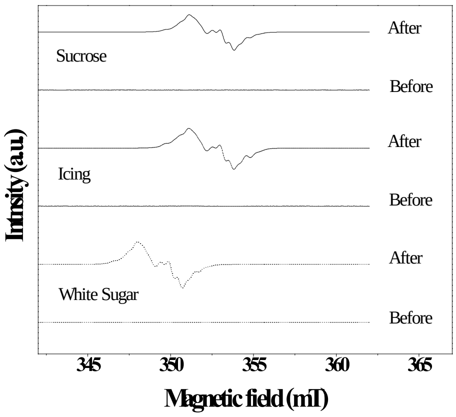

Fig. 1: ESR spectra before and after irradiation dose of different sugar

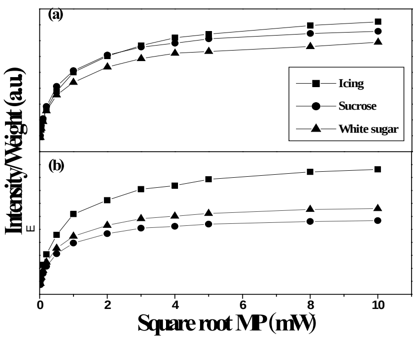

Fig. 2: The signal intensity of all samples as a function of microwave power after radiation dose (a) 1 kGy (b) 50 kGy

Dose response curve:

The samples irradiated to dose of 1, 3, 5, 7, 10, 20, 30, 40 and 50 kGy was used to construct the dose response curve. The variation of peak to peak signal intensity with the applied radiation dose was given in Fig. 3. Several mathematical function were tried to fit the experimental dose response data to describe the variation of signal intensity with absorbed radiation dose. The best correlation is obtained for second degree polynomial varying function as $y = a + bx + cx^2$ given in Fig. 3. In this function, y and x represent the ESR signal intensity and applied radiation dose in kGy, respectively, and the parameter a, b and c are constant to be determined. The parameter a in this function representing the ESR signal intensity at zero applied dose mean that the relative amount of free radical species of unirradiated sample and parameter b and c represent the rate of radical production and radiation yield upon irradiation at room temperature. The parameter of a, b and c of white sugar, icing sugar and sucrose calculated from fitting procedures was found to be $8x10^{10}$, $3x10^{10}$ and $8x10^7$ (r^2 = 0.994), $6x10^{10}$, $5x10^{10}$ and $6x10^7$ (r^2 = 0.997) and $5x10^{10}$, $4x10^{10}$ and $-9x10^7$ (r^2 = 0.999), respectively. Table 1 shown the dose calculated from polynomial function and table 2 shown the percentage errors applied dose.

Table 1: Radiation dose calculate from curve with ESR spectra and radiation dose of diferent sugar

Dose(kGy)	Dose from ESR (kGy)		
	White Sugar	Icing	Sucrose
1	-0.750	-0.003	0.138
3	1.879	2.587	3.198
5	4.322	4.543	5.615
7	5.721	7.582	6.936
10	9.655	9.509	11.509
20	19.216	18.110	21.807
30	24.780	25.991	32.656
40	37.396	34.539	41.303
50	48.204	44.217	51.757

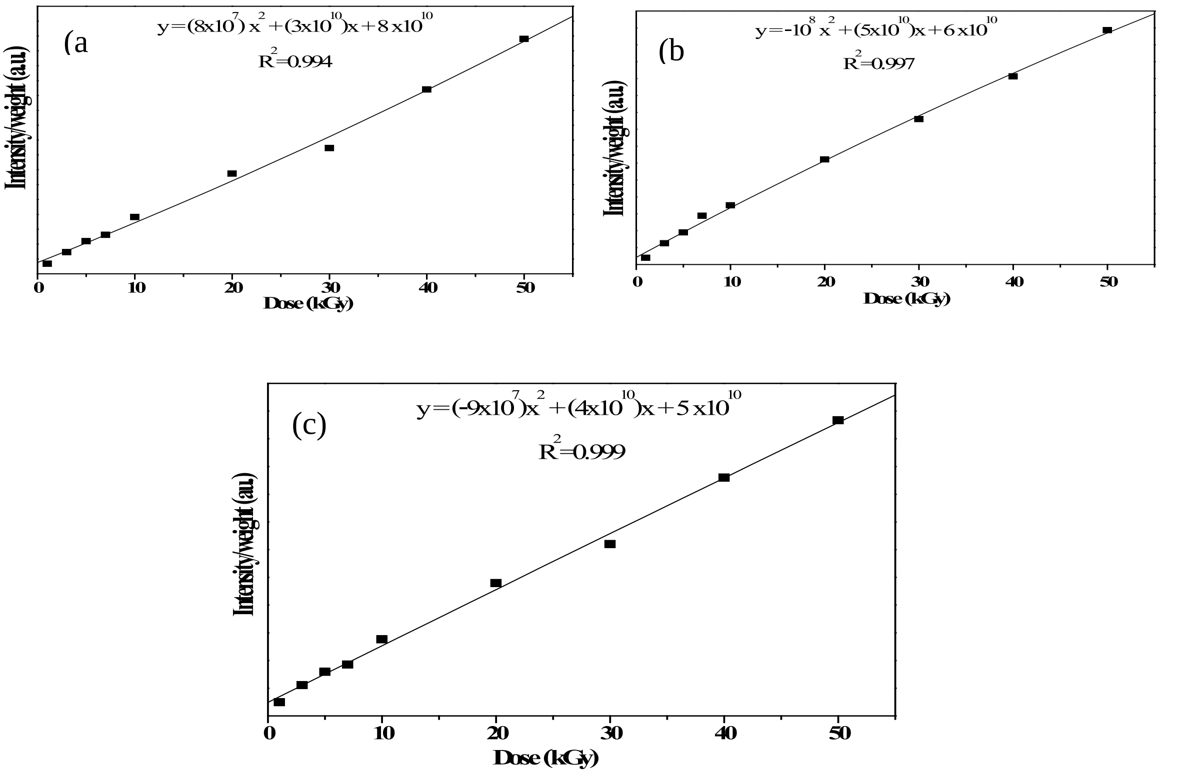

Fig. 3: The variation of peak to peak signal intensity with the applied radiation dose (a) 1 kGy (b) 50 kGy

Comparison between ESR and Red Perspex response of irradiated sugar:

Red Perspex dosimeter is common calibration radiation dosimeter and high accuracy, but Red Perspex has to calibration radiation minimum at 5 kGy only. The results from Red Perspex dosimeter were compared with the results from EPR measurement of different sugars as shown in table 3 and percentage error of different sugar given in table 4. The result shows that percentage error of sucrose less than another sugar with radiation dose rage 10 to 50 kGy. The sucrose was produced and purify by different manufactures than another sugar. The possibility of the inclusion of eventual impurities was considered. Such impurities may introduce extraneous free radicals, often difficult to be accurately evaluated [1].

Table 2: The percentage errors applied dose of diferrent sugar

Dose(kGy)	% Error		
	White sugar	Icing	Sucrose
1	-175.028	-100.309	-86.211
3	-37.378	-13.770	6.591
5	-13.550	-9.147	12.306
7	-18.266	8.308	-0.911
10	-3.453	-4.914	15.092
20	-3.919	-9.449	9.037
30	-17.400	-13.363	-8.583
40	-6.511	-13.653	3.257
50	-3.592	-11.565	3.514

Table 3: Radiation dose from Red Perspex dosimeter and EPR measurement of different sugars

Dose from Red Perspex (kGy)	Dose from ESR (kGy)		
	White sugar	Icing	Sucrose
5	5.680	4.654	4.577
10	12.510	10.806	10.323
20	23.276	21.390	20.110
30	28.920	31.001	30.093
40	40.549	41.326	37.826
50	49.564	52.879	46.928

Table 4: Radiation dose percentage errors from Red Perspex and different sugars

Dose from Red Perspex (kGy)	% Error		
	White sugar	Icing	Sucrose
5	13.596	6.925	-8.463
10	25.102	8.057	3.229
20	16.380	6.948	0.549
30	-3.600	3.338	0.310
40	1.374	3.315	-5.434
50	-0.872	5.758	-6.145

Conclusion:

Using ESR technique, the dosimetric characteristics of three type sugars were investigated. The radiation induced the g = 2.0035 of three types of sugar. The microwave power was optimized at 4 mW for ESR read out. Three types of sugar were irradiation from 1 to 50 kGy and analyzed by ESR. The result shows that percentage error of sucrose dose less than another sugar. In the detection by calibrating with sugar and further using ESR technique compared with the Red Perspex and UV spectroscopy, the average percentage errors of sucrose, icing sugar, and white sugar dose rage 10 to 50 kGy were 6.0, 8.0 and 25.0 respectively. In this case, sucrose and icing sugar, representing such low percentage errors, was tentatively a practical calibration radiation dosimeter together with ESR spectroscopy.

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