SỬ DỤNG MÁY CHIẾU XẠ TIA X NĂNG LƯỢNG THẤP HITACHI MBR-1618R-BE ĐỂ ỨC CHẾ SỰ NẢY MẦM CỦA KHOAI TÂY

PHẠM THỊ NGỌC HÀ, TRẦN ĐỨC MẠNH, NGUYỄN AN SƠN, TAMIKAZU KUME

Trường đại học Đà Lạt, 01 Phù Đổng Thiên Vương – Phường 8 – Đà Lạt

Email: haptn@dlu.edu.vn

Tóm tắt

Khoa Kỹ thuật Hạt nhân, trường Đại học Đà Lạt đã trang bị máy phát tia X năng lượng thấp, với mục đích thực hiện các nghiên cứu ứng dụng công nghệ bức xạ. Điện áp của máy phát tia X có thể thay đổi từ 35 - 160 kV và liều được phân bố theo độ sâu với 5 bộ lọc khác nhau.

Khoai tây là một trong những thực phẩm quan trọng hằng ngày. Để ức chế sự nảy mầm và tăng thời gian bảo quản khoai tây thì chiếu xạ là một trong những phương pháp rất hữu ích được sử dụng hiện nay. Trong bài báo này các điều kiện chiếu xạ tối ưu để ức chế sự nảy mầm khoai tây bằng tia X năng lượng thấp đã được xác định. Kết quả nghiên cứu cho thấy liều hấp thụ cần thiết và độ sâu hiệu quả để ức chế sự nảy mầm là 60 Gy ở độ sâu 10 mm từ bề mặt. Chiếu xạ với dải liều từ 60 - 150 Gy ở điện áp 100 keV, dòng 30 mA, với bộ lọc 0.5 mm Al + 0.1 mm Cu để chiếu xạ một phía và bộ lọc Al 1.0 mm khi chiếu xạ cả hai bên.

Từ khóa: *Tia X năng lượng thấp, liều theo độ sâu, ức chế nảy mầm, khoai tây, bộ lọc cắt*

SPROUT INHIBITION OF POTATO BY USING HITACHI MBR-1618R-BE LOW ENERGY X-RAY IRRADIATOR

PHAM THI NGOC HA, TRAN DUC MANH, NGUYEN AN SON, TAMIKAZU KUME

Dalat University, 01 Phu Dong Thien Vuong, Dalat

Email: haptn@dlu.edu.vn

Abstract

The Faculty of Nuclear Engineering, Dalat University installed a low energy X-rays irradiator for radiation applications. The irradiator can be changed the tube voltage at 35 – 160 kV and the depth dose distribution with 5 kinds of filter.

Potato is one of the important daily food and the irradiation is a very useful method to inhibit the sprout and increase the preservation period. This research is focused on determining the optimum irradiation conditions for sprouting inhibition of potato using low energy X-rays. The necessary absorbed dose and the effective depth for sprout inhibition of potatoes was 60 Gy at 10 mm of potato depth from the surface. To irradiate with dose range of 60 – 150 Gy by using X-ray opperated at 100 keV, 30 mA, the filters of 0.5 mm Al + 0.1 mm Cu were eqquiped for single side irradiation and a filter of 1.0 mm Al was applied for both side irradiation.

Keywords: *Low energy X-rays, depth dose, sprout inhibition, potato, cut filter*

1. INTRODUCTION

According to the Codex General Standard for Irradiated Foods (CAC 2003) [1], there are three types of radiation used for food irradiation: gamma rays (^{60}Co and ^{137}Cs), electron beam with energy less than 10 MeV and X-ray with energy less than 5 MeV. Among them, gamma-ray from ^{60}Co is most commonly commercial irradiation but it is becoming difficult to use due to the shortage of supply and transportation security problems. Electron beams and X-ray with high energy can radiation process various products in large quantities and at high speed. However, these high-energy irradiation machines are still expensive and the operation cost is also high, while a low energy machine required less investment and maintenance cost. However, the penetration into the samples of low energy electron beam is small and not suitable for irradiation of thick samples. A compact irradiation device using an X-ray tube with low energy has the advantage of being able to obtain the higher penetration than low energy electron beam. Food irradiation with the machine is expected for non-bulky food and small-scale irradiation.

Potatoes are widely used food in the world but the potato tubers are required to inhibit the sprouting for long storage. In the IAEA's extensive compilation of research findings, it was concluded that: "In potatoes doses between 0.05 and 0.15 kGy, preferably a dose range from 0.07 to 0.15 kGy is sufficient to inhibit sprouting regardless of cultivar, time of irradiation and post irradiation storage temperature". [3]. Kume et al. has reported on potato irradiation and their results indicated that the optimal dose range for sprouting inhibition of potatoes was 60-150 Gy [5].

This research is to study about potato sprout inhibition by using low energy X-ray to find out an optimum irradiation condition for potato and in order to apply for real radiation processing in near future.

2. MATERIALS AND METHODS

2.1. Potato samples

Potato *Solanum tuberosum* L. PO3 (abbreviated PO3) is used in the experiment. PO3 is a late blight resistant potato variety selected and developed by the Potato, Vegetable & Flower Research Center [4]. They were harvested from a farm in Phuoc Thanh, Da Lat, Lam Dong, from July 7^{th} to 6^{th} August of 2018. After harvesting, the potatoes were cleaned by using the soft brush and then kept in a dark room at the ambient temperature in 2 weeks. Each fraction of experiments, 10 pieces of potato sample is used. The average size of potatoes were about 70 x 70 x 50 mm. Potatoes were stored at room temperature after irradiation.

2.2. X-ray irradiator

Hitachi MBR-1618R-BE X-ray irradiator installed at the Faculty of Nuclear Engineering, Dalat University in 2018 [2] was used for potato irradiation (Figure 1). The size of irradiator is 1600 x 750 x 730mm. The irradiator can be changed the tube voltage (35 to 160kV), tube current (1 to 30mA) and irradiation time or irradiation dose to emit X-rays. Five types of filters shown in Figure 1 can be used to cut the very low energy part of X-ray beams.

Figure 1: X-ray machine and filters

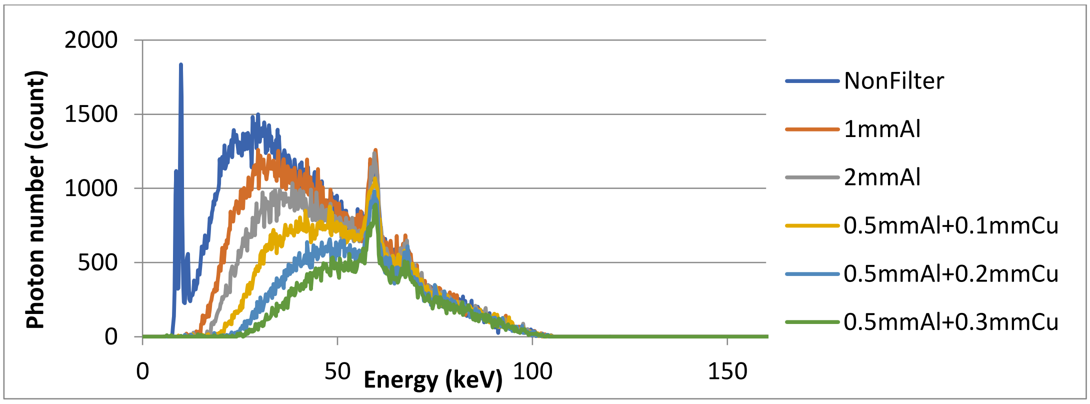

Figure 2: Energy spectrum with different filters, 100 kV (from Hitachi)

Figure 2 shows the low energy parts of X-ray beams cut by various filters. The different filters have different penetration. Higher energy X-rays have a better penetration and the smaller dose uniformity ratio inside of the potato could be obtained.

2.3. Dosimetry

Three types of dosimeter shown in Figure 3 were used in this experiment. Fricke dosimeter was mainly used to measure the absorbed dose of the potato sample. It is based on the chemical process of oxidation of ferrous ions (Fe^{2+}) in the aqueous sulfuric acid solution to ferric ions (Fe^{3+}) by ionizing radiation. The method was used for accurate absorbed dose (dose in water) determination by measuring the change in absorbance of an irradiated solution in a UV-VIS spectrophotometer at 304 nm wavelength (the peak of the absorption spectrum). Gaf chromic film HD-V2 was used for the dose distribution inside the potato. This film dosimeter is very thin (100 µm) and the dose range from 10 Gy up to 1000 Gy. Big film sheet was cut to small pieces (10 × 10 mm) and the sandwiched into 10 layers of potato slices (5mm thick each slice). This simulation system was irradiated to measure the dose distribution inside after being calibrated with Fricke dosimeter. The TN31013 ion chamber was used for the measurement of the dose distribution on the turntable.

Figure 3: Fricke dosimeter, Gaf chromic film and The TN31013 ion chamber

3. RESULTS AND DISCUSSION

3.1. Dose for sprout inhibition of potato

The necessary dose for sprout inhibition of potato was tested. Table 1 shows the effects of irradiation at various doses in 10 mm depth of potato.

Table 1: Potato sprout inhibition with different doses inside after 3 months storage

	Dose (Gy) at 10 mm depth	Sprout			Rot	
		Number		%	Number	%
		Top	Back			
Control	0	10	10	100	0	0
1	40	2	4	40	0	0

2	50	2	4	40	0	0
3	60	0	2	20	0	0
4	70	0	0	0	0	0
5	80	0	0	0	0	0

The results in Table 1 indicate that the higher dose of 70 Gy at 10 mm depth inhibited the sprout completely. The dose of 60 Gy at 10 mm depth inhibited the surface sprout but the sprout at backside were observed. From these data, sprout of potato can be inhibited 60 Gy at 10 mm depth.

Figure 4 shows the sprout inhibition of potato irradiated at 70 Gy.

Figure 4: Potatoes unirradiated and irradiated 70 Gy at 10 mm depth after 3 months storage

As shown in Figure 2, the low energy parts of X-rays are cut by various filter. To change the depth dose in potato, potatoes were irradiated at 150 Gy of surface using 3 kinds of filters. The doses inside of potato and the sprout inhibition are shown in Table 2.

Table 2: Doses in potatoes using different X-rays filter

	Dose (Gy)				Sprout		Rot	
	Surface	5 mm depth	10 mm depth	Back (50mm)	Number	%	Number	%
Control	0	0	0	0	10	100	0	0
F0	150	41	28	10	4	40	1	10
F1	150	104	72	21	3	30	0	0
F2	150	110	81	29	2	20	0	0
F3	150	144	137	75	0	0	0	0

F0:non-filter, F1:Al 1mm, F2:Al 2mm, F3:Al 0.5mm + Cu 0.1mm

Potatoes were stored for 2 months

When the dose of surface was adjusted as 150 Gy, the inside dose of potato were increased according to the thickness of filter. The sprout of potatoes was completely inhibited by using filter F3 (doses at surface and back side are 150 and 75 Gy).

3.2. Dose distribution for potato irradiation

Irradiation areas are different at the height of turntable as shown in Figure 5 due to the angle of X-rays.

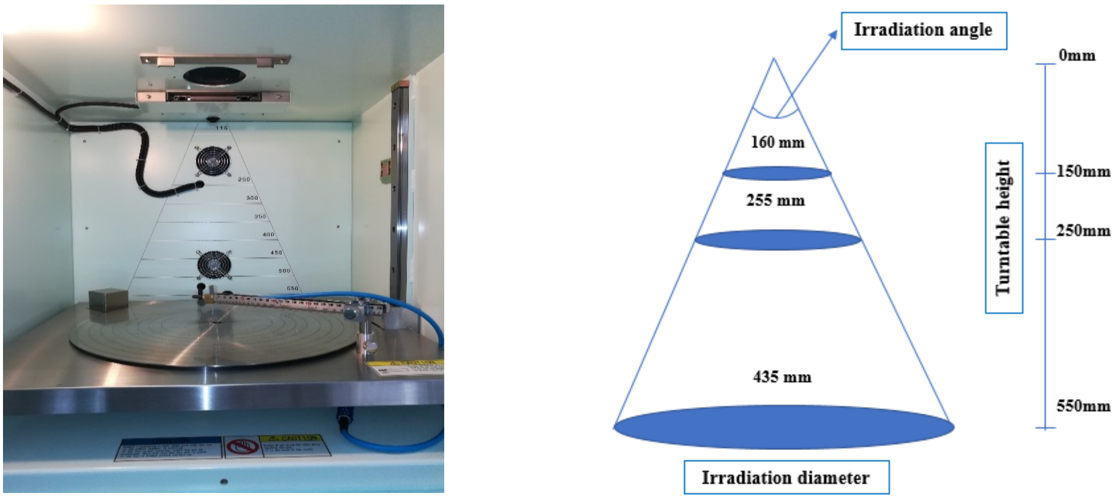

Figure 5: Irradiation room and irradiation angle

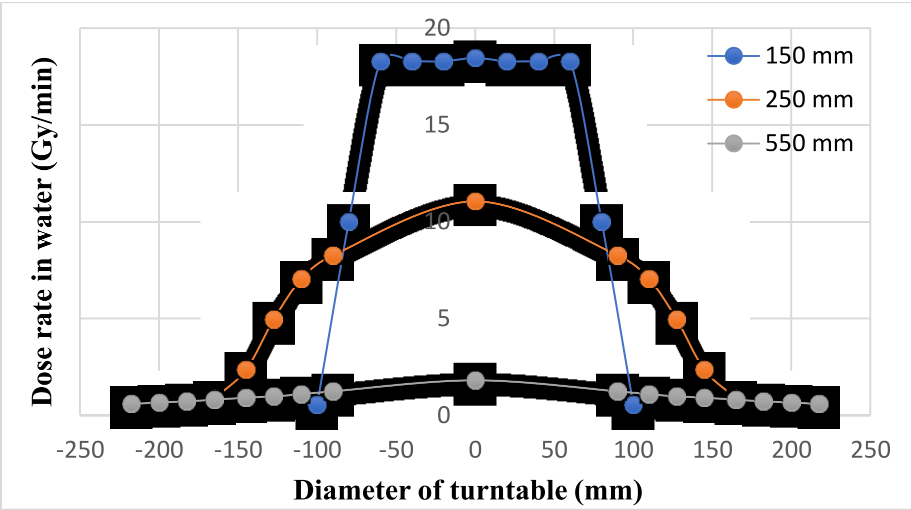

Figure 6: Dose rate distribution on turntable at different heights

As shown in Figure 6, the dose rate is decreased with increasing of the height of turntable (the distance to the source). The dose rates were 18.45 Gy/min at 150 mm, 11.05 Gy/min at 250 mm and 1.81 Gy/min at 550 mm, respectively.

The diameter of irradiation area (distance from center of turntable) is limitted with the radiation angle. The diameter of irradiation area on the turntable are φ160 mm at 150 mm height, φ255 mm at 250 mm height and φ435 mm at 550 mm height, respectively. Out of the irradiation area, the dose rates are dramatically dropped. The acceptable number of potato for irradiation are 6, 14 and 46 pieces at the above positions. The average weight of potatoes is 130 gram. The irradiation space at 150 mm height is not enough for potato irradiation (Figure 5). At the 550 mm height, the weights of potato for one time irradiation is 3 times (6.0/1.8 kg) higher but the irradiation time is 7 times (125/19 min) longer than that at 250 mm height. So the throughput capacity at 250 mm height is about 6 time (5.8/0.9 kg/h) bigger than 550 mm.

3.3. Throughput capacity for both sides irradiation

After irradiation with one side has been completed, turning each potatoes to the opposite side and continue irradiation in the same condition. The dose distribution in water at 250 mm height with filter F1 was shown in Figure 7.

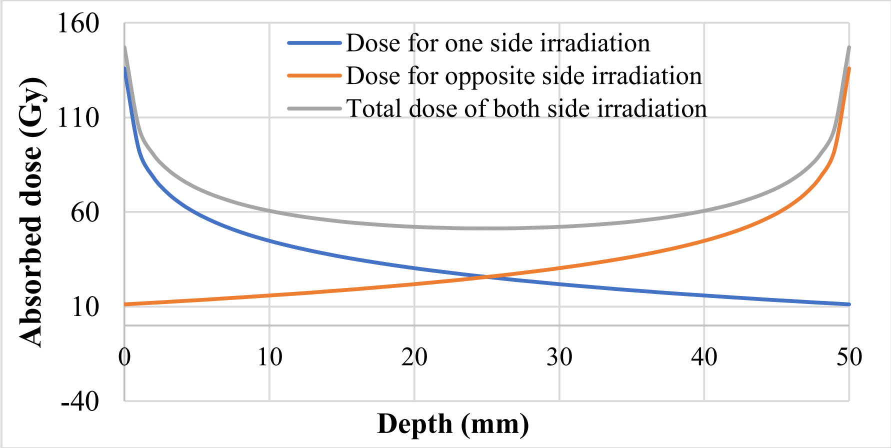

Figure 7: Dose distribution in water for both side irradiation with filter F1

When the potato was irradiated from one side, the absorbed doses at surface, 10 mm depth and back side are 142, 47 and 12 Gy, respectively. When irradiated from both sides, the dose are 154 Gy at surface, 63 Gy at 10 mm depth and 54 Gy at 25 mm depth. The result show that potato can be irradiated from both side with absorbed dose between 60 (10 mm depth) – 150 Gy (surface).

Table 3 shows the throughput capacity of potato irradiation at 250 mm height with 100 kV, 30 mA. The calculated throughput capacity is 0.34 kg/h for one side irradiation with F3 (0.5 mm Al + 0.1 mm Cu) and 1.29 kg/h for both sides irradiation with F1 (1.0 mm Al).

Table 3: The different factors for one side and both side irradiation

	One side irradiation with 60 Gy at back side	Both side irradiation 60 Gy at 10 mm depth
Filter	F3	F1
Dose rate (Gy/min)	0.19	1.41
Time irradiation (min)	316	84
Throughput capacity (kg/h)	0.34	1.29

4. CONCLUSION

The sprout inhibition of potato was studied by using low energy Hitachi MBR-1618R-BE X-ray irradiator. The necessary absorbed dose for potato sprout inhibition was from 60 Gy to 150 Gy and the effective depth to inhibit the sprout was 10 mm from the surface. Sprouting can be inhibited by F3 for one side irradiation. The maximum effective irradiation diameter of turntable was 255 mm at 250 mm height of the turntable.

The dose higher than 60 Gy at 10 mm depth could inhibit sprout for both side irradiation with 1.0 mm Al filter at 250 mm height of turntable.

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