

Original Paper

The Effect Of Ultraviolet Light Treatment In Extend Shelf Life And Preserve The Quality of Strawberry (*Fragaria x ananassa*) cv. Festival

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Abstract— Strawberry (*Fragaria x ananassa*) is a highly perishable product and rarely to be kept for more than 7 days. Cold chain system is the only methods apply in Malaysia strawberry industry to prolong the shelf life and preserve the quality of strawberry. UV light treatment proved to be effective in inhibit microbial loads and delay ripening process of fruit products where short wavelength (254 nm) ultraviolet-C was proved in keeping the freshness and quality of fruits or vegetables. This experiment was conducted to determine the effect of UV-C irradiation on extending shelf life and to determine the optimum radiation intensity of UV-C treatment on postharvest quality of treated strawberry. A total of 399 of strawberries cv. Festival were harvested in red colour with maturity stage of >80 – 85% from Cameron Highlands's strawberry farm. The strawberries were exposed to different doses (0, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0 kJ/m²) of ultraviolet-C (254nm, UV-C) radiation. The treated strawberries were randomly placed in the polystyrene trays and stored in the dark chilling room at -5°C for 9 days. The significant differences were found when the highest level of dosage was applied. UV-C treated strawberries with the highest doses (1.0 kJ/m²) are significantly firmer (0.557N), higher total soluble solids content (7.5 °Brix) and ascorbic acid contain (0.518mg/ml) on day 9 (p<0.05). There were no microbial loads or any diseases occur on the surface of the strawberry. The UV treated strawberries had improved the overall appearance of the strawberry includes the firmness, flavour and colour. The application of UV-light treatment can prevent diseased, and enhancing their shelf life and quality had shown in the present of data.

Keywords— postharvest quality, shelf life, strawberry, UV light

I. INTRODUCTION

Fruits are important components of a healthy and balanced diet since fruit products are consumed in raw. Processing of fruits after harvesting are important to control microbiological, chemical and biochemical changes occurred as a result of microbial and enzymatic activities and oxidation reaction. Nowadays, the exposure of UV-light on horticultural crops been used as a method to control microorganisms and postharvest diseases on the surface of fresh fruits. UV light can help to retard the microbial growth and sanitize the fresh produces without altering its quality [1].

Strawberries are extremely perishable and need proper postharvest handling treatment. Strawberry production is well suited to grow in Cameron Highlands, but the long-term

sustainability of the industry will require continuous improvements in production and postharvest handling technologies. Even under ideal conditions they can rarely be kept for more than 7 days after harvest. They must be cooled immediately to their lowest safe temperature (0 to 1°C) after harvesting and maintenance of cold chain during transportation and distribution to prevent over ripening and decay before marketing [2].

Strawberry harvest should begin in the early morning and avoid harvesting in the afternoon. Strawberry fruit intended for export should not be picked when the pulp temperature exceeds 25°C. Avoid to harvest the strawberry when the fruit is still wet to minimum the effect of Botrytis gray mold development and it is compulsory to keep the fruit under the shade before moving to the cold storage. Use forced air cooling system to circulate the cool air to bring down the fruit temperature to optimum level. Transport in appropriate containers and in optimal conditions. Delay in transportation to cooler beyond two hours after harvest reduces marketability. While shelf-life is longer at ±5°C [3].

Various methods were applied to the strawberries to extend the storage life and maintained the quality of the fruits. Postharvest treatments such as thermal treatments [4], fumigation [5] and coatings [6] significantly can minimize the postharvest losses of strawberries. Controlled atmosphere packaging and low temperature storage techniques were effective and popular strategies for shelf life extension of fresh strawberry however, these methods not be able to control certain pathogenic fungi and bacteria in the prevailing storage conditions [7]. UV- C irradiation has been successfully used as an alternative treatment for microbial disinfection and prolongs shelf life of strawberry.

UV-C light is considered to be germicidal. The exposure of horticultural crops to non-ionizing artificial UV-C light (180-280 nm with maximum at $\lambda = 254$ nm) has been considered as an alternative to chemical fungicide in order to control postharvest diseases. Low doses of UV light induce production of anti-fungal compounds in the fruits, ripening, softening delay and reduction of chilling injury [8]. The softening delay caused by changes in the activities of enzymes and proteins involved in the cell wall disassembly. Expansins, polygalacturonases (PGs), endoglucanases (EGs)

and pectin-methylesterases (PMEs) are cell wall proteins and enzymes involved in fruit softening [9]. UV-C light is very effective in inhibit large among of microorganism already has been reported [8, 10]. It causes physical shifting of electrons and breaking of bonds in deoxyribonucleic acid (DNA) in most of the microorganisms which causing their inactivation. UV- C treatment is a postharvest handling process. It had been proved that it maintains the overall quality and prolong the storability of harvested fresh produce. It is also could induce better maintenance of nutritional and sensory qualities, delayed ripening, softening and electrolyte leakage, retarded chlorophyll degradation, higher resistance to chilling injury, and reduced respiration rate and weight loss [10, 11]. Besides, UV- C light induces the accumulation of phytoalexins accumulation which important in fresh products against plant diseases and encoding pathogenesis related proteins [10].

Reference [12] reported that zucchini squash slices exposed to UV light for 10 and 20 minutes were reduced microbial activity and deterioration during storage at 5°C or 10°C. Besides, the respiration rate of the slices was stimulated while ethylene production and the degree of chilling injury at 5°C were unaffected. Similar results were obtained for apples, lettuce [13] and other fruits and vegetables. Ultraviolet light treatments on surface of fresh strawberries are able to extend the strawberries shelf life for 4 -5 days. UV-treated fruits had a lower respiration rate, higher titratable acidity and anthocyanin content, and were firmer than the untreated fruits [10].

Reference [14] reported that the combination of UV- C (4.1kJ/m²) and heat treatments (45°C, 3hours in air) decreased the hue angle and delayed the changes of L* parameter. All treatments reduced the accumulation of anthocyanins, inhibit fungal infection, more firmer and had lower amount of phenolics than untreated strawberry. The combination of UV-C and heat treatments were effective in extend strawberry postharvest life. In addition, [15] reported that fresh 'Kurdistan' strawberry (*Fragaria × ananassa*, Duch. cv Kurdistan) was exposed to 0.25 and 0.5 kJ/m dosage of ultraviolet-C (254 nm) radiation and stored up to 7 days at 5°C have significant differences in decreased the growth of yeast when higher level of dosage is applied. All UV-C radiation at an appropriate dose could reduce microbial loads without adversely affecting sensorial quality of Kurdistan' strawberry. Fruit treated with the highest doses (0.5 kJ/m) is significantly firmer on day 7 and this dose improved the sensory quality of the product. This UV technology could be an alternative technology, instead of application of antimicrobial compounds. Thus, the objective of this study was to evaluate the effect of UV light on the postharvest quality of strawberry (*Fragaria x ananassa*) cv. Festival.

II. MATERIALS AND METHODS

Plant Material

A total of 399 fresh strawberries cultivar Festival in red colour with maturity stage between 80% to 85% were harvested from Cameron Highlands, Malaysia farm and placed in an ice box at

25°C. The selected fruits were checked to ensure free from any mechanical injury, insects and pathogen damages for the experiment. The strawberries then were transported to Postharvest Laboratory, School of Food Science and Agrotechnology, Universiti Malaysia Terengganu, Terengganu where the experiment was conducted.

Treatments and postharvest analysis

There were 7 UV-C treatments were applied in this experiment, which are treatment i) 0 kJ/m² (Control), treatment ii) 0.5 kJ/m², treatment iii) 0.6 kJ/m², treatment iv) 0.7 kJ/m², treatment v) 0.8kJ/m², treatment vi) 0.9kJ/m² and treatment vii) 01.0kJ/m² with 3 replication for each treatment. One replicate consist of 18 strawberries was placed in one polystyrene tray. All of the strawberries were placed in a chiller at 5°C for about 1 h before UV-C radiation treatments applied [15]. After 1 hour, strawberries sample were exposed to UV-C treatments and the dosage was determine by using UV light meter (Figure 1). The different UV-C dosage was obtained by exposing the strawberries to the UV light in difference durations. Aluminium foil was used to fit all sides of the chamber to ensure good spreading of light.

Once the treatments were done, all of the sample were stored randomly in the chiller at 5±2°C for 10 days. Parameters such as colour, total soluble solids content, firmness and texture, titratable acidity, ascorbic acid concentration, disease severity and sensory test, were recorded for every 3 day intervals. The assessment days will include day 0, day 3, day 6, and day 9. All the data collected were subjected to one way ANOVA analysis using GenStat for Teaching and Learning (18th Edition), VSN International, United Kingdom. Treatments was further separated by Turkey (LSD) for least significance at p<0.05.



Fig. 1 a) UV-C treatment on strawberries and b) UV light meter

III. RESULT AND DISCUSSION

Table 1 showed the result on firmness, total soluble solid, totatable acidity and ascorbic acid evaluated on day 0, 3,6 and 9 after treatments. Result showed no significant changes on flesh firmness of strawberry except on day 6 and day 9 ($p \leq 0.05$). On day 6, 0kJ/m² of dosage recorded the lowest firmness reading (0.201N) by showing significant differences with all others treatments. Contrary, 0.9kJ/m² of dosage recorded the highest reading (0.668N) on day 9. On day 9, the firmness of 0.6kJ/m² dosage degrades significantly. According to the previous study, the flesh firmness of UV treated strawberry is expected to be increasing during the storage time same as the present study. The application of UV-C treatment on strawberry has been associated

with a delay ripening and changes in protein synthesis. The higher values of firmness observed in UV-C treated fruit could be associated with the effect of the radiation on the activity of enzymes involved in cell wall degradation. According to [16], cell wall degrading enzymes are one of the targets of UV-C, leading to slowed cell wall degradation. Cell wall degrading enzyme like endo-1,4-β-D-glucanase, pectin methyl esterase and β-galactosidase will continued to increase during the ripening process of the strawberry which causing cell wall softening but this activity tended to stabilize in UV-C treated fruits.

Total soluble solids content showed decreased slightly after UV-C applied on day 3. There were no significant differences found throughout the experiment except on day 9. On day 9, 1kJ/m² of dosage recorded the highest total soluble solids content (7.5°Brix) by showing significant differences with all others treatments. Meanwhile, 0kJ/m² of dosage showed the lowest total soluble solids content (5.0°Brix). In general, the total soluble solids content increased at the end of the storage for all UV treated strawberry. According to the previous study, the strawberry will not experience any climateric peak during its storage life [17] because it is a non-climateric fruit. Similar changes unduced by UV were reported for other fruit crops treated with UV-C light. Reference [9] and reference [18] found a delay in climateric peak of UV- treated tomatoes. On day 9, total soluble solids for UV-C treated strawberry were much more higher than non UV-C treated strawberry, a possible explanation for this situation is UV-C treatment increased the rate of accumulation of free sugars in strawberries. Presumably the accumulation of sugars is related to UV stress and stimulation of intercellular synthetic enzymes, such as the activity of sucrose synthase, and inhibition degradation of enzymes, such as invertase or phosphorylase [19].

There was no apparent effect recorded on titratable acidity of strawberry at $p \leq 0.05$. However, there is exception on day 9 which all the treated strawberry increase the percentage of citric acid. 1.0kJ/m² recorded higher percentage of citric acid (0.845%) than all other treatment on day 9. Though it is expected that the titratable acidity of strawberry should decline with increased of storage time, the titratable in the present study fluctuated throughout experimental period. Similar to orange, strawberry is consisted mainly of citric acid. However, the titratable acidity of UV treated strawberry were increase slightly on day 9, these could be due to accumulation of ethanol prior to alcoholic fermentation, as the consequence of anaerobic condition [20]. These obtained results are in agreement with those mentioned by [10] who indicated that UV treatment able to maintain a higher titratable acidity than untreated strawberry. UV treatment are able to minimize postharvest decay and obtain a lower rate of respiration, higher titratable acidity, and retain firmness which delay the ripening process occur in strawberry.

In the term of ascorbic acid concentration, treatments applied have no significant effect on ascorbic acid concentration except on day 6 and day 9. On day 6, the concentration of 1.0kJ/m² and 0.5kJ/m² of dosage increased significantly compare with all the others treatment and 1.0kJ/m² recorded the highest concentration (0.926mg/ml). The increase of ascorbic acids content of UV- C treated strawberry on day 6 might be attributed to the synthesis of ascorbic acid from monosaccharides, since in plants most

synthesis starts with preformed D-glucose [21]. 0kJ/m² of dosage recorded the lowest concentration on day 9 (0.259mg/ml.), this might be cause by decomposition of ascorbic acid content by the microbial loads and fruit under senescence [22].

Table 1 Data of firmness, total soluble solid, totatratable acidity and ascorbic acid evaluated on day 0, 3,6 and 9 after treatments.

Parameter	UV-C dosage (kJ/m ²)	Day			
		0	3	6	9
Firmness	0	0.48	0.41	0.20	0.20
	0.5	0.47	0.52	0.46	0.52
	0.6	0.50	0.56	0.50	0.39
	0.7	0.51	0.50	0.57	0.47
	0.8	0.49	0.56	0.48	0.53
	0.9	0.51	0.52	0.53	0.67
	1	0.51	0.58	0.55	0.58
	<i>lsd</i>	0.11	0.14	0.13	0.16
	Total Soluble Solid	0	5.73	5.53	6.30
0.5		5.50	5.37	5.97	6.13
0.6		5.57	5.60	5.97	6.13
0.7		5.40	5.47	5.97	6.13
0.8		5.43	5.40	6.13	5.97
0.9		5.50	5.10	5.97	6.97
1		5.60	5.60	5.97	7.53
<i>lsd</i>		0.26	0.15	0.18	0.34
Titratable Acidity		0	1.20	1.24	0.75
	0.5	1.28	1.31	0.67	0.71
	0.6	1.21	1.17	0.60	0.71
	0.7	1.21	1.11	0.67	0.78
	0.8	1.21	1.13	0.70	0.70
	0.9	1.21	1.13	0.60	0.74
	1	1.23	1.22	0.67	0.85
	<i>lsd</i>	0.06	0.03	0.04	0.04
	Ascorbic Acid	0	0.407	0.407	0.481
0.5		0.481	0.556	0.852	0.481
0.6		0.481	0.556	0.63	0.444
0.7		0.407	0.481	0.481	0.481
0.8		0.519	0.593	0.519	0.444
0.9		0.519	0.481	0.519	0.407
1		0.444	0.407	0.926	0.518
<i>lsd</i>		0.128	0.1205	0.1128	0.1205

The colour of freshly strawberry normally changes from a bright red to a dull red colour throughout the storage time, which then makes its appearance generally less acceptable for customer [23]. Based on the observation, the strawberry treated with 1.0 kJ/m² of dosage succeed to maintain the red colour of strawberry surface throughout the storage time, with showing more surface reddening than the control 0kJ/m² of dosage. This is corresponded to the result taken for lightness coefficient (L*) and chromaticity a*. According to CIELAB colour scale, the red colour of strawberry is determined through the measurements of L* and a*. L* represented brightness and a* indicated darkening of red colour or loss of red colour. The L* value tended to decrease either during development in the field or during storage, as a consequence of the pinkreddish color that naturally develops when strawberry fruit ripen while the chroma tended to decrease during the storage, which correspond to the development of a red-bronwish colour.

CONCLUSION

UV- C treatment is found to have potential in maintain the postharvest quality and prolong the shelf life of strawberry, especially those treated with 1.0 kJ/m² of dosage. UV- C treatment with 1.0 kJ/m² was more beneficial than lower dosage to maintain the overall quality of strawberry such as firmness, total soluble solids content, titratable acidity, ascorbic acid content and inhibit the growth of diseases. For future study, it is recommended to further increase the dosage of UV light to effectively delay the occurrence of ripening process and prolong the shelf life of fresh strawberry.

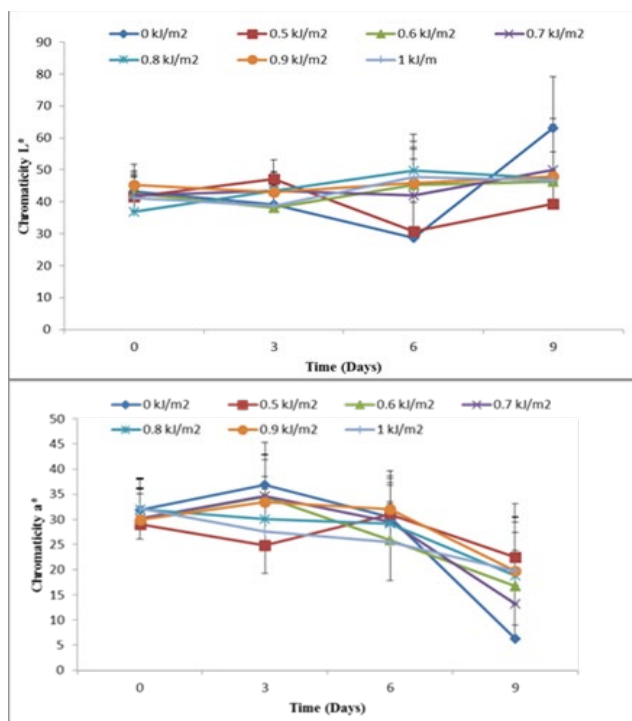


Figure 2 Effects of different dosage of UV- C light treatment on chromaticity L* of strawberry surface. Vertical bars represent LSD at 5% level. (LSD values on Day 0= 6.485, Day 3= 6.020, Day 6= 11.26 and Day 9= 16.25) and effects of different dosage of UV- C light treatment on chromaticity a* of strawberry surface. Vertical bars represent LSD at 5% level. (LSD values on Day 0= 6.071, Day 3= 8.36, Day 6= 7.682 and Day 9= 10.68).

REFERENCES

[1] M. T. Charles and J. Arul. "UV treatment of fresh fruits and vegetables for improved quality: a status report," *Stewart Postharvest Rev*, vol. 3, 2007, pp. 1-8.

[2] D. Picha, 2006. "Guide to post harvest care of strawberries in Moldova" [online]. Available from: www.acsa.md/public/publications/511250_en_postharvest_car.pdf [Accessed on 19 July 2017]

[3] D. Surenda, "Strawberry production, IPM and postharvest handling manual," 2010 [online]. Available from: pdf.usaid.gov/pdf_docs/PA00JGS9.pdf [Accessed on 2 August 2017]

[4] P. M. Civello, G. A. Martinez, A. R. Chaves, and C. A. Maria, "Heat treatments delay ripening and postharvest decay of strawberry fruit," *Journal of Agricultural and Food Chemistry*, vol. 45, 1997 pp. 4589-4594.

[5] R. B. H. Wills, V. V. V. Ku, and Y. Y. Leshem, "Fumigation with nitric oxide to extend the postharvest life of strawberries," *Postharvest Biology and Technology*, vol. 18(1), 2000, pp. 75-79 .

[6] N. S. Resende, G. A. S. Gonçalves, K. C. Reis, G. H. D. Tonoli, and E. V. B. V. Boas, "Chitosan/cellulose nanofibril nanocomposite and its effect on quality of coated strawberries," *Journal of Food Quality*, vol. 2018, Article ID 1727426, 13 pages, 2018. <https://doi.org/10.1155/2018/1727426>.

[7] R. W. Maraei, and K. M. Elsaywy, "Chemical quality and nutrient composition of strawberry fruits treated by γ -irradiation," *Journal of Radiation Research and Applied Sciences*, vol. 10(1), 2017, pp. 80-87. <https://doi.org/10.1016/J.JRRAS.2016.12.004>

[8] A. El Ghaouth, C. L. Wilson, and A. M. Callahan, "Induction of chitinase, β -1, 3-glucanase, and phenylalanine ammonia lyase in peach fruit by UV-C treatment," *Phytopathology*, vol. 93(3), 2003, pp. 349-355.

[9] R. Maharaj, J. Arul, and P. Nadeau, "Photochemical therapy in the preservation of fresh tomatoes by delaying senescence," Presented at Ann. Mtg., Inst. of Food Technologists. Chicago, Ill. 1993.

[10] M. Baka, J. Mercier, R. Corcuff, F. Castaigne, and J. Arul, "Photochemical treatment to improve storability of fresh strawberries," *Journal of Food Science*, vol. 64(6), 1999, pp. 1068-1072

[11] D. Marquenie, C. W. Michiels, A. H. Geeraerd, Schenk, A., C. Soontjens, J. F. Van Impe, and B. M. Nicolai, "Using survival analysis to investigate the effect of UV-C and heat treatment on storage rot of strawberry and sweet cherry," *International Journal of Food Microbiology*, vol. 73(2-3), 2002, pp. 187-196.

[12] M. Erkan, C. Y. Wang, and D. T. Krizek, "UV-C irradiation reduces microbial populations and deterioration in Cucurbita pepo fruit tissue," *Environmental and Experimental Botany*, vol. 45(1), 2001, pp 1-9.

[13] B. R. Yaun, S. S. Sumner, J. D. Eifert, and J. E. Marcy, "Inhibition of pathogens on fresh produce by ultraviolet energy," *International Journal Of Food Microbiology*, 90(1), 2004, pp. 1-8.

[14] J. Pan, A. R. Vicente, G. A. Martínez, A. R. Chaves, and P. M. Civello, "Combined use of UV - C irradiation and heat treatment to improve postharvest life of strawberry fruit," *Journal of the Science of Food and Agriculture*, vol. 84(14), 2004, pp.1831-1838.

[15] S. Darvishi, A. Fatemi, and K. Davari, "Keeping quality of use of fresh 'Kurdistan' strawberry by UV-C radiation," *World Applied Sciences Journal*, vol. 17, 2012, pp. 826-831.

[16] E. A. Barka, S. Kalantari, J. Makhoulf, and J. Arul, "Impact of UV-C irradiation on the cell wall-degrading enzyme sduring ripening of tomato (*Lycopersicon esculentum* L) fruit," *J Agric Food Chem*, vol. 48, 2000, pp. 667-671.

[17] M. G. Jose, C. Aguilera, and A. A. Migue, "Postharvest heat treatment on spanish strawberry (*Fragaria x ananassa* cv. Tudla)," *J. Agric. Food Chem*, vol. 43, 1995, pp. 1489-1492.

[18] J. Liu, C. Stevens, V.A. Khan, J.Y. Lu, C.L. Wilson, O. Adeyeye, M.K. Kabwe, P.L. Pusey, E. Chalutz, T. Sultana, and S. Drobny, "Application of ultraviolet-C light on storage rots and ripening of tomatoes," *J. Food Protec.*, vol. 56, 1993, pp. 868-872.

[19] M. Stitt, and M. Steup, "Starch and sucrose degradation" In *Higher Plant Cell Respiration*, 1985, pp. 347-390, Springer, Berlin, Heidelberg.

[20] M. O. Kelly, and M. E. Salheit, "Effect of endogenously synthesized and exogenously applied ethanol on tomato fruit ripening," *Plant Physiol.*, vol. 88, 1988, pp. 143-147.

[21] Liao M and Seib P., 1988. Chemistry of L-ascorbic acid related to foods. *Food Chem* 30:289-312.

[22] T. D. Bolyston, C. A. Reitmeier, J. H. Moy, G. A., Mosher and L. Taladriz, "Sensory quality and nutrient composition of three Hawaiian fruits treated by X-irradiation," *J. Food Quality*, vol. 25, 2002, pp. 419-433.

[23] M. Kadivec, P. Tijskens, M. Kopjar, M. Simčič, and T. Požrl, "Modelling the colour of strawberry spread during storage, including effects of technical variations," *Polish Journal of Food and Nutrition Sciences*, vol. 66(4), 2016, pp. 271-276. <https://doi.org/10.1515/pjfn-2016-0007>