

INTERCOMPARISON OF GAMMA CELL 220 IRRADIATOR FACILITIES AND DR. MIRZAN T RAZZAK GAMMA IRRADIATORS USING HARWELL DOSIMETERS

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ABSTRAK

Interkomparasi Fasilitas Iradiator Gamma Cell 220 dan Iradiator Gamma Dr Mirzan T Razzak Menggunakan Dosimeter Harwell. Iradiator gamma merupakan fasilitas multiguna yang dapat dimanfaatkan untuk pengawetan makanan, sterilisasi alat medis, rekayasa genetika dan proses polimerisasi. Pada fasilitas iradiasi gamma, dosis serap pada produk menjadi poin kunci pada proses. Standarisasi jaminan mutu produk diatur dalam *Technical Document IAEA nomor 409 tentang Dosimetry for Food Irradiation*, *ISO 14470 Food Irradiation* dan *ISO 11137-3 mengenai Guidance on Dosimetric Aspects of Development, Validation and Routine Control*. Dosis serap pada suatu fasilitas iradiasi dipengaruhi oleh pergerakan produk terhadap sumber, posisi sumber terhadap produk, besaran aktivitas radioaktif pada fasilitas dan laju dosis pada ruang iradiasi. Maka dari dilakukan uji performa dosimeter dan sistem jaminan kualitas melalui teknik interkomparasi fasilitas. Interkomparasi berfungsi menguji dosimeter (alat ukur) pada 2 fasilitas yang berbeda untuk menentukan kinerja alat ukur. Interkomparasi dapat dilakukan pada minimal 2 fasilitas atau lebih. Pada penelitian ini, interkomparasi dilakukan pada 2 fasilitas iradiasi menggunakan dosimeter rutin merek harwell. Interkomparasi dilakukan pada rentang dosis 1 kGy hingga 30 kGy dengan 20 titik dosis. Dari hasil penelitian yang dilakukan, didapatkan simpangan tertinggi mencapai sebesar 19% pada fasilitas Iradiator Gamma Cell 220 dan simpangan sebesar 21% pada fasilitas Iradiator Gamma Dr Mirzan T Razzak. Hasil simpangan ini menjadi evaluasi untuk performa dosimeter guna menentukan performa akurasi dan presisi alat ukur dosis (dosimeter).

Kata kunci: Dosimeter, Dosis Serap, Iradiator Gamma, Interkomparasi

ABSTRACT

The gamma irradiator is a multi-purpose facility that possibly used to preserve food, sterilize medical equipment, and conduct genetic engineering and polymerization processes, during which the absorbed dose of the product is critical. The standardization of product quality assurance was regulated by the IAEA Technical Document Number 409 considering Dosimetry for Food Irradiation and ISO 14470 and 11137-3 on Food Irradiation, as well as the Guidance on Dosimetric Aspects of Development, Validation, and Routine Control, respectively. The absorbed dose was influenced by the movement of the product to the source, its position, the amount of radioactive activity in the facility, and the dose rate in the irradiation room. The dosimeter performance test and quality assurance of the system were conducted using the Facility Intercomparison Technique which tested the dosimeter (measuring instrument) at 2 different facilities to determine the performance of the measuring instrument.. In this study, 2 irradiation facilities were tested using a Harwell routine dosimeter in the dose range of 1 kGy to 30 kGy and 20 dose points. The results showed that the highest deviation reached 19% and 21% at the Gamma Cell 220 and the Dr. Mirzan T Razzak Gamma irradiator facilities. This elevated the performance of the dosimeters to determine the precision accuracy of the dose-measuring instrument.

Keywords: Absorb dose, dosimeter, gamma irradiator, intercomparison

INTRODUCTION

There are 4 categories of gamma irradiators, including I, II, III, and IV [1]. Their nuclear installations use gamma radiation from a radioactive source, Cobalt-60 (Co-60), and upon targeting a material, they sterilize medical equipment and preserve food. In Indonesia, the use of gamma irradiation is regulated in the Head Regulation of Drug and Food Supervisory Agency on Food Packaging Supervision Number 3 of 2018 and an IAEA Technical Document Number 409 on Dosimetry for Food Irradiation that explains product standards, facilities, and quality assurance (irradiated dose dosimetry system).

From the 1950s to the early 2000s, there was a rapid growth of irradiator development, and this is expected to happen again based on the great potential of the gamma irradiator benefits in 2020. Furthermore, irradiation needs are supported by FAO, which shows that 25% of agricultural and food products are damaged by insects, bacteria, and other animals after harvest, and 40% of fruit products before reaching the market. In the irradiation process, quality assurance of irradiated products is fundamental, and it is ensured by administering the correct radiation dose to each product/sample. Therefore, a verification of the dosimetry system in an irradiation facility is critical. A dosimeter is a tool that measures the irradiation response [1], and it can be grouped into primary, reference, transfer, or routine categories. In previous studies, the intercomparison process was done using primary and secondary standard dosimeters at an international reference laboratory scale. However, this study used a routine standard dosimeter and aimed to assess the performance of the irradiator facility. This was to study the standard routine dosimetry on the category I of gamma irradiator using a routine dosimeter to guarantee that every irradiation process complies with quality standards.

THEORY

Gamma irradiator is a nuclear installation used to provide radiation intentionally and measurably. It has four categories, including I, II, III, and IV [1]. In category I, the source is stored in a dry container made of solid material that does not move (idle) as the sample to be

irradiated moves. Figure 1 shows category I of gamma irradiator.

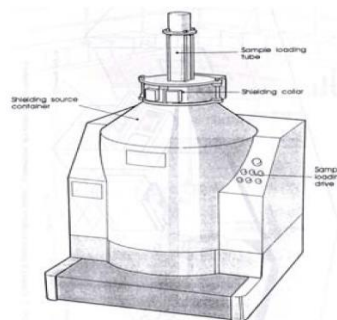


Figure 1. Category I of Gamma Irradiator.

Gamma irradiators probably use a radioactive Cobalt-60 source with an energy of 1.17 MeV to 1.33 MeV and a decay time of 5.27 years, or Cesium-137 with an energy of 0.662 MeV and a decay time of 30.5 years. Cobalt-60 is utilized because it has a relatively long half-life (5.27 years) and is not easily soluble in water. Therefore, it is safe to store the Cobalt-60 source in a pool of water [6].

The International Organization of Standards (ISO) is a community/association of experts joined to set standards for a process applicable in various countries. ISO 14470 and 11137 on Food Irradiation Validation and Routine Control, and Irradiation Healthcare Products Validation and Routine Control, respectively, are applied to a facility, where each clause includes facility-physical, source-safety, security-monitoring, traceability, dose monitoring, and protection of irradiated products [2].

ISO 11137 also describes what is required to develop, validate, and run a routine control of the sterilization process of health products [3]. Its Part 3 outlines how a dose is measured, the maximum acceptable dose is determined, the sterile dose is established, installation and performance are assessed for qualification, and how a routine is monitored and controlled [5].

In the control process, a dosimeter is needed to measure the obtained dose. Table 1. shows the classification of dosimeters.

Table 1. Dosimeter Classification.

Class	Dosimeter	Uncertainty
Primer	Calorimeter;	1%
	<i>Ionization Chamber</i>	
Reference	Alanine ;	2% - 3%
	Dichromate;	
	Ethanol-	

Class	Dosimeter	Uncertainty
Transfer	Chlorobenzene (ECB) ; Fricke	3% - 5%
	Alanine ; Fricke; Ethanol-Chlorobenzene (ECB)	
Routine	PMMA ; Radiochromic Film ; CTA ; Ethanol-Chlorobenzene (ECB)	=5%

There are several levels of irradiation dosimetry systems according to different uncertainties [1]. The primary dosimeter is used by national standard laboratories, where the calorimeter and ionization chambers are the standards and only calibrated once during the instrument’s lifetime, while the reference dosimeters are calibrated as a primary standard and are used to calibrate the lower ones. Moreover, the transfer dosimeter serves as a bridge between an accredited calibration laboratory and an irradiation facility and guides dosimeter traceability. In general, dosimeters are routinely used to map doses and run routine control. The irradiation dosimetry technique measures the absorbed dose of the product, which is the amount of ionizing radiation energy per unit mass of a particular material. In International Units (SI), it is expressed in J/kg, where the absorption value of 1 J/kg is equivalent to 1 gray (Gy).

The density of the irradiated product/sample and the position of the maximum and minimum doses can be determined using a dosimeter experiment on a certain density test material or through computation. Although this method has the disadvantage of high nominal prices and takes a long time, its results are close to the actual ones. When using computation, the Monte-Carlo method is the most widely used [7].

METHOD

Irradiation was conducted at 2 facilities, specifically Dr. Mirzan T Razzak Gamma Irradiator in Yogyakarta and Gamma Cell 220 in Jakarta, using a Harwell Amber and Red Perspex dosimeters. The dose rate, activity during irradiation, humidity, and room temperature readings were recorded. A total of

2 Harwell Amber and 1 Red Perspex dosimeters were placed in the same room called gamma phantom, which created the same conditions for all of them. Dosimeter measurements were read on a UV-Vis spectrometer. The Harwell Amber dosimeter was measured between a wavelength of 603 nm and 651 nm, while the Red Perspex one was at 640 nm. After taking the readings at each wavelength, the thickness of each dosimeter was measured in cm. By dividing the absorbance value by this value, specific absorbance was determined, and was converted to the absorbed dose value based on the calibration table.

RESULTS AND DISCUSSION

Irradiation occurred at 2 irradiator facilities, specifically the Gamma Cell 220 irradiator in Jakarta and Dr. Mirzan T Razzak in Yogyakarta, and used Harwell Amber and Red Perspex dosimeters made in England. The Harwell Amber dosimeter had a measurement range of 1-30 kGy, while the Red Perspex 5-50 kGy. Dosimeter measurements for Harwell Amber were read from a UV-Vis spectrometer at a wavelength of 603 nm in the dose range of 1-15 kGy, and 651 nm at 16-30 kGy. Moreover, Red Perspex used a wavelength of 640 nm at 5-50 kGy. In the first step, a specific absorbance response for dose analysis was performed, as shown by the graph in Figure 3.

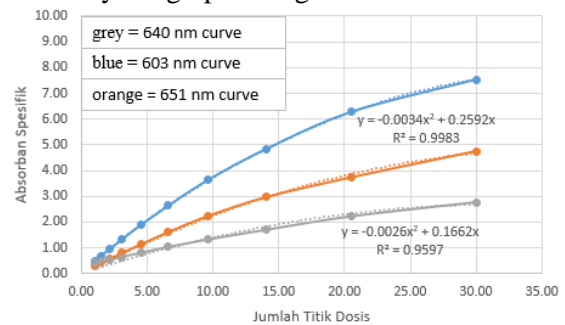


Figure 3. Specific Absorbant Response

According to Figure 3, the regression value is R=1 for the 603 nm, R=0.9983 for 651 nm, and R=0.9597 nm for the 640 nm curves in the dose range of 1-30 kGy. This shows that the specific absorbance value is linear with the absorbed dose.

A preliminary study was conducted on 27 August 2020 on the performance of the Harwell dosimeter at the Gamma Cell 220 Irradiator Facility in Jakarta, in which a dose

rate of 4134 Gy/Hour and source activity of Co-60 5544 Ci were used for irradiation. Figure 4 shows the experimental results of the absorbed dose-response dosimeter.

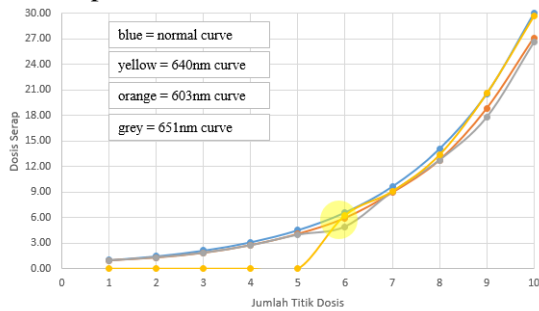


Figure 4. Absorbed Dose-Response

Based on Figure 4, the Harwell Amber dosimeter measurement readings at wavelengths of 603 nm and 651 nm had an error of 2% to 11% and the response at a 640 nm 1% to 5%.

Based on the initial experiment results, an intercomparison was made at the Dr. Mirzan T Razzak facility in Yogyakarta on 17 September 2020 at 3400 Gy/Hour dose rate, Co-60 activity of 8224 Ci, 28°C temperature, and 59% humidity. The comparisons used 2 Harwell Amber and 1 Red Perspex dosimeters. Furthermore, irradiation was conducted in a dose range of 1-30 kGy with 20 dose points determined using the calculation of the number of decades to obtain a logarithmic dose point, as shown in Table 2.

Table 2. Dosage Point in kGy Units.

No	Dose	No	Dose
1	1.00	11	5.99
2	1.20	12	7.16
3	1.43	13	8.57
4	1.71	14	10.25
5	2.05	15	12.26
6	2.45	16	14.66
7	2.93	17	17.53
8	3.50	18	20.97
9	4.19	19	25.08
10	5.01	20	30.00

Irradiation was carried out using gamma phantom to ensure temperature and humidity conditions remained homogenous. The results of the irradiation at Dr. Mirzan T Razzak's facility are shown in Figure 5.

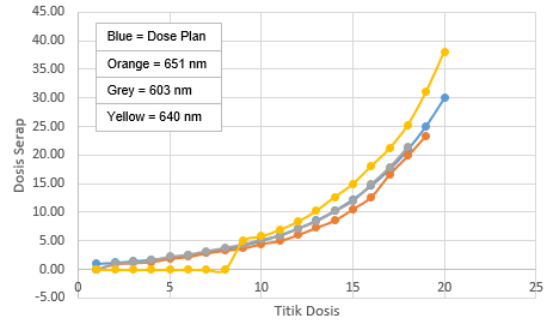


Figure 5. Results of irradiation at Dr. Mirzan T Razzak's facility.

Based on the graph, 651 nm wavelength measurement erred in the range of 1% to 21%, and the large variations could have resulted from the distance between irradiation and measurement or humidity factors. The error ranges at the wavelength of 603 nm and 640nm were 3% to 11% and 16% to 27%, respectively. The second experiment with the same method was conducted at the Gamma Cell 220 Irradiator Facility in Jakarta, and Figure 6 shows the results.

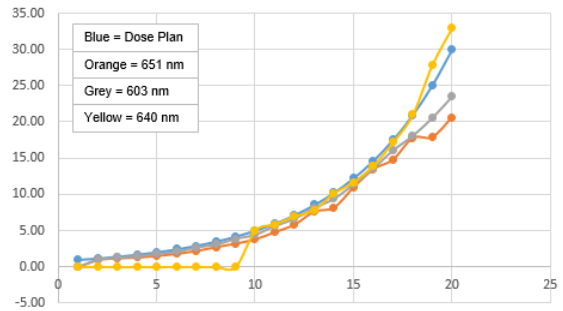


Figure 6. Gamma Cell 220 Facility irradiation results.

The facility dose rate was 4050 Gy/Hour with Co-60 activity of 5441 Ci on October 12, 2020, while the dosimeter measurement temperature and humidity were 28°C and 59%, respectively. The results showed that the error ranges at a wavelength of 651 nm, 603 nm, and 640 nm were 11% to 31%, 7% to 21%, and 640 nm is 2% to 11%, respectively.

The error variation could be influenced by the humidity, irradiation temperature, and the distance between the irradiation and the measurement. Harwell Amber and Red Perspex are clear/colorless PMMA (polymethyl methacrylate) dosimeters that capture radiation and change the absorbance value of the PMMA material. The result was used to obtain the specific absorbance value (absorbance per thickness (cm)), which possibly be affected by

high humidity or temperature changes that cause condensation on the material. Furthermore, if the distance and time between irradiation and measurement are long, the radiation trapped in the PMMA material escapes, affecting the specific absorbance. The value was converted into the absorbed dose based on the calibration table, which is very specific because it has differences in each PMMA dosimeter production batch.

CONCLUSION

The experiment was conducted on 2 irradiator facilities using 2 Harwell Amber and 1 Red Perspex dosimeters. The Red Perspex dosimeter experimental results gave a more stable response in the 5-30 kGy dose range, which was caused by the 1 measurement wave (640 nm). Therefore, the consistency of the absorbed dose value was better than the Harwell Amber dosimeter. However, there is a need for further studies on the performance of the Harwell Amber and Red Perspex as routine dosimeters.

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