THE STUDY OF USING GAMMA AND ELECTRON BEAM IRRADIATION AS QUARANTINE TREATMENT FOR STAR APPLE

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Abstract : After dragon fruits, rambutan, lychee and longan, Vietnamese star apple was officially imported into USA market. Star apples are commonly grown and exclusively exported from Vietnam. Therefore, it has many competitive advantages in the international market. After harvest, star apples normally are infested insect pests and harmful microorganisms that can spread and damage the agricultural production. Especially, *Lasiodiplodia theobromae* is one of the main causes of rotting and dieback diseases in star apple fruits. Irradiation doses ≥ 1 kGy can control this type of fungal infection but the quality of star apple changed significantly with doses higher than 0.6 kGy. Therefore, the combined treatment with sodium dichloroisocyanurate (NaDCC) 20ppm and irradiation was investigated in this study to reduce the irradiation dose of star apple. The results showed that irradiation in combination with NaDCC 20ppm can reduce D_{10} from 0.95 kGy to 0.13kGy (Gamma irradiation) and from 1.1 kGy to 0.19 kGy (Electron beam irradiation). The appearance of insects was not detected during the experiment at normal conditions. Gamma irradiation was appropriate for quarantine treatment when the current box size of L38 x W30 x H32 cm is suitable for both types of star apples and the dose uniformity ratio (DUR) is relatively small (1.44). Using the box size of 49 x 32 x 12cm during electron beam irradiation was appropriate for Lo Ren star apples, the small size of the fruits made it easier for the absorbed dose distributed evenly. Meanwhile, the purple star apple box needed an addition of wooden board (1 cm of thickness) to support proportion and reduce the DUR from 2.2 to 1.4. The quality of both types of star apples were tested to have recommendations before using radiation for quarantine treatment by 10MeV electron beam irradiator (UELR-10-15S2) in the commercial scale. The treatment using NaDCC (20 ppm) and EB irradiation (doses of 400-600 Gy) showed more effective in control fungi growth and in extending the shelf life of both kinds of star apples (13 days) than the control (non- treatment, un-irradiation) (6 days).

Keyword: *Electron beam, gamma, quarantine treatment, star apple*

I. Introduction

Star apple *(Chrysophyllum cainito)* is a famous kind of fruit in Vietnam. It becomes one of important fruits for exportation. It has the best nutrient when ripen. Several researchers have reported that mature star apple is an excellent source of vitamins and irons [1]. However, they are harvested for a limited period from December to March [2], and their quality will be lost and spoiled quickly during harvest, transport and storage by a number of disease moulds, especially *Lasiodiplodia theobromae* [3]. Traditionally, chemical fumigation method has been used for quarantine or for the preservation of fruit quality from fungi. However, the use of chemicals is unsafe for workers and environment. In addition, the fumigation could not treat a large quantity of fruits simultaneously and could take time to complete the treatment. So many researchers have focused on finding out the technologies that can contribute to replace the use of chemical fumigation. There were some methods reported such as heat treatment, ozone treatment, etc. However, individual treatment does not control fungi, scientists need to find other methods to combine.

There are three primary types of irradiation that are capable of phytosanitary treatment such as gamma rays, EB and X-ray. Although doses of as low as 0.4 kGy are sufficient to sterilize and most of harmful insects and fresh fruits irradiated at dose up to 1 kGy (US FDA, 2004), but it is impossible to fully control postharvest fungal diseases [4]. Moreover, the quality of fruits requited negative effect after irradiation. So reduction of irradiation dose is necessary to inhibit the development of postharvest disease with other treatments (hot water, chemical, etc). One of the treatments with irradiation to disinfect postharvest diseases is chlorination. Chlorination damages microbe cell membranes, proteins, and nucleic acid by oxidative degradation [5]. This chemical is an inexpensive and non-residual. It is used to reduce bacterial and fungal diseases on fruit and vegetable surfaces [6]. NaDCC is one form of chlorine used for disinfection. It has been approved by the United States Environmental Protection Agency and the World Health Organization for the routine treatment strongly recommended below 100 ppm for foods. Using NaDCC 70 ppm for the treatment pear fruits was also investigated by Jeong et al [7]. In this study, the effect of EB irradiation or combined treatment with NaDCC to control mould (*Lasiodiplodia theobromae*) on star apples was investigated.

In this report, the distribution of dose on the product's carton, and quality of irradiated star apple (Lo Ren and purple star apple) by gamma and EB irradiation at quarantine dose range were investigated. In addition an effective of Gamma or EB irradiation with NaDCC to control D_{10} value of mould (*Lasiodiplodia theobromae*) on star apples was determined.

II. Experimental

2.1. Materials and chemicals

- Lo Ren and purple star apple (*Chrysophyllum cainito*) were supplied by Lo Ren Vinh Kim agricultural co-operative in Tien Giang province.
- Packages: Each kind of star apple was packaged and wrapped by 40 perforated PE and foam wrap. Cartons with the dimension of L38×W30×H32 cm and gross weight of 10 kg of star apples were used for gamma irradiation. Cartons with the dimension of L49×W32×H12 cm and gross weight of 4 kg were used for EB irradiation.
- Fungi (*Lasiodiplodia theobromae*) were isolated directly from infested star apples to carry out the experiment. For a pure culture, isolated individual conidia were transferred to potato dextrose agar.
- Chemicals: NaOH, phenolphthalein, 2.6 dichlorophenolindophenol, vitamin C, Merk, Germany; sodium dichloroisocyanurate (NaDCC), China.

2.2. Equipments

- Irradiation facility: Electron beam accelerator UERL-10-15S2, 10 MeV, 15 kW supplied by CORAD Co. Ltd., Russia, SVST-Co60/B supplied by Hungary, at the Research and Development Center for Radiation Technology.
- Testing equipment: Colorimeter CR200, Minolta, Japan; Handheld refractometer scale 0-32^0 Brix, Atago, Japan; stereomicroscope, UK. Other equipments: cold storage, thermor temperature.

2.3. Methods

2.3.1. Irradiation treatment

Fresh star apple were harvested from a Global GAP model farm in Tien Giang province (Vietnam) in the afternoon and transported to laboratory in the early morning of the following day. The fruits were sorted, cleaned and dried in the air and spread on trays before irradiating at doses of 0.4, 0.6, 0.8, and 1.0 kGy by gamma rays or electron beams. Non-treated star apples were also studied as a control sample. After irradiation, they were moved and stored at ambient temperature to determine color, brix degree, weight loss, degree of damage of fruits, and insect infestation in duration of storage.

2.3.2. Combined treatment

To assess the effects of NaDCC on trading value of the irradiated star apple, the star apples were pretreated by soaking in NaDCC 20 ppm and irradiated at 0.4 and 0.6 kGy by EB. Non treated star apples were also studied as a control sample. After 7 days in storage, weight loss, color and degree of damage of fruits were evaluated.

2.3.3. Quality assessment of star apple

- Weight loss: Was determined as percentage of the initial weight with m (%) = $(m_o - m_i) \times 100/m_o$
- Color of fruit skin: measured by Colorimeter CR 200 (Minolta, Japan) with L* (darkness – brightness); a* (green to red); b* (blue to yellow).
- Postharvest disease index was assessed by using the scale: 0 (0%); 1 (0-5%); 2 (5-10%); 3 (10-25%); 4 (25-50%), and 5 (> 50% of fruit infected by disease).
- The brix degree was determined with the aid of hand-held refractometer.

2.5. Data analysis

Experimental data were analyzed of variance (ANOVA) using SPSS with the reliability P = 0.05.

III. Results and discussion

3.1. Effect of Gamma and EB irradiation on quality of star apple

The effects of Gamma and EB radiation at the dose range from 0.4 to 1.0 kGy on the quality of star apples were assessed and recorded in the Table 1, 2, and 3. Diseased fruits decreased with the increasing dose and increased with storage time. Lo Ren star apples started to have the disease symptom by 3 day after gamma ray irradiation and 6 days by EB irradiation. However, effects of radiations at different doses were similar by the day 9 and 12. Meanwhile, this symptom appeared after 6 days by gamma and 9 days for EB irradiation for purple star apple. The weight loss changed insignificantly at the doses 0.8 kGy and 1.0 kGy to compare with the control (non-irradiated) for both types of irradiation and both types of star apple. It means that the purple star apple could be more resistant with radiation than Lo Ren star apple and the quality of star apple changed significantly with doses higher than 0.6 kGy.

Table 1: Comparison of effects of gamma and EB irradiation on the disease of star apple during storage time (Temp. of 27±2°C; RH: 85±5%)

Type of star apple	Type of irradiation	Dose (kGy)	Storage time, day					Mean of dose
			0	**3**	**6**	**9**	**12**	
LR	EB	0	0.71	0.71	1.96± 0.14	2.35	2.35	1.58A
		0.4	0.71	0.71	1.68± 0.17	2.27±0.13	2.35	1.54AB
		0.6	0.71	0.71	1.78± 0.17	2.27± 0.13	2.35	1.56AB
		0.8	0.71	0.71	1.35± 0.21	2.35± 0.18	2.35	1.49BC
		1.0	0.71	0.71	1.35± 0.21	2.27± 0.13	2.35	1.48C
		Mean of time	0.71a	0.71a	1.63b	2.27c	2.35d	
	GM	0	0.71	1.05±0.3	1.68± 0.17	2.27± 0.13	2.35	1.61A
		0.4	0.71	0.71	1.56± 0.32	2.04± 0.14	2.35	1.47A
		0.6	0.71	0.71	1.74±0.46	1.93± 0.39	2.35	1.49A
		0.8	0.71	1± 0.5	1.18± 0.82	2.19± 0.27	2.35	1.49A
		1.0	0.71	1.17±0.44	1.64± 0.45	2.09± 0.44	2.35	1.59A
		Mean of time	0.71a	0.93b	1.56c	2.1d	2.35d	
P	EB	0	0.71	0.71	1.1 ± 0.67	2.11±0.24	2.35	1.4A
		0.4	0.71	0.71	0.71	1.29±0.5	2.27±0.13	1.14C
		0.6	0.71	0.71	0.71	1.56± 0.32	2.27±0.13	1.19BC
		0.8	0.71	0.71	0.71	2.11± 0.24	2.35	1.32AB
		1.0	0.71	0.71	0.71	2.11± 0.24	2.35	1.32AB
		Mean of time	0.71a	0.71a	0.79a	1.84b	2.32c	
	GM	0	0.71	0.71	0.88± 0.3	1.86± 0.27	2.35	1.3A
		0.4	0.71	0.71	0.71	1.95± 0.14	2.35	1.29A
		0.6	0.71	0.71	0.88± 0.3	1.77± 0.17	2.35	1.28A
		0.8	0.71	0.71	0.88± 0.3	2.11± 0.24	2.35	1.35AB
		1.0	0.71	0.71	1.05 ± 0.3	2.35	2.35	1.43B
		Mean of time	0.71a	0.71a	0.88b	2.01c	2.35d	

Mean values followed by the same letter are not significant difference at $P < 0.05$

Data of disease severity was transformed to $(xi+0.5)^{1/2}$ before analyze

LR and P were Lo Ren and Purple star apple, respectively

Table 2: Comparison of effects of gamma and EB irradiation on the weight loss (%) of star apple during storage time (Temp. of 27±2°C; RH: 85±5%)

Type of star apple	Type of irradiation	Dose (kGy)	Storage time. day					Mean of dose
			0	**3**	**6**	**9**	**12**	
LR	EB	0	0.03	0.2±0.01	0.27±0.02	0.41±0.05	0.42±0.04	0.27A
		0.4	0.03	0.18±0.04	0.25±0.09	0.36±0.5	0.4±0.13	0.24A
		0.6	0.03	0.23±0.07	0.26±0.06	0.38±0.1	0.46±0.13	0.27A
		0.8	0.03	0.1±0.05	0.36±0.04	0.46±0.03	0.49±0.01	0.29B
		1.0	0.03	0.23±0.11	0.37±0.09	0.47±0.12	0.66±0.09	0.35B
		Mean of time	0.03a	0.19b	0.3c	0.42d	0.49e	
	GM	0	0.03	0.22±0.07	0.31±0.06	0.4±0.04	0.48±0.03	0.3A
		0.4	0.03	0.23±0.05	0.3±0.03	0.37±0.02	0.45±0.01	0.29A
		0.6	0.03	0.22±0.04	0.33±0.03	0.38±0.03	0.49±0.02	0.3A
		0.8	0.03	0.25±0.02	0.36±0.01	0.46±0.02	0.6±0.01	0.35B
		1.0	0.03	0.23±0.05	0.38±0.01	0.49±0.03	0.67±0.02	0.37B
		Mean of time	0.03a	0.23b	0.33c	0.42d	0.54e	
P	EB	0	0.03	0.17 ± 0.02	0.23 ± 0.06	0.32 ± 0.2	0.36 ± 0.19	0.22A
		0.4	0.03	0.18 ± 0.12	0.33 ± 0.06	0.36 ± 0.05	0.4 ± 0.04	0.26AB
		0.6	0.03	0.15 ± 0.02	0.26 ± 0.1	0.36 ± 0.08	0.54 ± 0.2	0.27AB
		0.8	0.03	0.23 ± 0.1	0.32 ± 0.11	0.49 ± 0.16	0.56 ± 0.2	0.33B
		1.0	0.03	0.36 ± 0.04	0.41 ± 0.22	0.53 ± 0.16	0.56 ± 0.18	0.4C
		Mean of time	0.03a	0.22b	0.3c	0.41d	0.51e	
	GM	0	0.03	0.22 ± 0.06	0.33 ± 0.04	0.4 ± 0.01	0.44 ± 0.02	0.28AB
		0.4	0.03	0.22 ± 0.04	0.29 ± 0.01	0.35 ± 0.02	0.42 ± 0.01	0.26A
		0.6	0.03	0.21 ± 0.02	0.33 ± 0.06	0.38 ± 0.05	0.42± 0.03	0.27AB
		0.8	0.03	0.25 ± 0.01	0.32 ± 0.02	0.39 ± 0.03	0.48 ± 0.04	0.29B
		1.0	0.03	0.24 ± 0.04	0.35 ± 0.06	0.4 ± 0.05	0.47 ± 0.05	0.3B
		Mean of time	0.03a	0.230b	0.32c	0.38d	0.45e	

Mean values followed by the same letter are not significant difference at P < 0.05

Weight loss were arcsine transformed before analysis

LR and P were Lo Ren and Purple star apple, respectively

Measured color values of fruit skins were changed significantly during storage time starting from by day 6 to day 12 for EbI and from by day 3 to day 12 for GI for both kinds of star apple. The a* value (green to red) was significant difference from the dose of 0.8 kGy for EbI and 0.4 kGy for GI. The same result for purple star apple. The b value (blue to yellow) was diffirence form the dose of 0.4 kGy for both EbI and GI. The results indicated that the star apple (Lo Ren and purple) can’t keep skin color after irradiation. This is necessary to find some methods which keep the color of irradiated star apple skins.

Table 3: Comparison of effects of gamma and EB irradiation on the color (a* and b* values) of star apple during storage time (Temp. of 27±2°C; RH: 85±5%)

Parameter	Type of irradiation	Dose (kGy)	Storage time. day					Mean of dose
			0	**3**	**6**	**9**	**12**	
a* (LR)	EB	0	-13.65 ± 1.37	-11.67 ± 3.77	-5.39 ± 1.21	-0.31 ± 3.35	3.56 ± 2.28	-5.49A
		0.4	-12.61 ± 1.03	-11.17 ± 3.29	-5.00 ± 2.76	-0.14 ± 3.05	3.61 ± 0.42	-5.06A
		0.6	-11.77 ± 2.20	-10.25 ± 3.24	-5.99 ± 4.45	-0.68 ± 3.55	4.80 ± 3.11	-4.78A
		0.8	-12.73 ± 1.80	-10.69 ± 0.88	-3.56 ± 3.48	4.00 ± 0.59	4.80 ± 1.58	-3.64AB
		1.0	-10.43 ± 1.28	-10.21 ± 1.31	-1.57 ± 2.76	3.45 ± 0.60	5.84 ± 1.99	-2.58B
		Mean of time	-12.24a	-10.8a	-4.3b	1.26c	4.52d	
	GM	0	-12.28 ± 1.50	-8.42 ± 1.17	-5.45 ± 1.34	6.32 ± 0.74	4.38 ± 1.25	-5.62A
		0.4	-8.37 ± 0.75	-9.44 ± 0.70	-5.65 ± 0.80	0.43 ± 1.95	5.32 ± 1.07	-3.54B
		0.6	-10.51 ± 1.89	-7.68 ±1.84	-6.43 ± 1.26	2.47 ± 0.91	4.38 ± 0.67	-3.55B
		0.8	-9.27 ± 1.82	-4.57 ± 1.03	-4.69 ± 1.10	6.23 ± 1.72	2.15 ± 0.90	-2.03C
		1.0	-9.93 ± 1.70	-4.82 ± 1.12	-6.70 ± 1.40	3.96 ± 0.32	5.15 ± 1.72	-2.47C
		Mean of time	-10.07a	-6.99b	-5.78c	-1.35d	4.28e	
b* (P)	EB	0	20.26 ± 1.33	17.10 ± 3.08	11.24 ± 1.17	10.13 ± 0.71	10.10 ± 1.21	13.17A
		0.4	20.20 ± 2.29	19.52 ± 1.33	19.49 ± 1.20	14.85 ± 5.18	12.44 ± 2.11	17.30B
		0.6	19.03 ± 2.61	17.42 ± 1.46	18.78 ± 1.25	16.16 ± 4.54	12.57 ± 1.97	16.79B
		0.8	19.65 ± 1.03	19.09 ± 1.77	18.32 ± 1.95	18.19 ± 2.46	11.84 ± 1.17	17.42B
		1.0	19.54 ± 0.97	18.13 ± 2.02	17.71 ± 2.50	12.32 ± 2.59	11.37 ± 1.01	15.81B
		Mean of time	19.74a	18.25ab	17.11b	14.33c	11.66d	
	GM	0	19.03 ± 0.37	14.35 ± 1.03	9.78 ± 0.63	9.77 ± 0.84	5.70 ± 0.59	11.72A
		0.4	18.78 ± 1.66	15.47 ± 1.38	13.36 ± 1.88	12.17 ± 1.78	8.25 ± 1.17	13.61B
		0.6	19.96 ± 1.46	12.29 ± 1.57	11.91 ± 1.94	10.27 ± 0.84	9.46 ± 2.14	12.78B
		0.8	18.99 ± 1.04	14.34 ± 0.96	13.62 ± 0.82	13.23 ± 1.95	8.56 ± 1.76	13.75B
		1.0	17.46 ± 1.12	14.31 ± 1.52	13.23 ± 1.01	11.13 ± 1.00	7.71 ± 0.83	12.77B
		Mean of time		14.15b	12.38c	11.31c	7.94d	

Mean values followed by the same letter are not significant difference at P < 0.05

LR and P were Lo Ren and Purple star apple, respectively

3.2. Effects of gamma and EB irradiation to fungi and pest insects infesting on star apples

3.2.1. Effects of gamma and EB irradiation to pathogenic fungi and pest insects infesting commonly on star apples by observation of their appearance

In our observation. there was no appearance of any pest insect inside of fruits for both types of irradiation. It means that electron beams have effects in phytosanitary for star apples although its penetration is quite low. Fungi had appeared by the 6 day at doses of 0.4 and 0.6 kGy for EB and 0.4 kGy for gamma ray irradiation (Table 4).

Table 4. Appearance of fungi and pest insects loading on star apples by gamma ray and EB irradiation during storage time (15 fruits/observation time)

Subjects	Dose (kGy)	EB			GM		
		3d	6d	9d	3d	6d	9d
Pest insects	0 (Control)	-	+	++	-	+	++
	0.4	-	-	-	-	-	-
	0.6	-	-	-	-	-	-
	0.8	-	-	-	-	-	-
	1.0	-	-	-	-	-	-
Molds/fungi	0 (Control)	-	+	++	-	+	++
	0.4	-	+	++	-	+	++
	0.6	-	+	++	-	-	++
	0.8	-	-	++	-	-	+
	1.0	-	-	-	-	-	-

3.2.2. Comparison of resistance of fungal spores *Lasiodiplodia theobromae* isolated from fresh star apples to gamma and electron beam radiation

The sensitivity of *Lasiodiplodia theobromae* was significantly increased by dose – dependent gamma or EB irradiation ($P<0.05$). The survival curves for conidiospores *Lasiodiplodia theobromae* following gamma and EB treatment were expressed in Fig. 1. Based on the calculation. D_{10} values are 0.95 kGy and 1.1 kGy for gamma rays and electron beams. respectively. However. no significant difference of D_{10} values was obtained for both types of radiation ($P<0.05$).

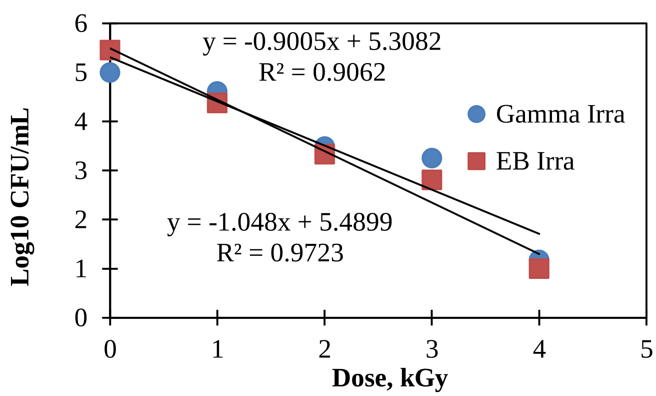

Figure 1. Survivial curves for conidiospores *Lasiodiplodia theobromae* following gamma and EB treatment

The synergistic effect of combined treatment with gamma and EB irradiation and NaDCC on *Lasiodiplodia theobromae* conidia is shown in Fig. 2. A synergistic effect was observed for combined treatment against *Lasiodiplodia theobromae* conidia. The sensitivity of *Lasiodiplodia theobromae* in combined treatment with NaDCC and irradiation was markedly increased in comparison to the gamma (GI) or EB irradiation (EbI) alone. The D_{10} value was also significantly reduced to 0.13 kGy (for NaDCC + GI) and 0.19 kGy (for NaDCC + EbI) in combination.

Similarly. there is no significant difference of D_{10} value for both types of irradiation ($P<0.05$). Thus. it will be concluded that the use of combined treatment with irradiation and NaDCC treatment has a synergistic effect on reducing the irradiation dose required to eliminate this spoilage fungal species. Thus. effects of GI and EbI on *Lasiodiplodia theobromae* fungus are similar for both types.

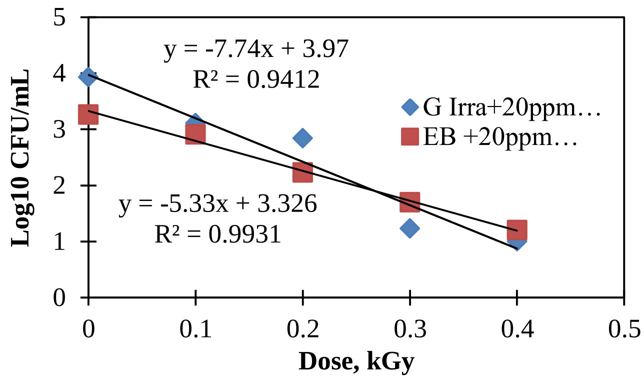

Figure 2. Survival curves for conidiospores *Lasiodiplodia theobromae* following gamma and EB combined with NaDCC treatment

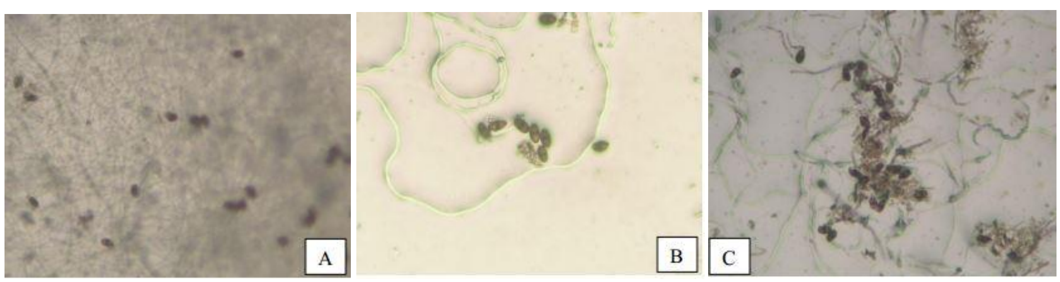

Figure 3. Spores and hyphae of *Lasiodiplodia theobromae* under microscope in combined treatment of irradiations and NaDCC: 20 ppm NaDCC + 0 kGy (A); 20ppm NaDCC + 0.4 kGy Gamma irradiation (B) & 20 ppm NaDCC + 0.4 kGy EB irradiation (C)

3.3. Determination of dose distribution on the carton of products

To determine the dose distribution, dosimeters were placed in different locations inside of carton containing star apples (Lo Ren and purple). The results showed that the carton dimension of 38×30×32 cm with gross weight of 10 kg is suitable for SVST-Co60/B due to DUR of 1.29. For EB irradiation, the carton dimension of 49×32×12 cm with gross weight of 4 kg is suitable for both kinds of star apples because DUR of 1.1 (Lo Ren) and 1.07 (purple). The DUR of 1.2 for Lo Ren and 2.2 for purple star apple were calculated. To assure the quality of irradiated purple star apples mdf wedges with 1 cm of thickness were suggested to put in the carton to get lower DUR (1.4) (Tab.5 and Fig. 3).

Table 5. Dose uniformity ratio (DUR) for purple star apple before and after using mdf wedge

Location	Before		After	
	Inside of fruit (kGy)	Outside of fruit (kGy)	Inside of fruit (kGy)	Outside of fruit (kGy)
1	2.5	1.8	2.2	1.8
2	2.2	2.0	2.2	2.1
3	2.3	1.9	2.4	1.9
4	3.3	1.9	2.6	2.0
5	4.0	2.4	2.5	2.2
DUR	2.2		1.4	

Figure 4. Purple star apples using mdf wedges inside the carton

3.5. Synergistic effect of combined treatment on Star Apple at trading condition

Using 20 ppm NaDCC in pre-treatment before EB irradiation (dose of 0.4 – 0.6 kGy) extended shelf-life of star apple when keeping them under the trade conditions (7 days at 9^{o}C in transportation by air to destination). The shelf-life of both types of star apples (13 days) was higher than the control (non- treatment. un-irradiation) (6 days) (Figure 4). The results indicated that the combined treatment significantly inhibited the fungal development in star apple fruits therefore extend the shelf-life of fruits. Similar results were reported by Salem and Moussa (2014) on pear fruits [8]. Thus, NaDCC treatment was an important factor in combined treatment. In addition. the integration of EB irradiation and ecofriendly agents has a potential use in the control of other pathogens such as bacteria and viruses. [7].

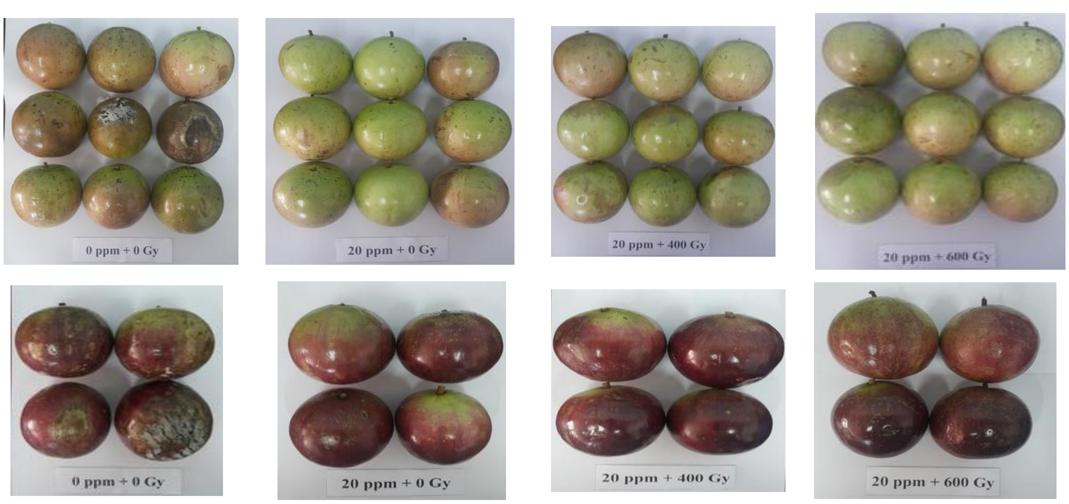

Fig 5: Star apples in different treatments after 13 days storage under trade conditions

IV. Conclusion

1. Purple star apples could be more resistant with radiation than Lo Ren star apples. However. the quality of both kinds of star apples was changed significantly when they were irradiated at the dose > 0.6 kGy and when the fungus *Lasiodiplodia theobromae* appeared.
2. Irradiation in combination with NaDCC 20 ppm can reduce D_{10} from 0.95 kGy to 0.13kGy (Gamma irradiation) and from 1.1 kGy to 0.19 kGy (Electron beam irradiation).
3. Mdf wedges with 1 cm of thickness were suggested to put in the carton to get lower DUR (1.4) to comprare with the normal one (with no mdf wedge) (2.2).
4. Using NaDCC 20 ppm in pretreatment before EbI could be applied in extending the shelf-life of fruits and inhibition of fungal growth. The quality of star apples in treated combination was evaluated to be equivalent to the control (untreated NaDCC. non-irradiated) after 13 days storage under trade conditions (7 days. 9^{o}C).

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