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Effect of Ultraviolet-C Irradiation on Storability of Sapota

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ABSTRACT: Sapota is a climacteric fruit and suffers high postharvest losses due to its quick ripening property. Sapota is also highly susceptible to fungi such as black mold rot, anthracnose, sour rot and blue mold rot. Ultraviolet-C irradiation has shown potential in increasing the shelf life of the product by reducing microbial count, inducing a beneficial hormesis effect and delaying ripening. In the current study, the sapota samples of *kalipatti* variety were treated with UV-C doses of 2.5, 5, 7.5 and 10 kJm^{-2} to check its effect on the decay count and total aerobic bacterial count. The treated and untreated samples were stored at a temperature of 12±1ºC and relative humidity of 85-90%. The UV-C radiation significantly reduced the total aerobic bacterial count of treated sapota fruits compared to untreated fruit at all doses. UV-C irradiation also significantly reduced the decay count of sapota fruit. The untreated fruit suffered a higher decay count during storage and displayed a shelf life of 14 days. However, shelf life of more than 21 days was observed in treated samples. Compared to the fruits treated with lower doses, the fruits treated with higher UV-C doses displayed a lower decay count. UV-C irradiation significantly reduced the initial plate count from 3.5± 0.1log cfu/g to a minimum of 1.70 ± 0.015 log cfu/g in fruits treated with a dose of 10 kJm^{-2}. The fruits treated with a dose of 10 kJm^{-2}were at par with the fruits treated with a dose of 7.5 kJm^{-2}.

Keywords: Ultraviolet-C, Sapota, Shelf-life, Aerobic bacterial count, Postharvest losses.

INTRODUCTION

Food is a major necessity and important factor for human civilization. Despite advancements in technology, humans are still struggling to provide food security. In the year 2020, around 821 million people faced hunger and this number is expected to be as high as 660 million in 2030 (FAO, 2021). The efficient utilization of the food and avoiding food loss might help in solving the problem of hunger. According to the food loss index, 14% of the total production is lost till it reaches the retail level. Among food products, fruits and vegetables are most susceptible to spoilage. In Sub-Saharan African countries, farm losses ranged from 0-50% for fruits and vegetables. As per a meta-analysis of Asia and sub-Saharan, 33% of losses in fruits and vegetables were incurred (FAO, 2019). India incurs losses of 30-40 per cent which amounts to 40 million tons (US$ 13 billion) due to improper transportation, cold chains, storage structure and infrastructure etc. (Rajasri *et al.*, 2014). Indian farmers are unable to sell even 40% of the total fruits and vegetables produced, which amounts to 63,000 crore rupees (Pandey, 2018).

Sapodilla or Sapota is an evergreen tropical plant of the *Sapotaceae* family. It is native to Central America and Southern America (Ankalagi *et al.*, 2017). The total sapota fruit production of India in 2021-22 was 834.08 metric tonnes with Gujarat being the top producer (273.87 metric tonnes) (Anon., 2022). Sapota is known for its quick ripening and it deteriorates very fast after reaching its climacteric peak. The postharvest losses of sapota are as high as 20-30% (Salunkhe and Desai 1984) which extend up to 30-35 per cent at the end of the distribution (Khurana and Kanawjia 2006).

It has a shelf life of 7 days under ambient conditions and can reach upto 14 days under cold storage (Madani *et al.,* 2018; Bharathi, 2002). The fruit is highly sensitive to fungi such as black mold rot (*Aspergillus niger*), sour rot (*Geotrichum candidum*), blue mold rot (*Penicillium itallicum*), and anthracnose (*Colletotrichum gloeosporioides*) and microbial infections by species *Botryodiplodia, Pestalotiopsis, Phytophthora and Phomopsis* also contribute towards the post-harvest losses of the product. Hence, delaying the ripening and controlling the microbial activity can increase the shelf life of sapota. Ultraviolet irradiation is one of the minimal processing technology which has the potential in delaying ripening and is known for its germicidal effect.

Ultraviolet irradiation is a low-costminimal processing technique withthe potential to increase shelf life and doesn't demand sophisticated systems. Ultraviolet radiation is a portion of electromagnetic spectra with a wavelength of 100-400 nm. It is non-ionising germicidal radiation with surface decontamination properties (Gardner and Shama 2000). Among ultraviolet spectra, ultraviolet-C radiation with a wavelength of 200-280 is most effective in inactivating viruses, bacteria and spoilage pathogens (Kowalski, 2009). Ultraviolet radiation works on two principles (1) It reduces the microbial count from the fruit surface and (2) the hormesis effect (Stevens *et al.,* 1999). Hormesis is the stimulation of the production of plant defence enzymes on the application of low doses of abiotic stresses (Shama, 2007).

The increased fruit resistance to spoilage is due to the formation of phenylalanine ammonia-lyase (PAL) which enhances the production of phytoalexins (Cisneros-Zevallos, 2003). UV-C irradiation is also known to delay the ripening (Idzwana *et al.*, 2020) hence can be used on sapota which suffers from quick ripening problems. The present study was used to investigate the effect of UV-C irradiation on the storability of sapota.

MATERIALS AND METHODS

The study was conducted in the College of Agricultural Engineering & Technology, Junagadh Agricultural University, Gujarat during 2021-2022. Sapota of *kalipatti* variety was procured from the instructional farm of Junagadh Agricultural University, Gujarat, India. Sapota fruit at physiological maturity when brown scaly scurf from the fruit surface was procured. Equal-sized fruits free from any defects and of similar maturity were selected for treatment. The fruits were washed and air-dried before treatment.

***UV-C treatment of sapota*:** The fruits were treated under a bank of 4 UV-C lamps of 30W placed in a semicircular orientation. The fruit was continuously rotated using two rollers at 5 rpm. The fruit was treated with average UV-C intensity of 36.3 Wm^{-2} and a dose of 2.5, 5, 7.5 and 10 kJ m^{-2}. The maximum dose was decided based on the pre-trials. The dose above which the fruit started showing negative effects on the fruit surface was selected as the highest dose. The treatment time was calculated by dividing the dose required by radiation intensity. A total of 10 fruits per treatment was given UV-C dose with three replications. The experiments were conducted in the month of April and May. The fruits were stored in transportation containers developed by Antala *et al.* (2021). The containers were then stored in cold storage with 12±1ºC temperature and 85-90% relative humidity. The container and stored sapota can be depicted in Fig. 1.

Decay count: Decay count was calculated based on the external appearance of the fruit. Fruits with the sign of damage, moulds or decay were considered decayed. The percent decay count was calculated by dividing decayed fruit by the total number of fruits decayed (Cote *et al.*, 2013). The decay count was calculated after 14 and 21 days after treatment. The shelf life of the sapota was considered as the days of storage when 60% of the fruits became unmarketable (Yadav, 2010) or the microbial load on the fruits exceed 6 log cfu/g (Gull, 2021).

Fig. 1. Sapota stored in a transportation container.

Microbiological analysis: The microbial analysis was carried out to evaluate the effect of ultraviolet-C irradiation on the microbial population. The total aerobic plate count of control and treated fruits was determined according to Hakguder Taze *et al.* (2015) using the spread plating method. The results were expressed in log colony-forming units. The microbial analysis was carried out on the day of treatment.

Statistical Analysis: The statistical analysis was carried out using OPSTAT (an Online Agriculture Data Analysis Tool) with one-factor analysis. To find the level of factor which caused a significant change in the log survival numbers of total mesophilic aerobic bacteria, (TAPC) Tukey's pairwise comparison test was also conducted using Minitab 18 (Minitab Inc., US

Canada). Each experiment was conducted in quadruplicates.

RESULTS AND DISCUSSION

Decay Count: The UV-C treatment significantly ($P<0.001$) reduced the decay count of treated samples compared to the untreated samples (Table 1). The higher doses resulted in a lower decay count compared to the untreated samples. The control samples displayed a decay count of above 60% on the 14th day of treatment hence can be considered as the end of the shelf life of the control fruit. The decay count of treated fruit didn't exceed the mark of 60% spoilage on 21 days of storage which indicates an extended shelf life on UV-C treatment. The decay count of fruits at 21 days of treatment can be interpreted from Fig. 2.

Similar findings of reduced decay count were reported by D'hallewin *et al*. (2000) in star ruby fruit, González-Aguilar *et al*. (2007) in mango and Michailidis *et al*. (2019) in sweet cherry. D'hallewin *et al*. (1999) attributed the decrease in decay development to the accumulation of scoparone and scopoletin, which induces the production of phytoalexins, which inhibits pathogens. González-Aguilar *et al*. (2007) also reported enhanced activity of phenylalanine ammonia-lyase which can significantly reduce the decay count of fruit. The decay count was found least at the highest dose. A similar finding of lower decay count at a higher dose was reported by Escalona *et al.* (2010).

Table 1: Effect of UV-C dose on decay count (14 and 21 days after treatment (DAT)).

Treatment	Dose (kJ m^{-2})	Decay Count (%)	
		14 DAT	21 DAT
Control	Control	63.33 ± 15.28^{a}	96.67 ± 5.77^{a}
T1	2.5	26.67 ± 10^{b}	56.67 ± 15.28^{b}
T2	5	20.33 ± 5.77^{b}	53.33 ± 5.77^{b}
T3	7.5	6.67 ± 5.77^{b}	36.67 ± 5.77^{b}
T4	10	3.33 ± 5.77^{b}	36.67 ± 11.55^{b}

*Means that do not share a letter within a column are significantly different.

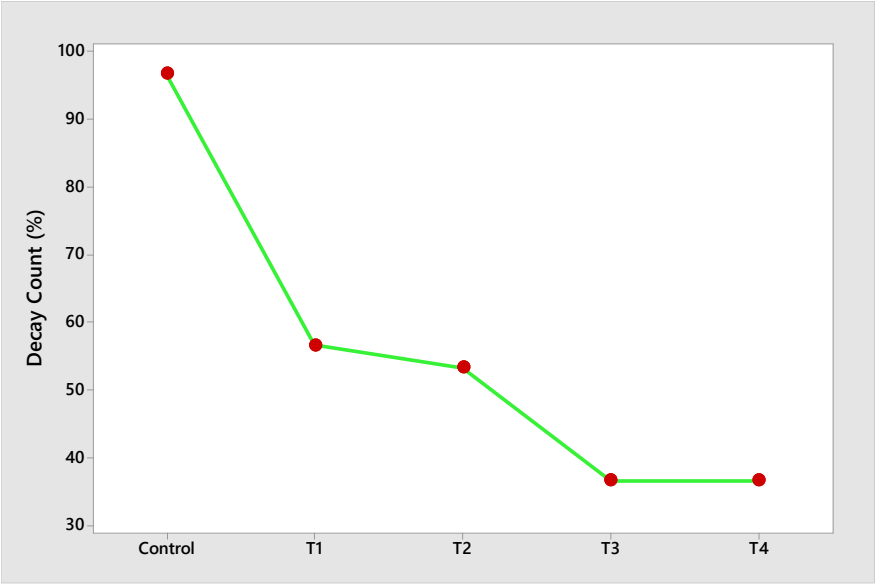

Fig. 2. Decay count of sapota on 21 days after treatment.

Microbial Analysis: The sapota samples were first microbiologically examined to determine their initial microbial flora of fruit. It was found that the sapota samples initially contained 3.5 ± 0.1 log cfu g^{-1} of total aerobic bacteria. The initial total plate count was in close approximation to the earlier study on sapodilla by Foo *et al.* (2019). The initial total aerobic plate count (TAPC) of the samples decreased from 3.5 log cfu g^{-1} to a minimum of 1.70 log cfug^{-1} following UV-C irradiation (Table 2). The fruits treated with UV-C displayed a significant ($P<0.001$) reduction in total aerobic plate count. The minimum surviving bacteria were found in the samples treated with 10 kJ m^{-2}. The microbial count of fruits treated with UV-C dose 7.5 and 10 kJ m^{-2} was at par. Similar findings of reduction in the microbial count were reported by HakguderTaze & Unluturk (2018) in apricot, Chen *et al*. (2020) in persimmon and Moreno *et al*. (2017) in fresh-cut carambola. On exposure to UV-C radiation, the hydrogen bond electrons of paired nucleotide get energised leading to breakage of the bond which results in the formation of the mutagenic lesion and cytotoxic, which ultimately leads to DNA disruption (Koutchma, 2014; HakguderTaze *et al*., 2015). In another

explanation, it was reported that UV-C irradiation stimulates the production of plant defence enzymes such as phytoalexins and phenols. The plant defence enzymes are toxic to pathogens and hence can cause a significant reduction in microbial count (Gonz´alez-Aguilar *et al*., 2001; Guan *et al*., 2012).

Table 2: Effect of UV-C dose on initial microbial count fruit.

Treatment	Dose (kJ m^{-2})	Bacterial Count (Log cfu/g^{-1})
Control	Control	3.5 ± 0.1^{a}
T1	2.5	2.97 ± 0.15^{b}
T2	5	2.4 ± 0.1^{c}
T3	7.5	1.74 ± 0.036^{d}
T4	10	1.70 ± 0.015^{d}

*The means that do not share a similar letter are significantly different.

CONCLUSION

UV-C irradiation has shown potential in reducing the decay and microbial count of the sapota. The shelf life of sapota under controlled conditions (12±1ºC temperature and 85-90% relative humidity)was only 14 days whereas treated fruit displayed a shelf life of more than 21 days. The higher doses displayed a lower decay count compared to the control. The minimum surviving bacterial was observed in fruits treated with a dose of 10 kJ m^{-2}. However, there was no significant difference between 7.5 and10 kJ m^{-2} doses. Based on the significant reduction in the surviving bacterial population and reduced decay count, it can be concluded that UV-C irradiation can be used for enhancing the shelf life of the sapota fruit.

FUTURE SCOPE

Sapota is a climacteric fruit and suffers high postharvest losses due to its quick ripening property. Ultraviolet-C irradiation has shown potential in increasing the shelf life of the product by reducing microbial count, beneficial hormesis effect and delayed ripening. UV-C irradiation can be used for enhancing the shelf life of the fruit and will ultimately benefit the farmer and sapota-related community.

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Conflict of Interest. Authors have declared that no competing interests exist.

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