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Storability studies of physical parameters in UV-C treated strawberry (*Fragaria x ananassa*) fruit

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Abstract
The study entitled "Development of Automated Photochemical Treatment Chamber for Enhancing the Shelf life of Strawberry (*Fragaria* x *ananassa*)" was carried out to see the effect of UV-C radiation for enhancing the shelf life of strawberry. The strawberry fruits were exposed to UV light produced by a bank of germicidal UV lamps. Fruits was irradiated at different UV-C doses of 1A (1.32 kJ/m^2), 2A (1.58 kJ/m^2), 3A (1.85 kJ/m^2), 1B (2.64 kJ/m^2), 2B (3.17 kJ/m^2), 3B (3.70 kJ/m^2), 1C (4.34 kJ/m^2), 2C (5.21 kJ/m^2), 3C (6.08 kJ/m^2). Treated and untreated fruit samples were taken for storability studies. Study revealed that maximum loss in physiological weight was occurred in control treatment i.e 9.76% during 6th day of storage period and minimum (6.07%) was occurred at UV-C of 6.08 kJ/m^2. The maximum decay occurred in control treatment (46%) and minimum in treatment dose of 6.08 kJ/m^2 (6.67%) at 6th day of storage period. Decrease in L* value was maximum in untreated sample and minimum at UV dose of 5.21 kJ/m^2. Similar trends were seen in croma and hue angle values. The maximum decrease in firmness was seen in untreated fruit over the six days of storage period. From the study it can be seen that, UV technology is viable for disinfection of solid foods instead of thermal treatment or application anti-microbial compound.

Keywords: UV-C, germicidal, physiological weight, decay, firmness

Introduction
Consumption of fresh fruits and vegetables is helpful in preventing a number of fatal diseases like cancer and cardiovascular diseases (Reddivari *et al.* 2007) [14]. Increased market demand for attractive appearance of high quality fruit, high nutritious value, good taste combined with the documented health benefits of biologically active ingredients such as antioxidants and phenolics has allowed researchers to pay closer attention to the preservation of fresh fruit quality (both physicochemical and flavour).

Strawberry (*Fragaria x ananassa*) is originated from France and it belongs to Rosacea, Rose family. The dominant cultivar of strawberry are *ofra, camarosa, chandler, sweet charlie, fair fox, black more, elista* and *seascape.* It is a good source of vitamin C, 100 g edible portion of strawberry have 89 g water, 0.07 g protein, 0.5 g fats, 8.4 g carbohydrates and 59 mg ascorbic acid and is mainly consumed as fresh fruits, processed products like ice cream, soft drink, confectionery and chewing gum and preserved like jam, jellies, and squashes which can be used in off-season (Galletta and Bringhurst, 1995) [7]. This fruit has good economic value. Its cultivation is practiced in many parts of world, at present the leading producers of strawberry in the world are USA (30.4%) followed by Turkey (7.0%), Spain (6.0%), Egypt (5.5%) and Mexico (5.3%) (FAOSTAT, 2019). In India, strawberry cultivation is majorly practiced in the hilly region but due to it's demand the crop is becoming increasingly popular in western and northern parts, especially in Maharashtra, Himachal Pradesh, Haryana and Punjab due to its high returns from cultivation as well as the availability of markets to sell the produce. It is suitable for a semiarid and subtropical zone, and it is an ideal fruit crop for Maharashtra, Himachal Pradesh, Haryana, and Punjab. India is the second-largest producer of fruit in the world after China. Its share in the world's output of fruits is 11% because of its different agro-climatic conditions. Recently, strawberry is successfully being cultivated in the plain area of Maharashtra, around Pune, Nashik, Sangali towns and Hisar and Bhiwani districts of Haryana state.

Strawberries are considered highly perishable having a very limited shelf life (Baka *et al.*, 1999, Araque *et al.*, 2018) [3, 2]. Storage at low temperatures tends to prolong the shelf life to a certain degree (Mishra and Kar 2014) [11].

There has been considerable interest in the quest for non-chemical dry methods in recent years that can prevent deterioration of fruit (Vicente and Lurie 2014) [16]. Non-thermal technologies are being applied recently in food processing as a good alternative to thermal processing. Non-thermal processing include pulsed electric fields, ultraviolet light processing, minimal thermal processes and batch or continuous high pressure processing etc. These novel technologies can provide food products without harmful microorganisms and enzymes that may Detroit the nutritional and sensory characteristics of foods, which are generally changed when thermal processes are applied (Butz and Tauscher, 2002) [4]. Ultraviolet light is used to inactivate many types of organisms, including viruses, but the problem associated with UV light is that, it only works on surfaces or clear liquids such as water. UV light radiation has been effectively used in pharmaceutical, electronic, and aquaculture industries as a disinfection medium (Anonymous, 2002b) [1].

Many researchers have started to evaluate UV-C treatments as one of the potential alternative to control spoilage (Xu *et al.* 2017, Araque *et al.*, 2018) [17, 2]. Various studies showed that in strawberry pre-storage UV-C treatments at doses ranging from 0.2 to 4.2 kJ m^{-2} reduced decay (Baka *et al.* 1999; Li *et al.* 2014; Xu *et al.* 2017) [3, 9, 17]. It has been found that UV-C radiation affect fungal metabolism (Trivittayasil *et al.* 2016) [15]. Study of Pan *et al.* (2004) [13] found that UV-C radiation (4 kJ m^{-2}), decreased the rate of germination of Botrytis and Rhizopus conidia. UV-C radiation has been shown to modulate ripening-associated processes such as softening and to evoke the accumulation of antioxidants and phytoallexins in addition to its direct impact on plant pathogens (Pan *et al.*2004) [13].

Methodology

Plant Material, UV treatment and storage conditions

Mature strawberries (*Fragaria*x *ananassa*), one-fourth to one-half red on the surface, was harvested from fields in Chhanna village in Hisar district. The "*winter dawn*" variety of strawberry was used in experiment. It is regarded as early varieties of strawberries i.e. sowing started from mid-September to October. The preparation of nursery was done from March-September. The harvesting of fruits started from mid- November and it continued till March. Harvesting continued till April if the variation in temperature is less. The fruits were transported within an hour to the laboratory and was put in polyethylene terephthalate (PET) trays, in groups. Fruit was then cooled down to the temperature between 4 °C - 13 °C in cold storage. The fruits of uniform size and color and free of external blemishes or infection was selected.

After 24 h, the pre-cooled fruits were exposed to UV light produced by a bank of germicidal UV lamps (TUV G15 T8, 15 W, Philips) with peak emission at 254 nm. Fruits was irradiated at 30 cm from the lamps for different duration (300, 360 and 420 seconds) and at three different UV intensities (0.440, 0.880 and 1.448 W/cm^2). The intensity of flux of lamps was measured by a UV digital radiometer.

The Storability studies of Strawberries after treatment was conducted in the Department of Processing and Food Engineering, Department of Food Science & Technology and Central Laboratory CCS Haryana Agricultural University, Hisar.

Table 1: Different UV-C dose used for treatment of Strawberry

Exposure Time (Characterters 1, 2, 3) (Seconds)	Intensity of Light used (Characterters A, B, C) (milli W cm^{-2})	UV-C Dose (kJ/m^2)
300 (1)	0.440 (A)	1.32 (1A)
360 (2)	0.440 (A)	1.58 (2A)
420 (3)	0.440 (A)	1.85 (3A)
300 (1)	0.880 (B)	2.64 (1B)
360 (2)	0.880 (B)	3.17 (2B)
420 (3)	0.880 (B)	3.70 (3B)
300 (1)	1.448 (C)	4.34 (1C)
360 (2)	1.448 (C)	5.21 (2C)
420 (3)	1.448 (C)	6.08 (3C)

Physical Parameters: The following physical properties of treated and untreated strawberries will be determined as per standard method (Baka *et al.* 1999, cote *et al.* 2013, Araque *et al.* 2018) [3, 5, 2].

1. Physiological loss in Weight (%)

Fruit weight was measured before packing and during storage. Weight loss (WL) was calculated from initial (IW) and final weights (FW) as described below:

$$\text{WL (\%)} = \frac{\text{IW} - \text{FW}}{\text{IW}} \times 100$$

2. Decay (%)

The external appearance of each fruit and the presence of macroscopic fungal growth were visually evaluated. Results were expressed as percentage of decayed fruit. Decay percentage is determined as:

$$\text{\% Decay} = \frac{\text{Infected strawberry fruit in package}}{\text{Total strawberry fruits in package}} \times 100$$

3. Colour

Fruit surface color was measured on 10 fruit from each replicate using a Croma meter (CR 410, Konica Minolta, Japan), t v o obtain L*, a* and b* values. Where L* indicates lightness, a* indicates chromaticity on a green (−) to red (+) axis, and b*chromaticity on a blue (−) to yellow (+) axis. Numerical values of a∗ and b∗ were converted into hue angle (H° = tan−1 b*/a*) and croma [Croma = (a*2 + b*2)1/2].

4. Firmness (N)

Fruit firmness was determined by uniaxial compression tests in a Texture Analyzer (TMS-touch, Food Technology Corporation, USA) equipped with a 2 mm diameter flat probe. Firmness was determined by compressing the fruit 4 mm in equatorial zone at a rate of 1 mm s^{-1}.The maximum force during the test was recorded.

Results

Physical Parameters

1. Physiological loss in Weight (PLW%): Fruit weight was measured before packing and during storage. Data on 0, 3 and 6th day of storage was recorded. It can be seen from the results that UV-C treatments on strawberries reduced physiological loss in weight during storage. Showed that maximum loss in physiological weight was occurred in control treatment i.e. 9.76% during 6th day of storage period. The PLW% on 6th day of storage at UV-C dose of 1.32, 1.58, 1.85, 2.64, 3.17, 3.70, 4.34, 5.21 and 6.08 kJ/m^2 was 6.96 ± 0.73, 7.16 ± 0.31, 7.21 ± 0.25, 6.91 ± 0.20, 6.96 ± 0.18, 6.91 ± 0.35, 6.66 ± 0.31, 6.41 ± 0.41 and 6.07 ± 0.38% respectively. Maximum PLW% was found in control treatment which was 9.76 ± 0.35% on 6th day of storage.

2. Decay (%): The external appearance of each fruit and the presence of macroscopic fungal growth were visually evaluated during day 0, 3 and 6 of storage. It can be seen from the results that UV-C treatments on strawberries decreased decay in fruit during storage. Maximum decay% was occurred in control treatment i.e 46% during 6th day of storage period. The decay% on 6th day of storage at UV-C dose of 1.32, 1.58, 1.85, 2.64, 3.17, 3.70, 4.34, 5.21 and 6.08 kJ/m^2 was 37.33 ± 2.31, 38.00 ± 2.00, 36.67 ± 1.15, 38.00 ± 0.00, 38.00 ± 2.00, 34.67 ± 2.31, 10.67 ± 1.15, 08.67 ± 1.15 and 06.67 ± 1.15 respectively. Maximum decay in treated strawberries was seen at treatment dose 1.58 kJ/m^2. The lowest Decay was occurred in treatment dose of 6.08 kJ/m^2 (6.67%) on sixth day of storage.

3. Colour: Fruit surface color of each replicate was measured using a Croma meter, to obtain L*, a* and b* values. Where L* indicates lightness, a* indicates chromaticity on a green (−) to red (+) axis, and b*chromaticity on a blue (−) to yellow (+) axis. Numerical values of a∗ and b∗ were converted into hue angle (H° = tan−1 b*/a*) and croma [Croma = (a*2 + b*2)1/2]. Variation in L*, croma and Hue angle is shown in table 4.3.

The L* values of treated and untreated strawberries were decreased which means that fruit developed darker colour. Decrease in L* value was maximum in untreated sample (control), which means untreated strawberry attains more darker colour than treated strawberry during storage. The change in L* value for UV-C dose of 1.32, 1.58, 1.85, 2.64, 3.17, 3.70, 4.34, 5.21 and 6.08 kJ/m^2 was 7.51, 6.41, 7.48, 7.35, 4.95, 5.06, 4.52, 3.15 and 3.37 respectively. Maximum change of L* value in treated fruit was observed at UV-C dose of 1.32 kJ/m^2.

The Croma value decreases in treated and untreated strawberries during storage period. The decrease in croma values shows increase in red brownish colour which is an indicator of ripening. Maximum decrease in croma value was occurred in control treatment, which is 6.64 during the six days of storage period. The change in croma value for UV-C dose of 1.32, 1.58, 1.85, 2.64, 3.17, 3.70, 4.34, 5.21 and 6.08 kJ/m^2 was 4.38, 4.52, 4.90, 3.99, 5.32, 3.38, 3.11, 3.25 and 3.52 respectively during six days of storage period. Maximum change in croma value occurred in UV-C dose of 1.85 kJ/m^2.

The hue angle of strawberries decreases during the storage period for both treated and untreated samples of strawberries. The decrease in hue angle shows red colour development on surface from white to pink. The decrease in hue angle value in control (untreated) strawberries during six days of storage was 4.58, which was slightly more than treated samples. The change in hue angle value for UV-C dose of 1.32, 1.58, 1.85, 2.64, 3.17, 3.70, 4.34, 5.21 and 6.08 kJ/m^2 was 2.23, 1.78, 2.09, 2.19, 1.89, 2.07, 1.52, 0.91 and 0.88 respectively over the span of six days. The maximum difference in hue angle values of treated sample occurred at UV-C dose of 1.32 kJ/m^2.

4. Firmness (N): Fruit firmness was determined by uniaxial compression tests in a Texture Analyzer equipped with a 2 mm diameter flat probe. The firmness of both treated and untreated fruit decreases during storage. The maximum decrease in firmness was seen in untreated fruit over the six days of storage period. The decrease was more after third day as compared to third to sixth day. According to table 4.4, the change in firmness value for UV-C dose of 1.32, 1.58, 1.85, 2.64, 3.17, 3.70, 4.34, 5.21 and 6.08 kJ/m^2 was 0.90, 1.00, 0.86, 1.03, 0.70, 0.93, 0.34, 0.30 and 0.73 N respectively during storage period of six days. The maximum and minimum decrease in firmness of treated strawberry fruit was occurred in UV-C doses of 2.64 and 5.21 kJ/m^2 respectively. In control (untreated) fruit decrease in firmness during storage was 1.17 N.

Experimental design and data analysis

The data analysis of variance (ANOVA) was performed by using the Statistical Package for the Social Sciences (SPSS), and Duncan's multiple range test was applied (at the level $P<0.05$) when the analysis was statistically significant.

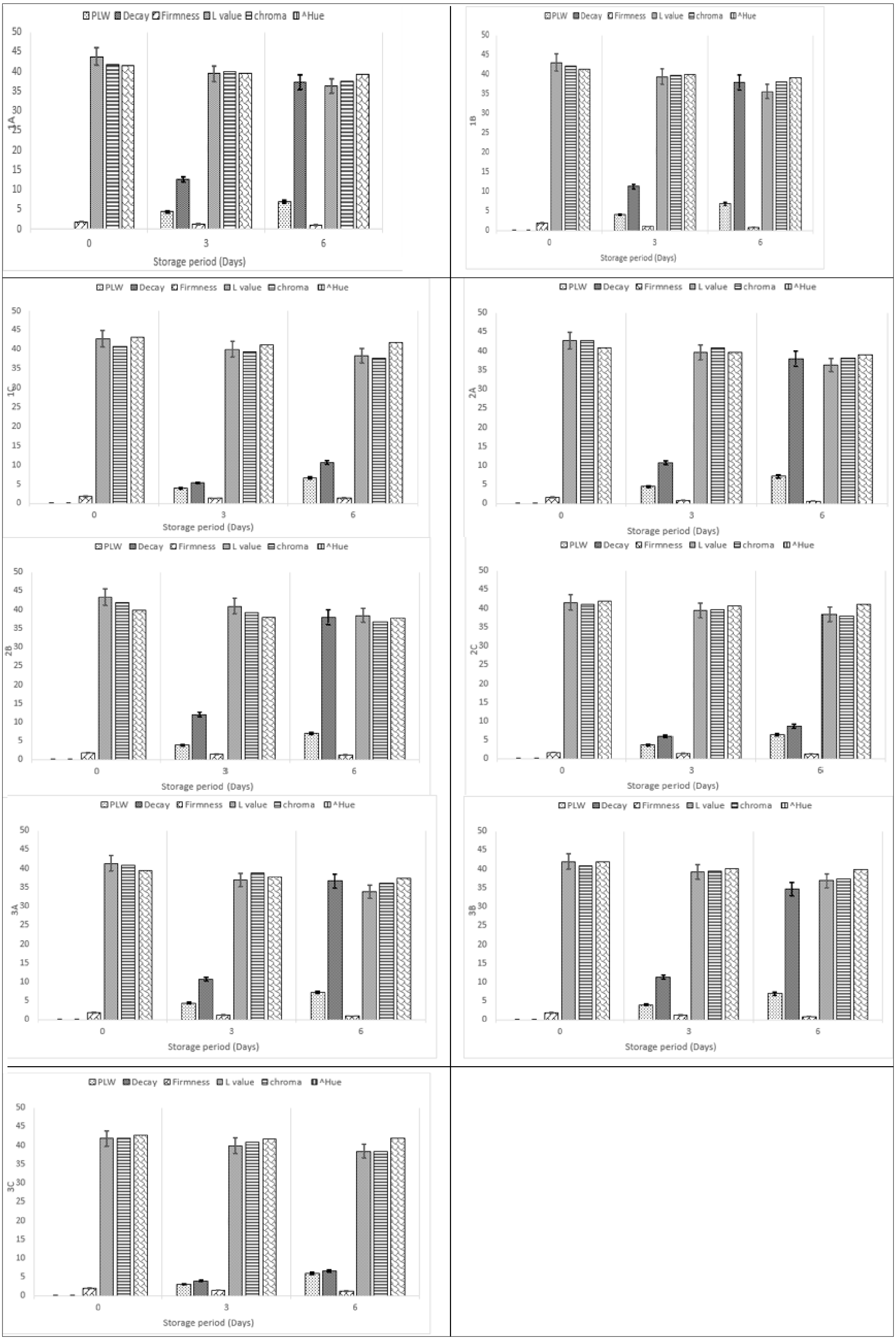

Fig 1: Variation in Physical Properties of treated Strawberries at UV-C dose 1A (1.32 kJ/m^2), 2A (1.58 kJ/m^2), 3A (1.85 kJ/m^2), 1B (2.64 kJ/m^2), 2B (3.17 kJ/m^2), 3B (3.70 kJ/m^2), 1C (4.34 kJ/m^2), 2C (5.21 kJ/m^2), 3C (6.08 kJ/m^2).

Table 2: ANOVA Table for Tests of Between-Subjects Effects (Physical, Chemical and Biological analysis)

Source	Dependent Variable	Sum of Squares	Degree of Freedom (df)	Mean Square	F	Probability Value (P Value)	Coefficient of Determination (R^2)
Corrected Model	Physiological loss in Weight% (PLW%)	805.217	29	27.766	396.306	0.000	0.995
	Decay%	19778.489	29	682.017	426.261	0.000	0.995
	Firmness (N)	14.093	29	0.486	10.539	0.000	0.836
	L* VALUE	687.743	29	23.715	5.118	0.000	0.712
	CROMA	375.381	29	12.944	4.683	0.000	0.694
	^{0}HUE	313.402	29	10.807	7.214	0.000	0.777

Table 3: L-S means of physical parameters of UV-C treated and untreated strawberries using Duncan's Multiple Range Test

Strawberry treatment type		Physiological loss in Weight% (PLW%)	Decay%	Firmness (N)	L* value	Croma	^{0}HUE
Control	Day 0	0.00 ± 0.00^{l}	00.00 ± 0.00^{j}	1.80 ± 0.20^{abc}	43.48 ± 2.56^{ab}	45.78 ± 1.00^{a}	39.89 ± 0.62^{cde}
	Day 3	5.87 ± 0.46^{f}	20.00 ± 0.00^{d}	0.87 ± 0.21^{gh}	37.40 ± 1.10^{efghi}	41.31 ± 0.37^{bcd}	35.85 ± 0.77^{gh}
	Day 6	9.76 ± 0.35^{a}	46.00 ± 4.00^{a}	0.63 ± 0.06^{h}	33.61 ± 0.29^{i}	39.14 ± 0.43^{cdefghij}	35.31 ± 1.04^{h}
1A (1.32 kJ/m^2)	Day 0	0.00 ± 0.00^{l}	00.00 ± 0.00^{j}	1.90 ± 0.17^{ab}	43.80 ± 1.36^{a}	41.86 ± 0.97^{bc}	41.43 ± 0.85^{abcd}
	Day 3	4.45 ± 0.37^{g}	12.67 ± 1.15^{e}	1.27 ± 0.12^{defg}	39.42 ± 0.82^{bcdefgh}	40.03 ± 0.92^{bcdefgh}	39.64 ± 1.39^{cdef}
	Day 6	6.96 ± 0.73^{bc}	37.33 ± 2.31^{b}	1.00 ± 0.10^{fgh}	36.29 ± 1.29^{ghi}	37.48 ± 0.65^{ghij}	39.20 ± 1.57^{def}
1B (2.64 kJ/m^2)	Day 0	0.00 ± 0.00^{l}	00.00 ± 0.00^{j}	1.90 ± 0.30^{ab}	42.99 ± 2.96^{ab}	42.07 ± 2.14^{bc}	41.43 ± 1.30^{abcd}
	Day 3	4.14 ± 0.21^{ghi}	11.33 ± 1.15^{e}	1.13 ± 0.32^{efg}	39.44 ± 2.71^{bcdefgh}	39.66 ± 2.45^{bcdefghi}	39.85 ± 1.16^{cde}
	Day 6	6.91 ± 0.20^{bc}	38.00 ± 0.00^{b}	0.87 ± 0.31^{gh}	35.64 ± 3.32^{hi}	38.08 ± 2.37^{defghij}	39.24 ± 1.41^{def}
1C (4.34 kJ/m^2)	Day 0	0.00 ± 0.00^{l}	00.00 ± 0.00^{j}	1.77 ± 0.15^{abc}	42.79 ± 3.27^{ab}	40.77 ± 0.79^{bcdefg}	43.25 ± 1.06^{a}
	Day 3	3.93 ± 0.23^{hij}	05.33 ± 1.15^{hi}	1.30 ± 0.17^{def}	39.98 ± 3.26^{abcdefg}	39.40 ± 0.59^{bcdefghi}	41.17 ± 0.99^{abcd}
	Day 6	6.66 ± 0.31^{cd}	10.67 ± 1.15^{ef}	1.43 ± 0.06^{cde}	38.27 ± 3.28^{defgh}	37.66 ± 0.85^{fghij}	41.73 ± 0.61^{abc}
2A (1.58 kJ/m^2)	Day 0	0.00 ± 0.00^{l}	00.00 ± 0.00^{j}	1.67 ± 0.21^{abcd}	42.69 ± 1.49^{abc}	42.64 ± 1.35^{b}	40.86 ± 1.72^{abcd}
	Day 3	4.46 ± 0.22^{g}	10.67 ± 1.15^{ef}	0.90 ± 0.10^{fgh}	39.56 ± 1.81^{bcdefgh}	40.94 ± 0.32^{bcdef}	39.61 ± 1.81^{cdef}
	Day 6	7.16 ± 0.31^{b}	38.00 ± 2.00^{b}	0.67 ± 0.21^{h}	36.28 ± 0.81^{ghi}	38.12 ± 1.04^{defghij}	39.08 ± 1.65^{def}
2B (3.17 kJ/m^2)	Day 0	0.00 ± 0.00^{l}	00.00 ± 0.00^{j}	1.90 ± 0.26^{ab}	43.40 ± 2.50^{ab}	41.97 ± 2.16^{bc}	39.73 ± 1.38^{cdef}
	Day 3	3.84 ± 0.10^{ij}	12.00 ± 0.00^{e}	1.47 ± 0.23^{cde}	40.88 ± 2.86^{abcdef}	39.16 ± 2.88^{cdefghij}	38.04 ± 0.97^{efg}
	Day 6	6.96 ± 0.18^{bc}	38.00 ± 2.00^{b}	1.20 ± 0.26^{efg}	38.45 ± 2.55^{cdefgh}	36.65 ± 2.64^{ij}	37.84 ± 0.91^{efg}
2C (5.21 kJ/m^2)	Day 0	0.00 ± 0.00^{l}	00.00 ± 0.00^{j}	1.73 ± 0.21^{abc}	41.50 ± 1.92^{abcde}	41.16 ± 1.17^{bcde}	41.89 ± 1.57^{abc}
	Day 3	3.65 ± 0.28^{j}	06.00 ± 0.00^{hi}	1.43 ± 0.29^{cde}	39.47 ± 1.39^{bcdefgh}	39.66 ± 1.63^{bcdefghi}	40.57 ± 1.47^{bcd}
	Day 6	6.41 ± 0.41^{de}	08.67 ± 1.15^{fg}	1.30 ± 0.26^{def}	38.35 ± 1.54^{defgh}	37.91 ± 1.72^{efghij}	40.98 ± 1.91^{abcd}
3A (1.85 kJ/m^2)	Day 0	0.00 ± 0.00^{l}	00.00 ± 0.00^{j}	1.83 ± 0.25^{abc}	41.30 ± 2.67^{abcde}	40.94 ± 2.24^{bcdef}	39.46 ± 1.21^{cdef}
	Day 3	4.37 ± 0.28^{gh}	10.67 ± 1.15^{ef}	1.27 ± 0.21^{defg}	36.93 ± 2.51^{fghi}	38.87 ± 2.91^{cdefghi}	37.68 ± 0.51^{efg}
	Day 6	7.21 ± 0.25^{b}	36.67 ± 1.15^{bc}	0.97 ± 0.38^{fgh}	33.82 ± 1.92^{i}	36.04 ± 2.54^{j}	37.37 ± 0.55^{fgh}
3B (3.70 kJ/m^2)	Day 0	0.00 ± 0.00^{l}	00.00 ± 0.00^{j}	1.83 ± 0.12^{abc}	41.92 ± 1.67^{abcd}	40.78 ± 1.85^{bcdefg}	41.80 ± 0.85^{abc}
	Day 3	3.96 ± 0.10^{hij}	11.33 ± 1.15^{e}	1.27 ± 0.15^{defg}	39.29 ± 1.64^{bcdefgh}	39.31 ± 1.36^{cdefghi}	40.03 ± 0.76^{cde}
	Day 6	6.91 ± 0.35^{bc}	34.67 ± 2.31^{c}	0.90 ± 0.10^{fgh}	36.86 ± 1.24^{fghi}	37.40 ± 1.50^{hij}	39.73 ± 0.61^{cdef}
3C (6.08 kJ/m^2)	Day 0	0.00 ± 0.00^{l}	00.00 ± 0.00^{j}	2.00 ± 0.10^{a}	41.83 ± 1.99^{abcd}	41.83 ± 1.31^{bc}	42.73 ± 1.31^{ab}
	Day 3	3.12 ± 0.18^{k}	04.00 ± 0.00^{i}	1.53 ± 0.21^{bcde}	39.92 ± 1.60^{abcdefg}	40.76 ± 1.01^{bcdefg}	41.74 ± 1.75^{abc}
	Day 6	6.07 ± 0.38^{ef}	06.67 ± 1.15^{gh}	1.27 ± 0.25^{defg}	38.46 ± 1.43^{cdefgh}	38.31 ± 1.22^{defghij}	41.85 ± 0.97^{abc}
Mean Square error		0.07	1.60	0.45	4.63	2.76	1.50

Discussion

Physical Parameters

Physiological loss in Weight (PLW%)

UV-C treatments reduced Physiological loss in Weight during storage. During both third and sixth day all UV-C treatments reduced dehydration in strawberry fruit. Remarkably the least PLW due to dehydration were observed in case of higher UV-C treatments of 4.34, 5.21 and 6.08 kJ/m^2. Previous studies have showed that high intensity UV radiation treatments, which applied before storage, can reduce physiological weight loss in strawberry fruit (Baka et. al. 1999, cote *et al.* 2013, Li et. al. 2014, Araque et.al. 2018) [3, 5, 9, 2].

Decay (%)

During third and sixth day of storage, there was significant difference in decay% values of treated and untreated strawberries. The decay in untreated fruit was more as compared to treated fruit. The reduction in decay was higher at doses of 4.34, 5.21 and 6.08 kJ/m^2. After third day there was rapid increase in fruit decay in untreated strawberries. Similar results were reported in previous studies (Pan *et al.* 2004, Cote *et.al.* 2013, Araque *et.al.* 2018) [13, 5, 2] showing that UV radiation can be useful to control decay by *Botrysis cinerea*. Remarkably, high UV-C doses of 4.34, 5.21 and 6.08 kJ/m^2 were significantly more effective than lower UV-C doses.

Colour

The L* value of the strawberry fruits decreased during the storage period, this decrease showed that fruit developed darker colour, regardless of maturity at harvest. On sixth day of storage at temperature ranges between 6-8 ^{0}C the L* values of treated fruit were higher (lighter colour) than untreated fruits. Results showed that L* values of untreated fruit (control) were lower (darker colour) than values of fruit treated with UV-C radiation. Overall, the L* value tended to decrease either during storage, as a consequence of the pink-reddish colour that naturally develops when strawberry fruit ripen. As revealed in present study, the L* values of strawberry fruit decreases from light pink to dark red have previously been reported by others (Ihl *et.al.* 1999, Menager *et.al.* 2004[10], Nunes *et.al.* 2006) [8, 10, 12].

The Croma value decreases in treated and untreated strawberries during storage period. The decrease in croma values shows increase in red brownish colour which is an indicator of ripening. Maximum decrease in croma value was occurred in control treatment. The decrease in croma value was lesser in treated fruit, which showed that UV-C treatment is helpful in delayed ripening.

The hue angle of strawberries decreases during the storage period for both treated and untreated samples of strawberries. The decrease in hue angle shows red colour development on surface from white to pink. The decrease in hue angle value in control (untreated) strawberries during six days of storage was slightly more than treated samples. Study (Menager *et.al.* 2004, Pan *et al.* 2004, Araque *et al.* 2018) [10, 13, 2] also reported that hue angle decreases during storage.

Firmness (N)

The firmness of both treated and untreated fruit decreases during storage. The maximum decrease in firmness was seen in untreated fruit over the six days of storage period. The decrease was more after third day as compared to third to sixth day. The maximum and minimum decrease in firmness of treated strawberry fruit was occurred in UV-C doses of 2.64 and 5.21 kJ/m^2 respectively. Strawberries subjected to UV-C irradiation showed higher tendency to maintain firmness than control samples. In the study (Cote *et al.* 2013) [5], It is mentioned that single application of UV-C dose before storage helps in firmness retention and it is highly dependent on the radiation intensity. Previous work (Araque *et al.* 2018) [2] revealed that UV may delay strawberry softening.

Conclusion

From study it was found that, UV technology is an emerging non-thermal process technology for disinfection of fruits and vegetable in the food industry. It can be said that, ultraviolet processing can provide more ideal food products with fresh-like characteristics. Short wave UV-C was found to be lethal to most microorganisms and can be applied to provide safe food products. At present, the application of UV light for disinfection of food products is in little use, but it could easily be applied to liquid and solid food products. Each food processing method is different, and it is concluded that, UV-C can be effective method of microbial disinfection.

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