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Possible Enhancement of Nutrients and Antioxidant Capacity of Two Tropical Fruits by UV Radiation Treatment

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Abstract
Ultraviolet (UV)-C radiation can elicit favourable reactions in biological systems especially in fruits and vegetables. This study was conducted to assess the effect of UV-C post-harvest treatment on the nutritional and antioxidant contents of tomato and cucumber**.** The samples were irradiated with UV-C, and then subjected to nutritional and antioxidant analysis to determine the proximate composition, mineral micronutrients, ascorbic acid, total flavonoid and total phenolics using standard methods. The result showed that post harvest treatment with UV-C radiation has varying effects on the nutritional contents and antioxidant activity of tomato and cucumber. Total flavonoid, total phenolics and crude carbohydrate content were significantly increased ($p<0.05$) while there was a reduction in the values of ascorbic acid and all mineral micronutrients except Iron. There was no significant difference in crude protein and moisture content. This study provides evidence that the novel technology of post-harvest treatment with UV radiation can enhance some health – promoting compounds of Tomato and Cucumber for the benefit of consumers.
Keywords: Ultraviolet radiation, Tomato, Cucumber, antioxidant, nutrient

1. Introduction

Fruits and vegetables play an important role in the nutrition of man. Apart from their nutritional values, they provide a variety of health-supportive phytochemicals such as flavonoids, saponins, terpenoids, and lignans (Oomah and Mazza, 2000). High intake of these nutritional and health promoting components of food has been associated with a low incidence of cancers, arthritis and other terminal diseases (Leong and Shui, 2002). Due to the perishable nature of fruits and vegetables, their nutritional and health-promoting values tend to diminish over time. Recent advances in the technology of UV-light irradiation have demonstrated that UV treatment holds considerable promise for shelf-life extension of fresh fruits and vegetables (Ribeiro *et al.,* 2012).
Tomato (*Solanum lycopersicum*) belongs to the *solanaceae* family. It is one of the world's most commercially produced vegetables (Olaiya *et al.*, 2010) and is also one of the world's major food crops (Frusciante *et al.*, 2000). However, tomato is highly perishable in the fresh state leading to wastage and losses during the peak harvesting period (Akanbi *et al*., 2006).
Cucumber (*Cucumis sativus*) is a cucurbitaceous vegetable grown in tropical regions. Emerald green young fruits are eaten as vegetables (Grover and Yadav, 2004). It is a good source of vitamin C, vitamin A, phosphorus and iron (Paul *et al.,* 1996). It is also a good source of phenolic compounds ((Horax *et al., 2005*). These phenolic compounds possess potent antioxidant activity that plays an important role in human nutrition as preventative agents against several diseases. (Myojin *et al.,* 2008).
Ultraviolet radiation is one portion of electromagnetic spectrum and there are three types namely UV-A, UV-B and UV-C. The wavelength for UV processing ranges from 100 to 400 nm (Koutchma *et al.,* 2009). UV-C (200–280nm) is called the germicidal range, since it effectively inactivates bacteria and viruses (Ribeiro *et al.,* 2012), low doses of UV-C irradiation stimulated beneficial reactions in biological organs, a phenomenon known as hormesis (Shama, 2007) and induction of plant defence system can also trigger the accumulation of phytochemicals such as total phenolics, carotenoids and vitamin C which exhibit antioxidant potential, improving the nutritional status of the fruit (Alothman *et al*., 2009).
Treating fresh fruits and vegetables with ultraviolet (UV) radiation is a new approach that holds promise for the extension of storage life of fresh horticultural crops (Ben-Yehoshua, 2003). However there is little information on the effects of ultraviolet-C radiation on the nutritional and antioxidant contents of tropical fruits, especially in sub-Saharan African. Therefore, the aim of this study is to evaluate the effect of ultraviolet-C post-harvest treatment on nutrient content and antioxidant capacity in two tropical fruits namely, tomato and cucumber.

2. Materials and Methods

The tomato and cucumber used in this study were purchased at one time from a farm at Olorunda village, Ibadan and identified in Botany Department, University of Ibadan. The fruits were of eating quality, with no blemishes

or damage and were carefully selected to be identical in terms of ripening stage, colour, shape and size. After cleaning, fruit samples were prepared according to the method of Alothman *et al*., 2009.

Ultraviolet-C radiation treatment: The UV-C lamps were stabilized by turning them on for 15min. Three replicates of fruit samples were placed on a rectangular polypropylene tray at the lower surface of the radiation chamber. Radiation was done in the dark at room temperature with the samples receiving a UV radiation dose of 2.217 J/m2 on the average. The UV-C lamp used is of wavelength 210nm and the tray was rotated four times during the treatment to ensure uniform exposure. Samples were divided into three treatment groups: group 1(120 min), group 2(240 min). Non illuminated samples were considered control.

After treatment with UV-C, samples were blended with 100ml of distilled water using electric blender and the blended samples were used for analysis.

Total phenolics: Total phenolics were determined according to method of (Singleton *et al.,* 1999). 0.5ml of sample was mixed with 0.5ml of freshly prepared Folin-ciocalteu reagent and 6ml of distilled water. After 5 min of incubation at room temperature, 2ml of 15% of sodium carbonate was added, shaken for 30 second and brought to up a volume of 10ml with distilled water. After 2 hour of incubation in the dark, the absorbance was measured at 750nm. Total phenolics was calculated and expressed as Gallic acid equivalent (GAE/mg) on a dry weight basis.

Total flavonoid: Total flavonoid content was determined according to method of (Zhishen *et al.*, 1999). 0.5ml of 2% ethanolic aluminum chloride ($AlCl_3$) solution was added to 0.5ml of sample. After 45min of incubation at room temperature, the absorbance was measured at 420nm. Total flavonoid was calculated and expressed as Rutin equivalent (RUT/mg) on a dry weight basis.

Ascorbic acid: Ascorbic acid was determined by the method of (Klein & Perry,1982).1ml of the sample extract was added to 1ml of 0.1mol/L potassium-phosphate buffer (pH 7.4), stirred gently at 4^0C for I hour. 1ml of the solution formed was added to 9ml of 0.05ml/L DPIP and it was allowed to mix for 15 second and the absorbance was measured at 515nm. Content of ascorbic acid was evaluated from the standard curve of ascorbic acid and expressed as (AsA) on a dry weight basis.

Proximate composition: The crude protein, crude fibre, ash, crude lipid and moisture content were determined by Standard methods (AOAC, 2005). The titratable acidity (TTA) was determined according to the method of (AOAC, 1999).

pH: pH was determined according to method of (Ademoroti, 1996). 40ml of the blended sample was filtered then 10ml of the filtrate was added with 90ml of distilled water and allowed to stand for 30 minutes and the pH was read using PHS-3C pH meter. .

Total carbohydrate: Total carbohydrate was determined by the method of (AOAC, 1995). The total carbohydrate content for samples was determined by subtracting all the values of proximate analysis from 100.

% Carbohydrate = 100 – (crude fiber + ash content + crude lipid + crude protein+ moisture content)

Determination of minerals: Minerals were determined by the method of (AOAC, 1995). Samples were dried at approximately 80^0C for 12 hours and it was finely grinded. 1g of the dried plant tissue was weighed into a 100ml berzeliu beaker and 5ml HNO_3 was added and 2ml $HClO_4$ was also added. It was covered and digested by heating to a final volume of 3-5ml. 10-15ml of distilled water was added and filtered through an acid-washed filter paper into a 50ml volumetric flask. The filter paper was washed with water and the filtrate was diluted to volume with deionized water. The absorbance was read using Buck atomic absorption spectrophotometer 210/211vgp.

Statistical Analysis: Data were expressed as mean ± SD. The significance of the differences between the means of the samples were established by analysis of variance, ANOVA ($p<0.05$)

3. Results and Discussion

Treating fresh fruits and vegetables with Ultraviolet-C (UV-C) radiation is a new approach that holds promise for the extension of storage life of fresh horticultural crops. This new approach involves the utilisation of hormic doses of UV-C light to elicit beneficial response in biological systems such as fruits and vegetables (Ribeiro *et al.*, 2012). The results in this study showed that UV-C irradiation has varying effects on the nutritional composition and antioxidant activity of Cucumber and Tomato. Table 1 showed the effect on pH and total titratable acidity .This result confirmed the literature available on the pH values of tomato fruit that although the pH of ripe tomatoes may exceed 4.6, tomato products are generally classified as acidic foods (pH<4.6) (Stevens 1972), pH and total titratable acidity increased in Cucumber while it decreased in Tomato after exposure to UV-C irradiation. Reduction in pH and titratable acidity of irradiated sample might be due to loss of citric acid which is the most abundant acid in tomato (Gordon *et al.*, 2011) while the increase in pH and total titratable acidity of cucumber might be due to enhanced metabolism and senescence in irradiated cucumber compared to the control (Mohammed *et al.*, 1999).

Table 2 shows the effect of UV-C on micronutrients of Cucumber and Tomato. The irradiation did not

significantly affect the micronutrients assayed in the two fruit samples.

The effect of UV-C irradiation on flavonoid, phenolics and ascorbic acid concentration are shown in Figures 1, 2 and 3 respectively. UV-C irradiation increased the concentration of phenolics and flavonoid while it caused reduction in the concentration of ascorbic acid. Increase in total phenolics or flavonoids might be a defense mechanism against UV-C mediated stress (Khartun *et al.,* 2012, Fan *et al.,* 2003). The increase in total phenolics and total flavonoids can also be attributed to the enhanced phenylalanine ammonia lyase (PAL) activity, which is one of the key enzymes in the synthesis of phenolic compounds in plant tissues (Frohnmeyer *et.al.,* 2003). Positive correlation has been reported between PAL and phenolic compounds in leaves of maize under environmental stress (Hura *et al.,* 2008). It has also been shown that the PAL activity can directly affect flavonoid formation and that the long wave of light can increase PAL activity (Cheng 2005). Therefore, the increase in total phenolics and flavonoid content of irradiated samples might be due to the activation of PAL and other enzymes required in the formation of these compounds. Increase in phenolic compounds of irradiated plant tissue has also been attributed to depolymerization and dissolution of cell wall polysaccharides, which facilitated higher extractability (Bhat *et al.,* 2007). In this study, ascorbic acid concentration decreases with increasing radiation probably due to enhanced respiration, resulting in increased enzymatic activity causing rapid degradation of ascorbic acid (Erdogdu *et al.,*, 2011; Mami *et al.*,2013). Also, ascorbic acid is a heat-sensitive bioactive compound and it gets degraded by oxidative stress, which is stimulated in the presence of light such as ultraviolet light (Davey *et al.,* 2000).

Effect of ultraviolet-C on the proximate contents is shown in Table 3. The moisture content and crude protein level were not significantly affected ($p>0.05$) by UV-C radiation. The carbohydrate content was observed to increase in irradiated samples compared with the control ($p<0.05$) This might be as a result of degradation of the starch by ultraviolet radiation leading to increase in the production of glucose and fructose, thus increasing the carbohydrate content (Petro-Turza 1987). There was also no significant difference ($p>0.05$) in the levels of crude fat, crude protein, crude fiber (cucumber) and crude ash (cucumber) after 240min of irradiation.

4. Conclusion

This study showed that Cucumber and Tomato illuminated with UV-C radiation consistently had higher phenolics and flavonoid contents suggesting that UV-C treatments may be a useful non-chemical way of enhancing the antioxidant post-harvest quality of Cucumber and Tomato.

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Table 1: Effect of UV-C irradiation on pH and Total titratable acidity

		CONTROL	120 min	240 min
pH	Cucumber	5.61 ±0.15^{a}	5.65 ±0.10^{a}	5.92 ±0.08^{b}
	Tomato	4.49±0.07^{b}	4.39±0.10^{ab}	4.33±0.05^{a}
Titratable acidity	Cucumber	0.57±0.01^{b}	0.47±0.01^{a}	0.83±0.02^{c}
	Tomato	0.80± 0.12^{c}	0.12±0.01^{b}	0.10±0.01^{a}

Values are mean±SD of three determinations. Means followed by the same letter within the same row are not significantly different (p>0.05).

Table 2: Effect of UV-C irradiation on micronutrients

Micronutrient%	Fruit	Control	120min	240min
Calcium	Tomato	0.011 ±0.002^{b}	0.010 ±0.001^{b}	0.011 ±0.002^{b}
	Cucumber	0.026 ±0.004^{b}	0.020 ±0.003^{ab}	0.024 ±0.003^{a}
Magnesium	Tomato	0.040 ±0.001^{b}	0.002 ±0.000^{a}	0.040 ±0.004^{b}
	Cucumber	0.011 ±0.001^{b}	0.008 ±0.002^{ab}	0.006 ±0.001^{a}
Potassium	Tomato	0.038 ±0.004^{b}	0.032 ±0.003^{a}	0.035 ±0.023^{ab}
	Cucumber	0.200 ±0.012^{b}	0.170 ±0.009^{ab}	0.160 ±0.007^{a}
Sodium	Tomato	0.001 ±0.000^{a}	0.001 ±0.000^{a}	0.001 ±0.000^{a}
	Cucumber	0.001 ±0.000^{a}	0.002 ±0.002^{a}	0.002 ±0.001^{a}
Iron	Tomato	0.001 ±0.000^{a}	0.001 ±0.000^{a}	0.001 ±0.002^{a}
	Cucumber	0.003 ±0.001^{a}	0.003 ±0.001^{a}	0.003 ±0.000^{a}
Total phosphorous	Tomato	0.061 ±0.002^{a}	0.063 ±0.004^{a}	0.061 ±0.002^{a}
	Cucumber	0.065 ±0.004^{a}	0.063 ±0.005^{a}	0.063 ±0.001^{a}

Values were mean±SD of three determinations, Means followed by the same letter within the same row are not significantly different (p>0.05).

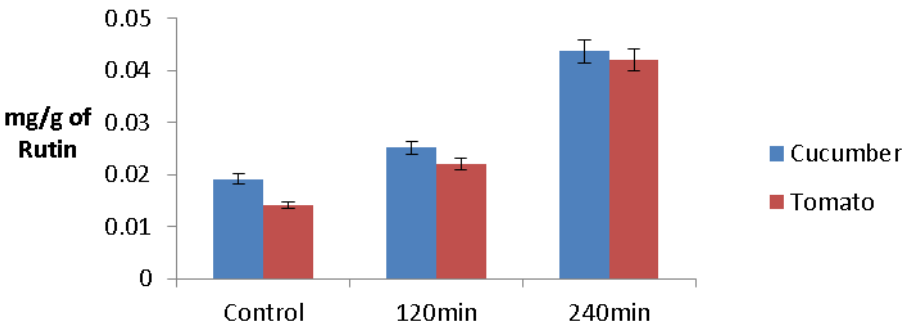

Figure 1: Effect of UV-C irradiation on flavonoid concentration

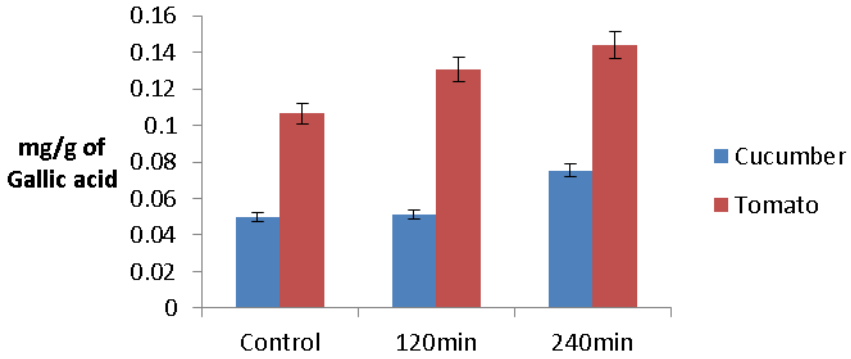

Figure 2: Effect of UV-C irradiation on phenolic concentration

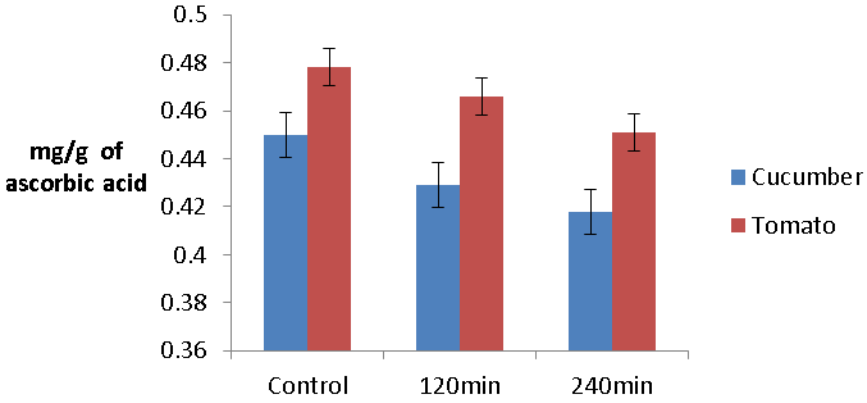

Figure 3: Effect of UV-C irradiation on Ascorbic acid concentration

Table 3: Effect of UV-C irradiation on proximate contents

Proximate(s)	Fruit	Control	120min	240min
Moisture	Cucumber	96.56 ±2.16^{a}	96.57±1.57^{a}	96.36 ±1.08^{a}
	Tomato	93.97 ±1.42^{a}	92.87 ±0.99^{a}	92.66 ±1.23^{a}
Crude Protein	Cucumber	0.56 ±0.040^{a}	0.52 ±0.05^{a}	0.58 ±0.02^{a}
	Tomato	1.98 ±0.033^{a}	2.20 ±0.039^{b}	2.01 ±0.027^{a}
Crude fat	Cucumber	0.11 ±0.01^{a}	0.10 ±0.03^{a}	0.15 ±0.01^{a}
	Tomato	1.02 ±0.012^{b}	0.80 ±0.09^{a}	1.01 ±0.07^{b}
Crude fibre	Cucumber	0.72 ±0.05^{a}	0.78 ±0.05^{a}	0.74 ±0.09^{a}
	Tomato	0.82 ±0.010^{a}	1.34 ±0.012^{b}	1.37 ±0.07^{b}
Ash	Cucumber	0.45 ±0.02^{a}	0.42 ±0.03^{a}	0.41 ±0.02^{a}
	Tomato	1.66 ±0.01^{c}	0.86 ±0.07^{a}	1.01 ±0.05^{b}
Crude- carbohydrate -	Cucumber	2.33 ±0.20^{a}	2.40 ±0.24^{ab}	2.51 ±0.22^{b}
	Tomato	0.55 ±0.04^{a}	1.93 ±0.10^{b}	1.94 ±0.13^{b}

Values were mean±SD of three determinations, Means followed by the same letter within the same row are not significantly different ($p>0.05$).