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Investigation of the response of chromium nitrate solutions as a chemical dosimeter for agricultural applications

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Abstract
In this work, Chromium Nitrate solutions with concentrations of 0.16, 0.24 and 0.32 mM have been prepared and irradiated. The purpose of this study is to investigate the dosimetry of these samples in the range of irradiation of agricultural products. Results show that the higher concentration sample is linear in about 100-1000 Gy dosimetry range and the optimal concentration must be found to achieve a stable sample in about 3 weeks periods . Also, samples that are in a darker environment are more stable than samples that are in a lighter environment.
Keywords: chromium nitrate, chemical dosimeter, agricultural products

Introduction
To achieve the final goal in radiation processing dosimetry is one of the most important factors [1]. Due to the dose ranges in the dosimetry of agricultural products, ie 10-1000 Gy, there are not many choices that cover the entire range [2]. Radiation can break or weaken the covalent bond of the complex, and thus change its color. Much work has been done in this field in Iran and other countries[3-6]. This property can be used for the dosimetry process. The purpose of this study is to fabricate chemical dosimeters based on the solution of Chromium Nitrate compounds to use in the desired dose range.

Experimental
Method of preparation of liquid Chromium Nitrate Cr/DPC dosimeters
To prepare dosimetry solutions, Chromium Nitrate ($Cr(NO3)3$) and DPC (DiPhenylCarbazone), were used. Samples should be in concentrations of 0.32, 0.24, and 0.16 mM of Chromium Nitrate and 0.536, 0.402, and 0.268 mM of DPC, respectively, and in a volume ratio of 1 to 3 V/V of water and acetone are mixed together. The samples were read using a BECKMAN Coulter-Du 800 spectrophotometer in the range of visible light wavelengths from 400-800 nm.The cuvettes with dimensions of 1.2×1.2×4.5 mm^3 used as a containers.

Results and discussion
Dose response of liquid Chromium Nitrate
In this study, absorbance changes are plotted in terms of dose. To plot the dose-response curve, the following equation is considered.

$$response\ dosimetry = \frac{HPUI - HPI}{HPUI}$$

That in this equation, HPUI is the height peak of the unirradiated sample and HPI is the height peak of the irradiated sample [3]. values of optical absorbance is measured at 540 nm. Dose-response curves in different concentrations of Chromium Nitrate on the first day of irradiation are shown in Figure 1. Results show that samples with the lowest concentration are the most sensitive ones. This sapmle is satureted in about 800 Gy.

Table 1 presents the dosimetric equations of the Cr/DPC solution samples. According to linear equations, samples with 0.24 mM and 0.32mM concentrations, have the same slopes and as a consequence the solutions have the same sensitivity. There is less complex agent in the lower concentration solution and therefore it will be not sensitive to increasing the dose.

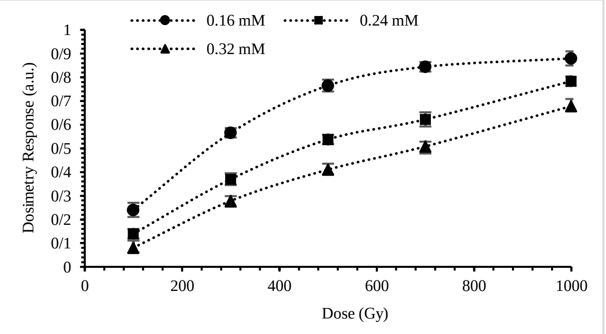

Figure 1 : Dose-response curve of Cr/DPC liquid irradiated samples at different concentrations

Table 1: dosimetry equations of the Cr/DPC dosimetry solution samples

sample	Linear range of dosimetry response	equation
0.16 mM	100-500 Gy y = 0.0013x + 0.1302 R² = 0.9812	y = 0.2921ln(x) - 1.0926 R² = 0.9835
0.24 mM	300-1000 Gy y = 0.0006x + 0.2209 R² = 0.9827	y = 0.2725ln(x) - 1.1436 R² = 0.9800
0.32 mM	100-1000 Gy y = 0.0006x + 0.0569 R² = 0.9808	y = 0.0006x + 0.0569 R² = 0.9808

As can be seen from the results in Table 1, the linearity of the responses are100-1000 Gy, 300-1000 Gy, and 100-500 Gy dosimetry range for the samples with a concentration of 0.32, 0.24, and 0.16 mM respectively. Except for the sample with a concentration of 0.32 mM, the dosimetric equations in this dosimetry range are logarithmic. Therefore, in general, it can be concluded that despite the higher sensitivity of the samples made with lower concentrations, the range of linearity of the dosimetric response in these samples is less than the samples with higher concentrations. Therefore, to increase the range of dosimetry response, it is better to select samples with higher concentrations.

Investigation of stability curve of Cr/DPC Chromium Nitrate dosimeter response

Stability changes over time for irradiated samples at the dose of 500 Gy can be seen in Figure 2.

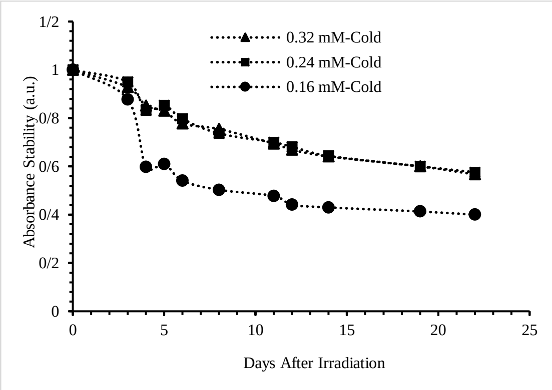

Figure 2: Stability curve of Cr/DPC irradiated samples at 500 Gy dose with different concentrations

Results show that samples have no a regular stability curves over time and even at the end of the third week, it moves towards instability. Samples with concentrations of 0.24 and 0.32 mM have 60% of their initial response after approximately 22 days after irradiation. Considering the similarity of the stability rate of 0.32 mM and 0.24 mM concentration samples, it can be concluded that increasing the concentration has no effect on increasing stability.

Brightness study on Cr/DPC Chromium Nitrate dosimeter response

To examine the changes in absorbance spectrum relative to the changes in light, experiments were performed in bright and dark environments. For testing in the darkness, the aluminum foil is wrapped around the test tubes and kept away from the light. Absorbance changes and relative differences of these values are presented in Table 2.

Table 2: Comparison of absorbance values of Chromium Nitrate solution samples in different lighting conditions

Chromium Nitrate concentration (mM)	Absorbance (In lighting)	Absorbance (in darkness)	Percentage of relative difference
0.23	1.39	1.58	13
0.24	0.59	0.66	12
0.16	0.20	0.26	28

As shown in Figure 3 and Table 2, samples that were in a dark environment had a higher absorbance height. The relative differences of absorbance for 0.32, 0.24, and 0.16 mM concentrations are approximately 13, 12, and 28%, respectively and relative changes in absorbance are greater for lower concentration samples. Figure 3 shows the stability of the samples, ie changes for absorbance compared to the first day in different lighting conditions over 6 days. The results show that samples that were placed in a dark environment are in a more favorable condition in terms of stability than samples that were in the environment and available to light.

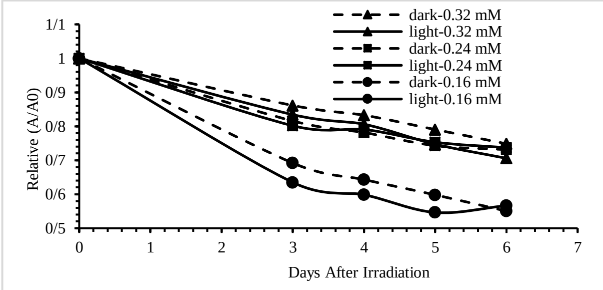

Figure 3: Stability curve of different Cr / DPC samples under different lighting conditions at different concentrations and a dose of 500 Gy

Conclusions

In this study, Chromium Nitrate solutions with concentrations of 0.16, 0.24 and 0.32 mM have been prepared and irradiated. Most chemical dosimeters have not a wide dosimetry range. As the results show, the sample with a concentration of 0.32 mM is linear in the wide range of dosimetry 100-1000 Gy and the optimal concentration must be found to achieve a stable sample in about 3 weeks duration. Also, samples that are in a darker environment are more stable than samples that are in a lighter environment. This research can be a clear result for use in industrial applications.

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