EFFECTS OF UV-C TREATMENT ON KIWIFRUIT QUALITY DURING THE STORAGE PERIOD

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ABSTRACT

This experiment was conducted at Namik Kemal University, Agriculture Faculty and Department of Horticulture in Turkey and Actinidia deliciosa cv. Hayward was used for this aim. In this study, Kiwifruits were irradiated with different doses of UV-C treatment (50, 75 and 100 cm distance for 5, 10 and 15 min). Later, they were put in polyethylene container with packed polyethylene bags and stored under the conditions of cool air store (at 0-1^{0}C, 90-95 % relative humidity) for 200 days. During the experiment, quality attributes of kiwifruit was assessed at 40 days intervals and UV-C treatment from 75 cm distance for 10 min was especially found to be more effective than the others.

KEY WORDS: Kiwifruit, UV-C treatment, eating quality, storage, maturity

INTRODUCTION

In recent years, as far as health is concerned, quality and safety in foods and non-risk foods are factors which are demanded by consumers. The food industry needs new alternative in processing and preservation techniques in order to meet the consumer expectations with safer and fresher horticultural products. Most of these emerging technologies (modified atmosphere packing (MAP), O_3, H_2O_2, ultraviolet radiation, etc.) are milder, less damaging to product quality and more natural than current techniques [20].

UV-C is generally harmful but can produce beneficial effect on horticultural products at low doses, a phenomenon known as hormesis (the stimulation of plant response by low levels of inhibitors or stress) [23]. Treating fresh fruits and vegetables with ultraviolet radiation (UV) is a new approach that holds promise for the extension of storage life of fresh horticultural crops [8].

Although UV-C irradiations are not ionized irradiation, it is simpler, more economic and reliable for usage than of ionized irradiation [22].

Recently, the use of UV-C at 254 nm alone or combined with MAP was proposed to reduce microbial growth and keeping quality in some intact and minimally processed fruit and vegetables (i.e., apple, tomato, bell pepper, grape, plum, lettuce) [16, 36, 6, 3, 4].

These studies showed that UV-C treatment on some fruits delays senescence and maturity [22, 21]; protects against pathogenic fungi attack [33]. Effectiveness of UV-C treatments varies with fruit species, maturity level, irradiation dose and duration.

Kiwifruit are climacteric and the flesh of kiwifruit changes from hard to soft and from acid to sweet during ripening. These variations in fruit structure and taste can be speeded or slow down depending on postharvest treatment and storage conditions. During the storage of kiwifruit, an ethylene removal system may be used or the fruit may be treated with ethylene blockers to slow ripening and delay senescence [30]. Consumer preference for kiwifruit is determined primarily by the sugar–acid balance with fruit firmness and fruit volatile content causing a large moderating effect [14].

The aim of this study was to examine effectiveness of different UV-C treatment at low doses on storage period and eating quality of kiwifruit in postharvest period.

MATERIALS AND METHODS

This experiment was conducted with Actinidia deliciosa cv. Hayward. Kiwifruits (total soluble solids: 6.2°Brix ± 0.17 and kiwifruit firmness: 7.11 kg ± 0.19) and harvested kiwifruits in November were irradiated with different doses of UV-C treatment. For this aim, kiwifruits were irradiated using three germicidal, low pressure vapor lamps (Osram HNS OFR). Each of 3 lamps (2.5 cm tube diameter, 88 cm length) had a nominal power output of 30 W and emitted wave energy at 253.7 nm.

According to Akbudak and Karabulut [3], the light emission area in the upper cabin surface was 60x100 cm and UV-C treatments onto kiwifruits were performed for 5, 10 and 15 min at 50 cm (1 kJ/m^2), 75 cm (0.5 kJ/m^2) and 100 cm (0.25 kJ/m^2). No treatment was performed for control kiwifruits.

After treatments, 8 kiwifruits were put in polyethylene container and packed with polyethylene bags (having 10.5 µ thicknesses). The data of the experiment was analyzed according to completely randomized blocks design with three replicates and each replicate consisted of 3 packages [19].

Analyses and measurements such as weight loss (%), kiwifruit firmness (kg), vitamin c content (mg/100 g), titratable acidity (%), pH, total soluble solids content (°Brix). Kiwifruits were weighted before and after the storage period to calculate percentage of fresh weight loss. Fruit firmness was determined on opposite sides of the fruit after peel removal using a penetrometer with 8 mm diameter tip. The 2,6-dichloroindophenol titrimetric method [5] was used to determine the ascorbic acid content of pressed fruit juice. Titratable acidity was determined by titration with 0.1 N NaOH and expressed as % citric acid. pH was measured with digital pH meter (WTW 526). Total soluble solids content was determined with a hand-held refractometer. Fruit taste was evaluated by 7 panelist using a scale of 9 point scale (1: very poor, 3: poor, 5: fair, 7: good and 9: excellent). The assessments were made on kiwifruits which were stored under the conditions of cool air store (at 0-1^{0}C, %90-95 relative humidity) for 200 days. Kiwifruits were sampled at 40 day intervals and the data were interpreted using TARIST statistical software [2].

RESULTS AND DISCUSSION

Although weight loss, which is one of the most important factors limiting life of fresh fruits in postharvest period, change depending on different UV-C treatment, values of weight loss increase with elevating storage period.

Besides, respiration decrease and weight loss were observed in products, which are covered by permeable films, under the storage condition [18], UV-C treatments at different doses also limited to weight loss compare control kiwifruits. At the end of 200th day, while the highest weight loss value of kiwifruit was 3.96% for control, the highest value among UV-C treatments was

Table 1 Weight loss (%) of kiwifruit exposed to different UV-C treatment during the storage period

		Day number after UV-C treatment					Treatment
Duration	**Treatments**	**40th day**	**80th day**	**120th day**	**160th day**	**200th day**	**effect**
Control		0.65	0.99	2.02	2.83	3.96	2.09^{e}
	50 cm	0.46	0.75	1.89	2.50	3.54	1.83^{bc}
5 min	**75 cm**	0.47	0.55	1.70	2.10	3.17	1.60^{a}
	100 cm	062	0.95	1.90	2.77	3.69	1.99^{cde}
	50 cm	0.41	0.67	1.89	2.49	3.64	1.82^{bc}
10 min	**75 cm**	0.31	0.59	1.72	2.34	3.42	1.68^{ab}
	100 cm	0.47	0.82	1.92	2.60	3.65	1.89^{cd}
	50 cm	0.35	0.69	1.64	2.29	3.45	1.68^{ab}
15 min	**75 cm**	0.43	0.80	1.93	2.96	3.90	2.00^{de}
	100 cm	0.59	0.96	2.04	2.63	3.65	1.97^{cde}
Time effect		0.48^{a}	0.78^{b}	1.86^{c}	2.55^{d}	3.61^{e}	
$p<0.05$	$LSD_{treatment}$: 0.176		LSD_{time}: 0.124				

Table 2 Fruit firmness (kg) of kiwifruit exposed to different UV-C treatment during the storage period

		Day number after UV-C treatment					Treatment
Duration	**Treatments**	**40th day**	**80th day**	**120th day**	**160th day**	**200th day**	**effect**
Control		5.01	2.91	1.56	0.34	0.00	1.96^{f}
	50 cm	5.65	3.41	2.34	1.47	0.78	2.73^{bc}
5 min	**75 cm**	5.64	3.54	2.58	1.63	0.78	2.83^{ab}
	100 cm	4.91	2.79	1.84	0.59	0.34	2.09^{ef}
	50 cm	5.70	3.33	2.30	1.36	0.67	2.67^{bc}
10 min	**75 cm**	5.82	3.67	2.77	1.75	1.37	3.08^{a}
	100 cm	5.52	3.18	2.05	0.99	0.45	2.44^{cd}
	50 cm	5.74	3.45	2.68	1.56	0.80	2.84^{ab}
15 min	**75 cm**	5.01	2.76	1.63	0.34	0.00	1.95^{f}
	100 cm	5.28	2.91	2.14	0.66	0.34	2.26^{de}
Time effect		5.43^{a}	3.19^{b}	2.19^{c}	1.07^{d}	0.55^{e}	
$p<0.05$	$LSD_{treatment}$: 0.314		LSD_{time}: 0.222				

3.90 % by UV-C treatment from 75 cm distance for 15 min and lowest value was 3.17% by UV-C treatment from 75 cm distance for 5 min (Table 1).

Cemeroglu [10] declare that as a general rule, 4-6% of weight loss in fruits lead to shriveled fruits and loss of commercial values. In terms of weight loss values and eating quality, kiwifruits were found to be marketable in our study.

UV-C research results on different species conducted by Akbudak and Karabulut [3], Karasahin et al. [16], Bal and Celik [6] showed that UV-C treatments led to less weight loss in UV-C treated fruits than control.

Kiwifruit firmness is an important quality attribute and its mean values decrease from harvest to eating ripe stage. Crisosto et al. [12] declare that high consumer satisfaction occurs when kiwifruit are purchased and eaten ripe or "ready to eat" with firmness within the range of 0.9-1.3 kg.

Along with kiwifruit maturity, decreasing fruit firmness changed depending on storage period and UV-C treatments. While mean firmness value of kiwifruit after 40th day was 5.43 kg, it progressed to 0.55 kg at the end of the storage period of 200 days (Table 2). As a result, UV-C treatments have an important effect on kiwifruit firmness and it was found out those different doses of UV-C treatment delayed softness of fruit tissues. Regarding kiwifruit firmness, the lowest values were observed in control (1.96 kg), UV-C treatment from 75 cm distance for 15 min (1.95 kg) and the highest value was UV-C treatment from 75 cm distance for 10 min (3.08 kg).

Barka [7] and Liu et al. [21] report that UV-C treatments delay maturity and result in obtaining firmer tomatoes than control according to their study results. Marquenie et al. [25] indicate that UV-C treatment in strawberry delay fruit softening and maintain fruit firmness.

With increasing awareness of the importance of vitamin c for human nutrition by consumers, vitamin c is considered to be a quality index for fruits. Kiwifruits are also very

Table 3 Vitamin c content (mg/100 ml) in juice of kiwifruit exposed to different UV-C treatment during the storage period

Duration	Treatments	Day number after UV-C treatment					Treatment effect
		40th day	80th day	120th day	160th day	200th day	
Control		143.6^{ab}	131.2^{d-j}	122.6^{h-p}	113.8^{o-s}	109.8^{rs}	124.2^{e}
	50 cm	124.7^{g-n}	132.0^{c-h}	127.0^{e-l}	123.9^{g-o}	115.3^{n-s}	124.6^{de}
5 min	75 cm	137.1^{b-e}	130.9^{d-k}	131.0^{d-k}	121.8$^{ı-j}$	118.5^{l-s}	127.9^{a-e}
	100 cm	141.8^{abc}	131.3^{d-j}	127.9^{e-l}	112.2^{qrs}	108.5^{s}	124.3^{de}
	50 cm	123.4^{g-o}	124.1^{g-n}	144.3^{ab}	124.1^{g-n}	116.8^{m-s}	126.5^{c-e}
10 min	75 cm	141.7^{abc}	135.1^{b-f}	138.1^{bcd}	124.5^{g-h}	118.9^{l-r}	131.7^{a}
	100 cm	138.4^{bcd}	130.2d^{-k}	125.4^{f-n}	127.7^{e-l}	113.1^{p-s}	127.0^{b-e}
	50 cm	136.4^{b-e}	133.2^{c-g}	131.9$^{c-ı}$	121.5^{j-q}	121.0^{k-q}	128.8^{a-d}
15 min	75 cm	149.0^{a}	133.2^{c-g}	130.7^{d-k}	126.1^{f-m}	118.2^{l-s}	131.4^{ab}
	100 cm	129.7^{d-k}	132.1^{c-h}	141.8^{abc}	127.9^{e-l}	116.0^{n-s}	129.5^{abc}
Time effect		136.6^{a}	131.3^{b}	132.1^{b}	122.3^{c}	115.6^{d}	

p<0.05 $LSD_{treatment\ x\ time}$: 10.128 $LSD_{treatment}$: 4.524 LSD_{time}: 3.199

Table 4 Titratable acidity content (%) in juice of kiwifruit exposed to different UV-C treatment during the storage period

Duration	Treatments	Day number after UV-C treatment					Treatment effect
		40th day	80th day	120th day	160th day	200th day	
Control		1.62^{a}	1.51^{f-k}	1.42^{p-s}	1.41^{o-s}	1.36^{s}	1.46^{d}
	50 cm	1.58^{a-d}	1.54^{c-h}	1.56^{b-f}	1.48$^{ı-m}$	1.42^{n-r}	1.52^{a}
5 min	75 cm	1.60^{ab}	1.56^{b-f}	1.52^{e-j}	1.47^{j-n}	1.47^{j-n}	1.52^{a}
	100 cm	1.53$^{d-ı}$	1.51^{f-k}	1.47^{j-n}	1.41^{o-s}	1.42^{n-r}	1.47^{cd}
	50 cm	1.56^{b-f}	1.50^{g-l}	1.45^{l-p}	1.43^{m-q}	1.38^{qrs}	1.46^{d}
10 min	75 cm	1.57^{a-e}	1.55^{b-g}	1.54^{c-h}	1.46^{k-o}	1.41^{p-u}	1.50^{ab}
	100 cm	1.56^{b-f}	1.49^{h-l}	1.50^{g-l}	1.40^{p-s}	1.38^{qrs}	1.46^{d}
	50 cm	1.59^{abc}	1.53$^{d-ı}$	1.51^{f-k}	1.43^{m-q}	1.37^{rs}	1.49^{bc}
15 min	75 cm	1.52^{e-j}	1.53$^{d-ı}$	1.48$^{ı-m}$	1.45^{l-p}	1.36^{s}	1.47^{cd}
	100 cm	1.55^{b-g}	1.55^{b-g}	1.48$^{ı-m}$	1.42^{n-r}	1.39^{qrs}	1.48^{cd}
Time effect		1.57^{a}	1.53^{b}	1.49^{c}	1.43^{d}	1.39^{e}	

p<0.05 $LSD_{treatment\ x\ time}$: 5.123 $LSD_{treatment}$: 0.021 LSD_{time}: 0.015

rich in terms of vitamin c content. In the present study, while mean value of vitamin c content at harvest period was 131 mg/100g; later, it decreases depending on time and treatments. Turk and Celik [35] also point out that decreases are observed in vitamin c content of kiwifruit during the cold storage with the parallel to storage time. Increases in vitamin c content were examined in UV-C treatments from 50 cm distance for 5 and 10 min and from 100 cm distance for 15 min between 40 and 120th day of storage period and later, decreases occurred (Table 3). At the end of 200th day, the lowest vitamin c content was determined in UV-C treatment from 100 cm distance for 5 min (108.5 mg/100g) and in control (109.8 mg/100g). Barka [7] and Maccarrone et al. [24] report a decline in the activity of ascorbate oxidase enzyme in the UV-C irradiated produce. In our study, results showed that UV-C treatments from 75 cm distance for 5, 10, 15 min and from 50 cm distance for 10 min decreased losses of vitamin c content.

The variation in fruit juices affects development of fruit characteristic forming eating quality of consumer. In general, it is known that there is a reduction in citric acid content of kiwifruit during the storage period [26] and titratable acidity content of kiwifruits in our study also exhibited reduction dependence on exposure to different UV-C irradiations towards the end of storage period. The lowest titratable acidity content (the highest maturity level) of kiwifruits was detected in control (1.36%) and UV-C treatment from 75 cm distance for 15 min (1.36%) at the end of 200th day (Table 4).

Table 5 pH in juice of kiwifruit exposed to different UV-C treatment during the storage period

Duration	Treatments	Day number after UV-C treatment					Treatment effect
		40th day	80th day	120th day	160th day	200th day	
Control		3.64^{c-j}	3.49^{mn}	3.61^{e-l}	3.69^{a-h}	3.71^{a-f}	3.63
	50 cm	3.64^{c-j}	3.41^{n}	3.50^{lmn}	3.61^{e-l}	3.71^{a-f}	3.57
5 min	75 cm	$3.68^{a-ı}$	3.56^{j-m}	3.52^{k-n}	3.61^{e-l}	3.73^{a-d}	3.62
	100 cm	3.71^{a-f}	$3.57^{ı-m}$	3.66^{b-j}	3.62^{d-k}	3.70^{a-g}	3.65
	50 cm	3.62^{d-k}	3.51^{k-n}	3.56^{j-m}	3.61^{e-l}	3.76^{ab}	3.61
10 min	75 cm	3.69^{a-h}	3.58^{h-m}	3.61^{e-l}	3.65^{b-j}	$3.68^{a-ı}$	3.64
	100 cm	3.72^{a-e}	3.52^{k-n}	3.59^{g-m}	3.65^{b-j}	3.72^{a-e}	3.65
	50 cm	3.78^{a}	3.51^{k-n}	$3.57^{ı-m}$	3.60^{f-m}	3.73^{a-d}	3.64
15 min	75 cm	3.74^{abc}	3.55^{j-m}	3.59^{g-m}	3.58^{h-m}	3.73^{a-d}	3.64
	100 cm	3.72^{a-e}	3.59^{g-m}	3.61^{e-l}	3.70^{a-g}	$3.68^{a-ı}$	3.66
Time effect		3.69^{a}	3.53^{d}	3.58^{c}	3.63^{b}	3.72^{a}	

$p<0.05$ $LSD_{treatment\ x\ time}$: 0.114 $LSD_{treatment}$: 0.049 LSD_{time}: 0.035

Table 6 Total soluble solids content (°Brix) content in juice of kiwifruit exposed to different UV-C treatment during the storage period

Duration	Treatments	Day number after UV-C treatment					Treatment effect
		40th day	80th day	120th day	160th day	200th day	
Control		10.43^{o}	12.80^{h-k}	14.20^{f-g}	16.66^{a}	16.16^{a-d}	14.05^{a}
	50 cm	8.73^{pq}	11.73^{lmn}	13.23^{g-j}	15.60^{b-e}	16.06^{a-d}	13.07^{bc}
5 min	75 cm	8.00^{q}	10.93^{no}	$12.70^{ı-l}$	15.40^{de}	16.46^{abc}	12.70^{c}
	100 cm	9.13^{p}	11.33^{no}	13.40^{g-j}	16.03^{a-e}	16.00^{a-e}	13.18^{b}
	50 cm	8.50^{pq}	11.80^{k-n}	13.16^{g-j}	15.73^{a-e}	16.10^{a-d}	13.06^{bc}
10 min	75 cm	8.23^{p-q}	10.83^{n-o}	12.40^{j-m}	15.00^{ef}	16.70^{a}	12.63^{c}
	100 cm	8.80^{pq}	12.46^{j-m}	13.16^{g-j}	15.76^{a-e}	15.83^{a-e}	13.20^{b}
	50 cm	8.06^{q}	11.43^{mno}	$13.00^{hıj}$	15.43^{cde}	16.50^{ab}	$12..88^{bc}$
15 min	75 cm	8.53^{pq}	11.43^{mno}	$13.66^{ghı}$	16.70^{a}	16.10^{a-d}	13.28^{b}
	100 cm	8.83^{pq}	11.66^{lmn}	13.76^{gh}	16.26^{a-d}	15.83^{a-e}	13.27^{b}
Time effect		8.72^{d}	11.64^{c}	13.27^{b}	15.86^{a}	16.17^{a}	

$p<0.05$ $LSD_{treatment\ x\ time}$: 1.047 $LSD_{treatment}$: 0.468 LSD_{time}: 0.331

Park and Kim [29] and Kaynas [17] point out that during the storage period, there are differences in titratable acidity content of kiwifruit depending on various treatments, reduction rate in titratable acidity content will vary depending on length of storage time.

Contrary to variations in titratable acidity content of kiwifruits in this study, increases in pH values were found out with extending storage period than harvest period (3.57) (Table 5).

Galeta and Himelrick [13] and Karacali [15] declare that towards maturity, reduction in titratable acidity content of fruits is usually observed in contrast to increase of pH. While the lowest pH value was obtained in 80th day (3.53), the highest value was 3.72 for 200th day. No significant differences in pH values were observed among the means of treatments for this study.

Total soluble solids content is an important attribute of kiwifruit as total soluble solids is associated with eating quality of ripe fruit [27, 12]. Studies have specifically shown that consumers preferred fruit with a higher ripe total soluble solids content [32, 9].

During the storage period, significant increase in total soluble solids content of kiwifruits was detected for all treated samples and control fruit. It is thought that these variations derived from different maturity levels in kiwifruit and differences in treatment and storage period. Transformation from starch to sugar in kiwifruit is likely responsible for the increment in total soluble solids content as well as for the improvement of eating quality. The highest value was 14.05 °Brix for control; the lowest values were obtained from UV-C treatment from 75 cm distance for 10 min (12.63 °Brix) and UV-C treatment from 75 cm distance for 5 min (12.70 °Brix) (Table 6). Rapidly increases in treatment groups were

Table 7 Fruit taste for kiwifruit exposed to different UV-C treatment during the storage period

Duration	Treatments	Day number after UV-C treatment					Treatment effect
		40th day	80th day	120th day	160th day	200th day	
Control		3.20^{p-t}	4.50^{h-m}	7.77^{a-e}	6.47^{fg}	4.43^{i-n}	5.27^{b}
	50 cm	3.27^{p-t}	4.40^{i-o}	7.83^{a-d}	8.17^{abc}	4.73^{h-l}	5.68^{ab}
5 min	**75 cm**	2.73^{st}	4.23^{j-p}	7.30^{b-f}	8.30^{ab}	7.07^{def}	5.93^{a}
	100 cm	3.67^{m-s}	5.17^{hij}	8.33^{ab}	7.20^{c-f}	$5.33^{h-ı}$	5.94^{a}
	50 cm	3.13^{g-t}	4.17^{j-q}	7.80^{a-e}	7.17^{c-f}	$5.30^{hı}$	5.51^{ab}
10 min	**75 cm**	2.93^{rst}	3.87^{l-r}	6.97^{def}	8.40^{a}	7.40^{a-f}	5.91^{a}
	100 cm	3.67^{m-s}	4.70^{h-m}	7.87^{a-d}	7.83^{a-d}	5.50^{gh}	5.91^{a}
	50 cm	2.40^{t}	4.10^{k-q}	7.10^{def}	8.43^{a}	6.67^{f}	5.74^{ab}
15 min	**75 cm**	3.37^{o-t}	4.77^{h-l}	6.60^{f}	6.87^{def}	4.93^{h-k}	5.31^{b}
	100 cm	3.40^{n-t}	5.00^{h-k}	8.40^{a}	6.77^{ef}	4.20^{j-p}	5.55^{ab}
Time effect		3.17^{d}	4.49^{c}	7.60^{a}	7.56^{a}	5.56^{b}	

$p<0.05$ $LSD_{treatment\ x\ time}$:1.050 $LSD_{treatment}$: 0.469 LSD_{time}: 0.322

found out in days of 40th, 80th and 120th for control and in 160th day for control and UV-C treatment from 75 cm distance for 15 min. From 160th day to 200th day, total soluble solids content of kiwifruits in our study exceeded the 14 °Brix level reported by Crisosto et al. [12]. In the present study, it was determined that UV-C treatment from 75 cm distance for 10 min indirectly slowed down increase in total soluble solids content by slowing down kiwifruit maturity.

No decay symptom was observed on kiwifruits throughout the survey period (data not shown). The mean taste score increased with maturity level (Table 7). Lower score were recorded for control and fruit treated at 100 cm for 15 min at the end the study period. On the other hand, the highest taste score was obtained from UV-C treatment from 75 cm distance for 10 min.

Stevens et al. [34] inform in peach study that UV-C irradiation delay maturity and depress ethylene synthesis and Charles et al. [11] declare that due to a delay in ripening, sensory evaluation of UV treated tomato fruits reveal lower scores for texture than untreated fruits. It is thought that inhibitor effect of UV-C irradiation on ethylene synthesis reported by Abeles et al. [1]; Reid [31] can lead to reason of maturity retardant of some UV-C doses used in our research.

Our study results were consistent with those declared by Ozer and Akbudak [28] and it wasn't detected linear relationship between kiwifruit quality and UV-C doses in our study with parallel to increase in UV-C doses.

In conclusion, UV-C treatments have various effects on kiwifruit quality characteristics and it is thought that it has potential as an alternative means of postharvest ripening control for kiwifruit. In present study, UV-C treatment from 75 cm distance for 10 min was especially found to be more effective among the all other treatments used in this study.

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