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# Response of 2-Hydroxymethyl Methacrylate Polymer Gel Dosimeter with Maltose Additive for Radiation within Diagnostic X-Ray Energies

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**ABSTRACT:** The use of polymer gel dosimeters (PGD) in x-ray radiography has not yet been confirmed. However, if it could be applied, it could help to improve patient dosimetry, dose optimization, and quality assurance through its three-dimensional (3D) image display. This research aimed to evaluate the response of a 2-hydroxymethyl methacrylate (HEMA) polymer gel dosimeter at lower energies for possible use in diagnostic x-ray radiography and to determine the effect of maltose concentrations on the sensitivity. The dosimeter was made under normoxic conditions using Gelatin, HEMA, N, N'- Methylene – bis – acrylamide (BIS), Ascorbic Acid, deionized water, and maltose of various concentrations (10 – 50 mM). The PGDs were then irradiated using a conventional x-ray machine with exposure settings ranging from 10-200 mA, 40-100 kV, and s = 1 s. Afterward, the irradiated dosimeters were scanned using UV-spectroscopy. The result showed that the dosimeters responded to low-energy x-rays, and the effect of the maltose concentration within the tested range was not linear with the sensitivity. We concluded that the HEMA polymer gel dosimeter could be used for clinical x-ray dosimetry, but further research on the effect of maltose concentrations on the sensitivity is needed.

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Polymer gels are becoming increasingly popular for radiation dosimetry due to their ability to accurately assess radiation doses in 3D with high spatial resolution (Mohammad and Abtahi, 2019). They are commonly used in radiotherapy to ensure that the required dose is delivered accurately to the target tissue without affecting healthy tissue (Alyani Nezhad and Geraily, 2022). However, the use of PGDs for conventional x-ray radiography is not common; it is superseded by one-dimensional (1D) dosimeters such as ion chambers and Thermoluminescences Dosimeters (TLDs) and two-dimensional (2D) dosimeters such as radiographic films. For an accurate PGD, the dose distribution and representation shall be a function of the absorbed dose and in linear manner (Alyani Nezhad and Geraily, 2022). To achieve this, researchers have proposed the addition of inorganic salts in PGDs such as VIPET in which magnesium chloride was added to formed iVIPET. The addition of the salt resulted in up to 3.4 times more sensitivity than that of the VIPET (Watanabe et al., 2019). But this approach has a drawback, as addition of inorganic salts such as magnesium chloride ($MgCl_2$), Calcium Chloride ($CaCl_2$) and Manganese Chloride ($MnCl_2$) was reported to deteriorate the rigidity of PGDs based on acrylamide (Chacón et al., 2018). The idea of

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adding saccharides, like glucose then arose in order to improve the melting point (Al-jarrah et al., 2016). Previous works show that addition of glucose into Methacrylic acid PGD improves both the sensitivity and melting point of the gel and also make its elemental composition to resemble that of soft tissue (Al-jarrah et al., 2016). Also increasing the concentration of organic molecules soluble in water, such as glycerol, and isopropanol has shown a promising result (Al-jarrah et al., 2016). In this study, we evaluated the response of HEMA PGD with maltose additive for radiation dosimetry within x-ray diagnostic energies.

## MATERIALS AND METHODS

*Samples Preparation:* Five (5) sets of polymer gel samples A, B, C, D and E were prepared using the compositions given in Table 1. The gelatin was initially dissolved in 50% of the total deionized water at room temperature and allowed to swell for 10 minutes. The mixture was then heated to 48°C while stirring with a magnetic bar stirrer until a clear solution was obtained. The cross linker, BIS was dissolved in another 40% of the total deionized water at room temperature and heated to 48°C using a magnetic bar stirrer. Once a clear solution was obtained, the temperature setting was adjusted, and the two mixtures were mixed together when both were at 37°C. Then, 10 mM of maltose was added to the mixture and stirred continuously. When the temperature of the mixture dropped to 30°C, the monomer HEMA was added, and finally, 10 mM of ascorbic acid was dissolved in the remaining 10% of the total water and added to the mixture. The mixture was then stirred for another 10 minutes to obtain the prepared gel recipe. The gel recipe was poured into 4.5 mL cuvettes and tightly covered with parafilm.

The procedure was repeated with maltose concentrations of 20 mM, 30 mM, 40 mM, and 50 mM. The samples were stored inside a refrigerator maintained at 4-6°C for 24 hours before irradiation.

*Samples Irradiation:* The samples were exposed to radiation using a conventional x-ray machine. The machine settings used were mA = 10 - 200, kV = 40 - 100 V, and s = 1 s. The cuvettes containing the gel dosimeters were arranged within the collimation area, in a rectangular array of 10 x 10 $cm^2$, on the table, which was placed 100 cm away from the x-ray source. An ionization chamber connected to an electrometer was placed at the midpoint of the cuvettes to measure the absorbed dose.

The absorbed dose values were displayed on the digital screen of the electrometer. The background radiation was automatically subtracted from the absorbed radiation, and the doses were recorded for each exposure.

**Table 1**: Compositions of the manufactured PGDs.

| Component | Amount |
|---|---|
| Gelatin | 5 % (w/w) |
| BIS | 3 % (w/w) |
| HEMA | 4 % (w/w) |
| Ascorbic Acid | 10 mM |
| Maltose | 10 – 60 mM |
| Water | 82 % (w/w) |

**Fig 1:** Sample preparation on magnetic stirrer hot plate.

*PGDs Dose Readout:* The UV-Visible Spectroscopy was utilized to measure the absorbance in relation to wavelength. The maximum absorbance was recorded, and the change in absorbance at $\lambda_{max}$ due to the variation in maltose concentration was determined for each sample. The change in absorbance was plotted on the vertical axis, while the absorbed dose was plotted on the horizontal axis for each case, and the resulting Dose-Absorbance (D – A) graphs were analyzed.

## RESULT AND DISCUSSION

The relationship between the absorbance and the absorbed doses was presented in Figures 2-6 for samples A, B, C, D, and E, each with a different maltose concentration of 10, 20, 30, 40, and 50 mM, respectively. The absorbed dose for all samples was within the range of 0-250 mGy.

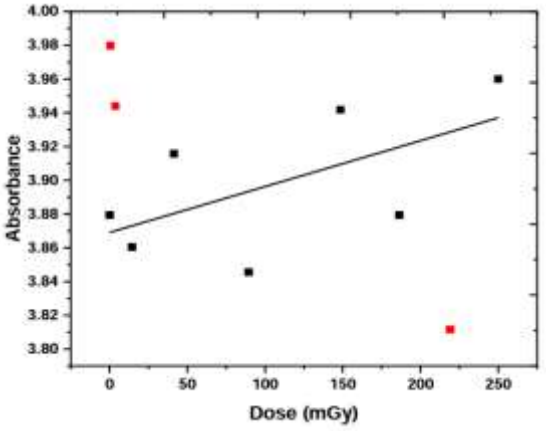


Fig 2: D – A graph, maltose concentration equals 10 mM.

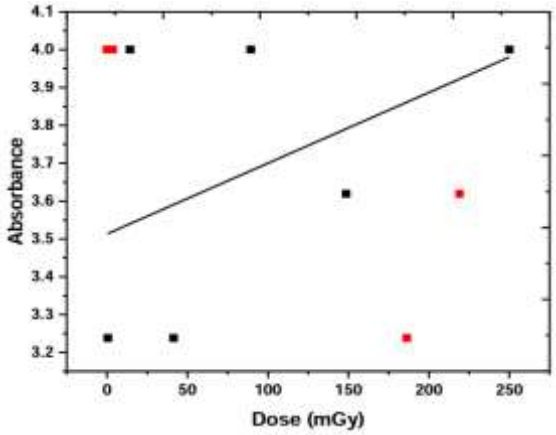


**Fig 3:** D – A graph, maltose concentration equals 20 mM

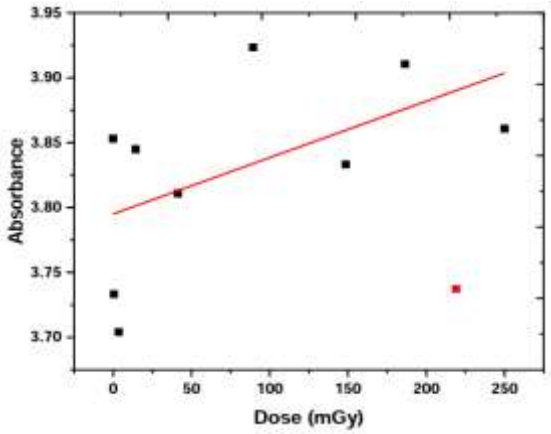


**Fig 4:** D – A graph, maltose concentration equals 30 mM.

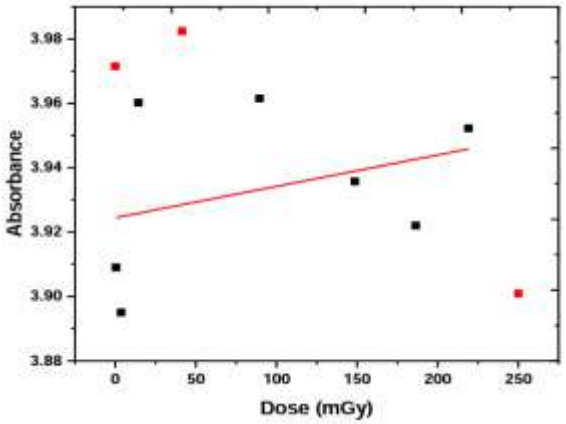


**Fig 5:** D – A graph, maltose concentration equals 30 mM

The figures above show an increase in absorbance with an increase in dose for each sample, indicating the PGDs' ability to respond to the absorbed dose in a proportional manner. This relationship qualifies these PGDs for use in radiation dosimetry. The effect of maltose additive was studied by analyzing the variation of the minimum absorbance (intercepts) and the rate at which the absorbance changes (slopes) as the maltose concentration varied.

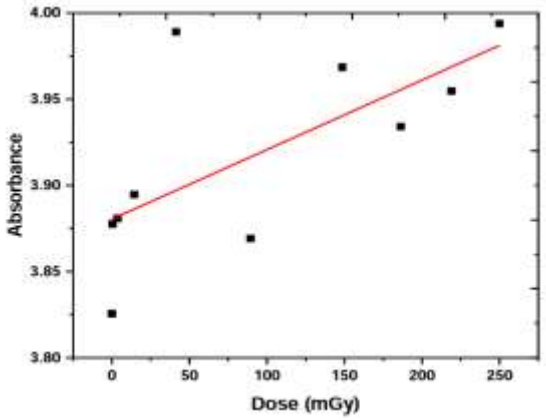


**Fig 6:** D – A graph, maltose concentration equals 50 mM.

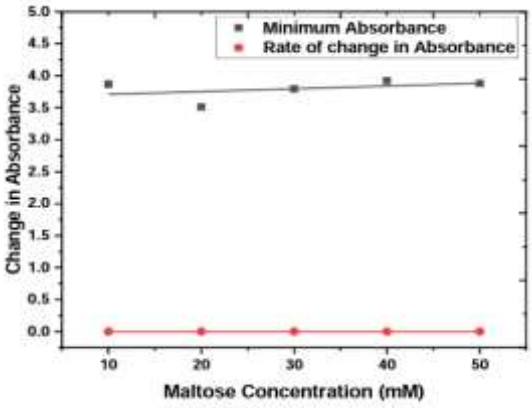


**Fig 7:** Relationship between absorbance and Maltose concentration.

These two relationships were presented in Figure 7. The result indicates that the minimum absorbance increases with absorbed dose as the maltose concentration increases from 10 – 50 mM at the rate of 0.00434/mM, while the slope (which indicates sensitivity) of the PGD decreases at the rate of 0.0000151/mM. This effect does not follow the effect of sucrose concentrations in nPAG, which shows a significant increase in sensitivity with increasing sucrose concentration (Maryanski et al., 1997; Mohammad et al., 2017). This difference may be attributed to the type of monomer used or the concentration of the added disaccharides maltose and sucrose.

*Conclusion***:** In this study, different concentrations of maltose were added to the HEMA polymer gel dosimeter, and the dosimeters were exposed to conventional low-energy X-rays to assess their response within diagnostic X-ray energies and to

evaluate the effect of maltose on dosimeters' sensitivity. The results indicate that the PGD was able to respond to small doses, but the range of maltose concentrations tested did not enhance the dosimeter's sensitivity within the X-ray energies studied.

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