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The effect of Combined Treatment with Sodium Dichloroisocyanurate and Electron Beam Irradiation in Controlling Mold (*Lasiodiplodia theobromae*) on Star Apples

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Abstract: *Lasiodiplodia theobromae* causes decay of star apple fruits (*Chrysophyllum cainino)* during harvest, transport and storage. If the irradiation dose is higher than 800 Gy, this mold will be controlled. However, the quality of star apple was significantly changed when they were irradiated at the dose higher than 0.6 kGy by electron beam (EB). To keep irradiation dose under 0.6kGy, the synergic effect of the combined treatment of EB irradiation and sodium dichloroisocyanurate (NaDCC) was investigated. In this study, star apples were pretreated with NaDCC concentrations in range of 10 -70 ppm in order to decrease the growth of mold and extend the shelf-life of treated star apples. The results showed that pretreatment with 20 ppm NaDCC had also kept the color and reduced disease of stored star apple. Dipping star apples into 20 ppm NaDCC solution before irradiating at 400 Gy and 600 Gy could be chosen as the best way to inhibit the development of *Lasiodiplodia theobromae* and extend the shelf life of star apple in the trading condition (7 days, 9^{o}C).

Keywords: *star apple, electron beam, irradiation, phytosanitary, pretreatment*.

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

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does not control fungicides (not clear), 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 the minimum doses for quarantine treatment (0.4 kGy) are sufficient to sterilize, 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. 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.

II. MATERIALS AND METHODS

A. EB 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 400,600, 800 Gy and 1000 Gy by EB of 10 MeV accelerator UERL-10-15S2. 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, vitamin C content and extent of damage of fruits in duration of storage.

B. Postharvest treatment

Star apples were immersed for 10 minutes in sodium dichloroisocyanurate (NaDCC) at various concentrations (0 - 70 ppm) and then dried on a cleaned tray. All samples were stored at room temperature of 28ºC±2 for 12 days to determine the growth of fungi on the surface skin of star apple, extent of damage of fruits to choose the best concentrations for pretreating star apples before EB irradiation.

C. 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 and irradiated at 400 and 600 Gy by EB. Non treated star apples were also studied as a control sample. After 7 days storage, weight loss, color and extent of damage of star apples were evaluated.

D. Postharvest quality evaluation

Color measurement [8, 9]

Skin color of star apples was measured by using a Minolta Chroma Meter (Model CR200, Minolta Co., Japan). Each assessment used 3 fruits from each of three replicate groups. Measurements were taken on 3 different points of each fruit, and the mean value calculated. The average value of L (luminosity), a (green-red), b (blue-yellow), color changes from green to yellow were indicated by calculating the hue angle (H), from $\tan^{-1}$ b/a, and $\triangle$E for each fruit was collected for analysis.

Fresh weight loss [10]

The weight loss of each treatment included 3 fruits was tested. The percentage of weight loss was calculated by the following formula:

The weight loss (%) =100 × (Fresh weight − Weight at storage interval)/ Fresh weight

Disease of stored star apple [11]

Incidence of disease caused by mould on the stored star apple was determined by observation every 3 days. Postharvest disease index was assessed by using the scale (Table I). The occurred mould was sent to The Post Entry Plant Quarantine Center to identify.

Table I. Scales used for postharvest disease severity

Scales	Percentage of fruit infected by disease (%)
0	0
1	0 - 5
2	5 - 10
3	10 - 25
4	25 - 50
5	> 50

Insect infestation assessment [12]

Insect infestation was determined initially on the fresh star apple and subsequently on the deteriorating terminal test sample. The star apples were cut opened to observe the presence of insect larva.

Analyses of other properties

Soluble solids (^{o}Brix) determination: The brix was determined with the aid of hand-held refractometer, also called able refractometer (TIRBX32, Trans Instruments Pte Ltd., Singapore).

Vitamin C content determination: The vitamin C content was determined according to the method of AOAC 967.21.

E. Statistical analyses

Data were subjected to analyses of variance (ANOVA) at $P < 0.05$ using SPSS 13.0 software and Duncan's multiple range tests were used to compare the differences among the mean values. Percentages of weight loss were arcsine transformed before analysis. Data of disease severity was transformed to $(xi+0.5)^{1/2}$.

III. RESULTS AND DISCUSSION

A. Effect of EB irradiation on quality of star apple

Results showed that vitamin C and diseased fruits decreased with the increasing dose; while the percentage of weight loss increased with increasing dose and changed significantly in storage time (Table II).

The results showed from Table II also indicated that the vitamin C content in fruits also decreased gradually in storage time from 4.27 mg/ 100 g at the first day to 3.05 mg/ 100 g after 12 days. The difference in vitamin C content was not significant different between the control and samples irradiated up to 800 Gy. Similar results have been shown by Thomas and Beyers in papaya, lychee and mango fruits [13].

Fresh weight loss of stored star apple was not significant different between control and irradiated sample up to 800 Gy, but significant different at 1000 Gy under storage conditions. The results indicated that the irradiation treatment with high doses (0.8–1 kGy) would cause a change in the membrane function of the irradiated star apple which increased in permeability causing higher respiration [14].

The total soluble solids had no considerable changes in both treatments ($P>0.05$). These values significantly decreased after 9 days of storage (Table III). The result can be explained that, the star apple is a non-climacteric fruit so it must mature on the tree

before being harvested. At the time of mature, the TSS content of the fruit was the greatest. After harvesting, the TSS did not increase any more. In addition, respiration of the fruits and their structural polysaccharides were used for this process.

The development of fungi causes the fruit rot of star apples. The presence of fruit rot can cause significant postharvest losses and can negatively affect the fruit's quality. In the 3 conducted trials, the fruit rot of star apple fruit was not observed after harvest. However by 12 days the disease was appeared in all samples (Table II).The onset of development of this disease can be seen in latent stage of peel color development of star apple fruits. The non-irradiated fruits exhibited with the higher score compared to irradiated fruits. Disease severities on star apple decreased with increasing dose (Table II). The results indicated that irradiated star apple from 400 to 1000 Gy could not constrain the development of fungal diseases. On the other hand the fruits were not treated with fungicide prior to storage. Furthermore, ripe fruits are more vulnerable to biodeterogens and high humidity, high moisture inside containing bags were convenient conditions for disease growing during storage time [12].

Table II. Effect of EB irradiation on chemical ingredient and weight loss during storage time

Parameter	Dose (Gy)	Storage period (days)					Mean of Dose
		0	3	6	9	12	
TSS,%	Control	12.0 ± 1.6	11.8 ± 0.9	11.6 ± 0.5	10.2 ± 0.3	9.2 ± 0.7	10.96A
	400	11.9 ± 2.0	12.1 ± 0.4	11.6 ± 1.7	10.1 ± 0.4	8.8 ± 2.5	10.92A
	600	11.9 ± 0.1	11.3 ± 0.8	11.2 ± 0.3	10.2 ± 0.3	8.3 ± 1.4	10.59A
	800	12.9 ± 0.5	11.8 ± 1.3	11.1 ± 0.8	10.6 ± 0.4	9.3 ± 2.1	11.14A
	1000	12.3 ± 1.1	12.1 ± 1.1	11.3 ± 1.0	10.3 ± 0.6	9.2 ± 2.0	11.03A
Mean of Time		12.2a	11.83a	11.38a	10.28b	8.95c	
Vitamin C	Control	4.49 ± 0.00	4.38 ± 0.8	3.44 ± 0.15	3.38 ± 0.48	3.21 ± 0.51	3.78A
	400	4.49 ± 0.83	4.39 ± 0.00	3.38 ± 0.96	3.21 ± 0.29	3.16 ± 0.11	3.73A
	600	4.14 ± 1.11	3.94 ± 0.48	3.29 ± 0.00	3.11 ± 0.48	3.04 ± 0.04	3.50AB
	800	4.21 ± 0.48	4.17 ± 0.48	3.38 ± 0.96	3.26 ± 0.09	2.83 ± 0.00	3.57AB
	1000	4.04 ± 0.48	3.94 ± 0.48	3.11 ± 0.48	3.08 ± 0.47	3.03 ± 0.07	3.44B
Mean of Time		4.27a	4.16a	3.32b	3.21b	3.05b	
Weight loss,%	Control	0.19 ± 0.01	11.49 ± 0.39	15.27 ± 1.30	23.41 ± 2.84	23.93 ± 2.55	15.20A
	400	0.18 ± 0.02	10.05 ± 2.06	14.25 ± 5.07	20.86 ± 8.32	22.72 ± 7.37	13.93A
	600	0.18 ± 0.01	13.10 ± 3.77	14.84 ± 3.54	21.55 ± 5.94	26.12 ± 7.30	15.48A
	800	0.19 ± 0.01	5.67 ± 3.08	20.88 ± 2.02	26.17 ± 1.80	28.03 ± 0.64	16.53A
	1000	0.18 ± 0.01	13.13 ± 6.57	21.26 ± 5.15	26.83 ± 6.71	37.84 ± 5.40	20.17B
Mean of Time		0.18a	10.69b	17.30c	23.76d	27.73e	
Disease severity	Control	0.71 ± 0.00	0.71 ± 0.00	1.96 ± 0.14	2.20 ± 0.13	2.35 ± 0.00	1.58A
	400	0.71 ± 0.00	0.71 ± 0.00	1.68 ± 0.17	2.27 ± 0.13	2.35 ± 0.00	1.54ABC
	600	0.71 ± 0.00	0.71 ± 0.00	1.78 ± 0.17	2.27 ± 0.13	2.35 ± 0.00	1.56AB
	800	0.71 ± 0.00	0.71 ± 0.00	1.35 ± 0.21	2.35 ± 0.00	2.35 ± 0.00	1.49BC
	1000	0.71 ± 0.00	0.71 ± 0.00	1.35 ± 0.21	2.27 ± 0.13	2.35 ± 0.00	1.48C
Mean of Time		0.71a	0.71a	1.63b	2.27c	2.35d	

Mean values within same a row or column followed by the same letter are not significant different at $P < 0.05$.

Table III. Observation appearance of moulds and insects on unirradiated and irradiated star apple during storage time

Subjects	Dose (Gy)	Storage period (days)				
		0	3	6	9	12
Insect	0 (Control)	-	-	-	-	-
	400	-	-	-	-	-
	600	-	-	-	-	-
	800	-	-	-	-	-
	1000	-	-	-	-	-
Mold	0 (Control)	-	-	+	++	++
	400	-	-	+	++	++
	600	-	-	+	++	++
	800	-	-	-	+	++
	1000	-	-	-	-	++

(-), (+), and (++) were not appearance, beginning appearance and a lot appearance, respectively

L* and b* values did not change by an irradiation dose, but these values were significantly affected by the storage time. While a* value increased with increasing irradiation dose (Table IV). The lightness and yellowness of star apple decreased with storage time and significant after 9 days storage at room temperature. This discoloration of the star apple could be attributed to the browning reaction, fungal activity and water loss in the fruits.

Table IV. Effect of EB irradiation on color of star apple during time storage

Parameter	**Dose (Gy)**	**Days of storage**					**Mean of Dose**
		0	**3**	**6**	**9**	**12**	
L*	Control	58.2±5.33	62.04±1.14	60.55±3.04	56.05±4.15	40.54±6.96	55.48A
	400	57.9±3.12	58.95±1.35	60.71±6.01	57.24±5.72	38.45±4.43	54.65A
	600	56.74±0.53	61.61±0.81	61.64±1.73	53.63±2.16	40.06±5.57	54.74A
	800	60.31±4.28	63.37±5.14	60.97±1.84	51.18±2.87	47.99±0.79	56.76A
	1000	57.92±1.53	63.14±6.86	63.16±1.08	49.47±2.75	45.88±0.91	55.91A
Mean of Time		58.21b	61.82a	61.41a	53.51c	42.58d	
a*	Control	-13.65 ± 1.37	-11.67 ± 3.77	-5.39 ± 1.21	-0.31 ± 3.35	3.56 ± 2.28	-5.49A
	400	-12.61 ± 1.03	-11.17 ± 3.29	-5.00 ± 2.76	-0.14 ± 3.05	3.61 ± 0.42	-5.06A
	600	-11.77 ± 2.20	-10.25 ± 3.24	-5.99 ± 4.45	-0.68 ± 3.55	4.80 ± 3.11	-4.78A
	800	-12.73 ± 1.80	-10.69 ± 0.88	-3.56 ± 3.48	4.00 ± 0.59	4.80 ± 1.58	-3.64AB
	1000	-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	
b*	Control	31.75 ± 0.01	30.24 ± 1.16	28.89 ± 0.90	26.44 ± 3.05	15.63 ± 7.80	26.59A
	400	30.00 ± 3.99	31.56 ± 2.85	29.45 ± 3.70	26.17 ± 1.93	16.81 ± 6.26	26.80A
	600	30.16 ± 1.09	29.45 ± 1.54	30.25 ± 3.37	25.99 ± 1.41	12.72 ± 4.91	25.71A
	800	30.32 ± 1.27	28.96 ± 1.30	28.42 ± 1.70	22.44 ± 0.82	19.21 ± 3.46	25.87A
	1000	29.13 ± 1.32	29.08 ± 1.63	26.51 ± 0.85	22.56 ± 1.21	20.14 ± 0.67	25.48A
Mean of Time		30.27a	29.86a	28.7a	24.72b	16.9c	

Mean values within same a row or column followed by the same letter are not significant different at $P < 0.05$.

B. Effect of NaDCC on star apple

Radiation at high doses could be completely control diseases, but it also has a negative effect on the skin color and texture of stored fruits and vegetables [15]. Chlorination, sodium dichloroisocyanurate (NaDCC), is one of the promising treatments with irradiation to inhibit the growth of postharvest diseases.

The microorganism detected initially and in the deteriorating star apple was presented in Table 5. The results showed that increasing the concentration of NaDCC would increase the time to detect the appearance of fungal infection on the star apple. The fungi appeared after 6, 9 and 12 days in 0, 10 and 20 ppm respectively. However, NaDCC in concentration higher than 30 ppm did not extend time to detect fungal. In addition, the lightness and redness of these higher concentrations were not significant to compare with the control sample (Table 6). Similar result was reported by Lai and Phan (2006) that total microbial populations reduced by using chlorine solution to wash Salad-cut lettuce. However, high concentration in chlorine decreased the time to observe the browning on the Salad-cut lettuce [16]. So, the results indicated that NaDCC concentration of 20 ppm could be used to treat star apple before irradiation to keep color, reduce disease and extend time to detect fungal.

Table V. Detection of growing fungi on star apples treated with different concentrations of NADCC during storage time

NaDCC concentration (ppm)	Storage period (days)				
	0	**3**	**6**	**9**	**12**
0	-	-	+	++	++
10	-	-	-	+	++
20	-	-	-	-	+
30	-	-	-	-	+
40	-	-	-	-	+
50	-	-	-	-	+
60	-	-	-	-	+
70	-	-	-	-	+

(-), (+), and (++) were not appearance, beginning appearance and a lot appearance, respectively

Table VI. Effect of NaDCC on color of star apple during time storage

Parameter	NaDCC (ppm)	Storage period (days)					Mean of NaDCC
		0	**3**	**6**	**9**	**12**	
L	0	58.46 ± 3.53	62.85 ± 4.52	57.67 ± 6.26	52.74 ±10.3	40.00 ± 3.49	54.34A
	10	61.06 ± 5.01	61.22 ± 3.49	59.01 ± 4.70	56.79 ± 8.22	42.50 ± 7.95	56.12A
	20	63.73 ± 4.00	62.85 ± 3.08	63.23 ± 5.91	56.35 ± 2.31	52.06 ± 4.83	59.64B
	30	63.40 ± 3.63	63.04 ± 3.87	58.80 ± 8.08	58.23 ± 1.75	55.11 ± 3.93	59.72B
	40	61.13 ± 3.14	57.98 ± 1.95	57.03 ± 4.55	54.75 ± 3.65	48.85 ± 7.85	55.95A
	50	62.29 ± 2.67	61.10 ± 4.21	61.16 ± 2.52	49.94 ± 8.83	43.47 ± 7.27	55.59A
	60	62.08 ± 2.60	58.45 ± 3.25	56.43 ± 6.60	55.89 ± 5.56	43.59 ± 4.02	55.29A
	70	62.91 ± 1.88	59.81 ± 3.88	58.63 ± 2.42	56.12 ± 3.02	43.52 ±13.02	56.20A
Mean of Time		61.88a	60.91ab	59.00b	55.10c	46.14d	
a	0	-8.19 ± 3.01	-4.94 ± 3.38	-2.82 ± 4.35	0.47 ± 2.45	4.55 ± 1.43	-2.19A
	10	-9.48 ± 3.93	-7.10 ± 3.67	-6.01 ± 5.39	-1.99 ± 5.14	4.47 ± 3.30	-4.02AB

	20	-13.82 ±1.41	-11.91 ±2.41	-11.65 ± 2.08	-2.10 ± 4.18	2.04 ± 1.36	-7.49C
	30	-10.11 ±3.24	-7.28 ± 3.05	-6.12 ± 4.86	-1.33 ± 4.53	1.65 ± 2.64	-4.64B
	40	-8.02 ± 3.65	-4.41 ± 3.68	-0.85 ± 6.80	-1.21 ± 6.38	0.48 ± 5.52	-2.80AB
	50	-9.54 ± 5.45	-6.61 ± 6.06	-5.40 ± 6.70	-1.15 ± 6.47	1.52 ± 4.53	-4.24AB
	60	-10.31 ±1.88	-7.46 ± 2.20	-4.89 ± 4.16	-1.48 ± 3.07	5.50 ± 2.90	-3.73AB
	70	-9.10 ± 2.73	-6.76 ± 2.87	-4.95 ± 2.20	3.12 ± 3.00	1.20 ± 3.30	-3.30AB
Mean of Time		-9.82a	-7.06b	-5.34c	-0.71d	2.68e	

Mean values within same a row or column followed by the same letter are not significant different at P < 0.05.

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

Using 20 ppm NaDCC in pre-treatment before EB irradiation extended shelf-life of star apple when keeping them under the trade conditions (7 days at 9ºC in transportation by air to destination). The weight loss, color and disease were showed at Table 7. Means of L* and ΔE values did not have any significant difference between N-400 Gy, N-600 Gy and control (non-treated, unirradiated). Meanwhile, there was the significant difference between the N-0 Gy and the others. The weight loss was not changed during 7 days for all applications. Sample N-0 Gy was the lowest weight loss (2.82%) while the control was 4.4% for 16 days at room temperature. Disease and a* value in control sample were significantly higher than the others. The results indicated that the combined treatment with 400 Gy; 600 Gy of EB irradiation and 20 ppm of NaDCC significantly inhibited the fungal development in star apple fruits (Fig. 1 and Table VIII) and had no detrimental effects on the fresh weight of the star apple fruits. So treatment star apples with NaDCC combined to irradiation can extend the shelf-life of fruits. Similar results were reported by Salem and Moussa (2014) on pear fruits [17]. These results can be explained as the combined treatment can sufficiently damage the membrane of the fungal pathogen, leading to a release of intra cellular contents and eventually cell death. NaDCC seemed to have more effect to physiological changes than EB irradiation of fungal spores. Irradiation mainly damaged DNA, whereas NaDCC significantly affected cell membrane, resulting in the loss of intra cellular contents. 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].

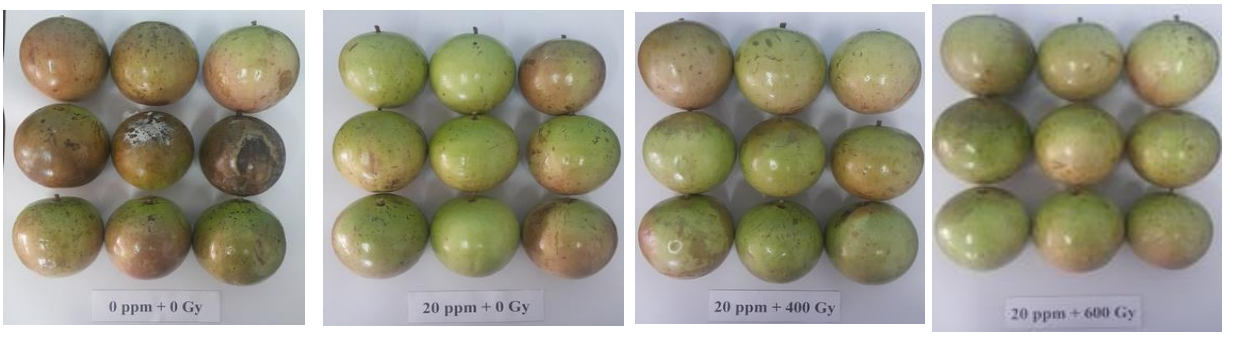

Fig 1. Star apples in different treatments after 13 days storage under trade conditions

Table VII. Color, weight loss and disease of star apple during storge time at trade conditions

Parameter	Sample	Time (Days)					Mean of sample
		0	7	10	13	16	
L*	Control	61.03 ± 4.18	60.50 ± 4.13	60.30 ± 3.95	59.76 ± 6.33	54.42 ± 3.86	59.20B
	N - 0 Gy	64.05 ± 2.48	63.52 ± 2.52	62.98 ± 2.68	61.80 ± 2.30	59.42 ± 5.39	62.35A
	N - 400 Gy	62.41 ± 2.90	61.89 ± 2.91	62.32 ± 1.87	62.07 ± 2.28	48.65 ± 8.46	59.47B
	N - 600 Gy	61.60 ± 1.85	61.07 ± 1.91	61.65 ± 1.38	58.22 ± 2.17	48.05 ± 3.94	58.12B
Mean of Time		62.27a	61.74a	61.81a	60.46a	52.63b	
a*	Control	-6.36 ± 3.21	-3.89 ± 4.61	-2.24 ± 5.17	0.44 ± 2.51	6.51 ± 1.34	-1.11C
	N - 0 Gy	-10.82 ± 1.41	-7.47 ± 2.90	-5.63 ± 3.23	-1.18 ± 2.89	0.62 ± 4.26	-4.90A
	N - 400 Gy	-6.79 ± 2.54	-5.89 ± 2.53	-5.83 ± 3.46	-1.59 ± 3.61	5.24 ± 3.12	-2.97B
	N - 600 Gy	-7.56 ± 2.69	-6.21 ± 2.46	-5.00 ± 2.80	-2.09 ± 2.72	5.75 ± 2.03	-3.02B
Mean of Time		-7.88a	-5.87b	-4.67b	-1.10c	4.53d	
DeltaE	Control	40.88 ± 4.77	40.21 ± 4.77	40.12 ± 5.03	38.85 ± 4.27	27.90 ± 3.83	37.59B
	N - 0 Gy	43.87 ± 4.05	43.20 ± 4.05	42.59 ± 4.57	40.54 ± 3.11	38.12 ± 6.00	41.66A
	N - 400 Gy	42.57 ± 2.48	41.90 ± 2.48	41.74 ± 1.50	41.17 ± 3.14	26.57 ± 8.99	38.79B
	N - 600 Gy	42.35 ± 1.75	41.68 ± 1.75	41.24 ± 1.74	37.03 ± 2.27	25.52 ± 5.25	37.56B
Mean of Time		42.42a	41.75ab	41.42ab	39.40b	29.52c	
Disease severity	Control	0.71 ± 0.00	0.71 ± 0.00	0.97 ± 0.51	1.24 ± 0.67	2.35 ± 0.00	1.19A
	N - 0 Gy	0.71 ± 0.00	0.71 ± 0.00	0.71 ± 0.00	0.80 ± 0.29	1.43 ± 0.71	0.87B
	N - 400 Gy	0.71 ± 0.00	0.71 ± 0.00	0.71 ± 0.00	1.00 ± 0.44	2.25 ± 0.12	1.07A
	N - 600 Gy	0.71 ± 0.00	0.71 ± 0.00	0.71 ± 0.00	1.03 ± 0.49	2.30 ± 0.10	1.09A
Mean of Time		0.71a	0.71a	0.77a	1.02b	2.08c	
Weight loss,%	Control	0.17 ± 0.01	3.63 ± 0.13	6.53 ± 3.26	9.29 ± 3.10	11.75 ± 3.24	6.27A
	N - 0 Gy	0.18 ± 0.01	4.14 ± 0.12	6.10 ± 1.68	7.76 ± 0.95	9.57 ± 1.15	5.55B
	N - 400 Gy	0.18 ± 0.00	4.24 ± 0.11	5.68 ± 0.22	8.23 ± 0.90	10.77 ± 1.23	5.82AB
	N - 600 Gy	0.18 ± 0.01	4.28 ± 0.18	6.16 ± 0.37	8.25 ± 0.53	12.19 ± 2.05	6.21B
Mean of Time		0.18a	4.07b	6.12c	8.38d	11.07e	

Mean values within same a row or column followed by the same letter are not significant different at $P < 0.05$.

N - 0 Gy; N - 400 Gy and N - 600 Gy were NaDCC + 0 Gy; NaDCC + 400 Gy and NaDCC + 600 Gy, *respectively*

Table VIII. Appearance of fungi on star apples in combined treatments during storage time

Sample	Day after treatment				
	0	7	10	13	16
Control	-	-	+	++	++
N - 0 Gy	-	-	-	-	-
N - 400 Gy	-	-	-	-	+
N - 600 Gy	-	-	-	-	+

(-), (+), and (++) were not appearance, beginning appearance and a lot appearance, respectively

III. CONCLUSION

EB irradiation at 800 and 1000 Gy could inhibit the development of fungi on star apples. However, at these doses, physical properties and quality of fruits were changed significantly. Pre-treatment of star apples with 20 ppm NaDCC and before EB irradiation at 400 Gy 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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