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Comparative Effects of Postharvest Ultraviolet-Light Treatments on Antioxidants Properties, Nutritional and Vitamin D Contents of Some Indigenous Green Leafy Vegetables

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Abstract
Ultraviolet lamps irradiation has been extensively used in water treatment, surface disinfection, and as a germicidal agent. Yet, activation of some essential reactions in fruits and vegetables occurs at low doses of irradiation, which in turn leads to an improvement of their shelf-life or bioactive compounds. In this study, postharvest effects of ultraviolet irradiation at different wavelengths were investigated on antioxidants properties, nutritional and vitamin D contents of six leafy vegetables. The six vegetables were each subjected to UV-A, B, and C lamps irradiation at wavelengths of 400, 315, and 230 nm respectively in irradiation chambers. The results revealed that ultraviolet irradiation increased the phenolic and flavonoid contents with a better-reducing power ability and antioxidant capacity in tested vegetables. More also, the essential amino acid contents were significantly ($P \leq 0.05$) increased. In UV-A treatment, increased nutritional and antioxidant properties were significant ($P \leq 0.05$) in *M. oleifera* leaf extract. On the other hand, a significant ($P \leq 0.05$) increase in the level of vitamin D2 and D3 synthesis in the leaves of all the vegetables was observed under UV-B treatment. The results revealed that *M. oleifera* leaf responds more positively to ultraviolet irradiation than other treated vegetables. Therefore, this study shows that postharvest treatments with UV-A and B lamps may be a useful biological strategy for enhancing the antioxidant and nutritional quality of vegetables.
Keywords: Antioxidant activity, UV-radiation, Vegetables, Bioactive compounds, Vitamin D.
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1. Introduction

Free radical's generation is not far-fetched in organisms' natural processes of metabolism. The endogenous antioxidant enzymes in an organism scavenge these free radicals. Any derangement in the antioxidant functions of an organism results to the accumulation of free radicals in the body, which causes damage to biomolecules and in turn brings about various diseases like cardiovascular disease, atherosclerosis, hormonal disorder, and other related diseases (Li *et al*. 2013). Kidney disease is one of the major life-threatening diseases that decrease the quality of life, and it is ranked the eighteenth highest cause of death worldwide in 2010 (Lozano *et al*. 2012). The most common causes of chronic kidney disease (CKD) in the developed world are diabetes mellitus and hypertension, whereas, in sub-Saharan Africa, the commonest causes are hypertension and chronic glomerulonephritis (Rashad & Barsoum, 2006). The study confirms that high consumption of vegetables and fruits with health benefiting bioactive compounds reduces the incidence of diseases that constitute economic problems (Dyshlyuk *et al*. 2017). Hence, a potential source of natural antioxidants can be derived from plant products. The use of plants for ethnomedicine is fast gaining recognition and publicity in Africa and the rest of the world, because of their affordability and availability and they are relatively cheap (Choi *et al*. 2012). Vegetables have a large number of bioactive compounds such as saponin, lignans, terpenoids, and flavonoids (Oomah & Mazza, 2000). It has been reported that vegetables have phytochemicals with similar activity as the synthetic chemicals recommended by USA NKF KDOQ/I (NKF, 2002). Oxalate in plants acts as calcium binders, phytate acts as phosphorus binder and vitamin D_2 which has similar activity with synthetic calcitriol. More also, recent advances suggest that plants could also synthesize calcitriol (Japelt *et al*. 2011) which has better and more effective outcome than vitamin D_2. Vitamin D_3 have been identified in some plant species like Solanaceae, Cucurbitaceae, Fabaceae, and Poaceae (Skliar *et al*. 2000). This led to the estimation of vitamin D in plant matrixes: *Amaranthus hybridus, Brassica oleracea, Hibiscus sabdariffa, Lactuca capensis, Solanum melongena*, and *Moringa oleifera*, which are some of the important vegetables in Nigerian diets. However, it is noteworthy that the vitamin D contents in these vegetables are very low (Magalhaes *et al*. 2007). A method or strategy to improve this in vegetables will be of great value.

Recent development in the use of UV light irradiation has shown a considerable promise for the shelf-life extension in fruits and vegetables (Allende & Artes, 2003). Also, UV-light irradiation helps in the postharvest

treatment of fruits and vegetables, which has reported to reduce decay, delay senescence, increase antioxidant activity, and induce several phytochemicals (Lu *et al.* 2016). Irradiation with UV-C lamp has been known for flavones enhancement in grape berry skin (Crupi *et al*. 2013). Ultraviolet-C lamp irradiation increased flavonoid accumulation, which in turn contributes to free radical scavenging and improves the antioxidant activity in fruits and vegetables (Rivera-Pastrana *et al*. 2014). According to Zhou *et al*. (2007) who reported a molecular mechanism of flavonoids accumulation in plants treated with UV-A and B. However, in our literature search, there is a paucity of information regarding postharvest UV-A, B and C treatments effects on *A. hybridus*, *B. oleracea*, *H. sabdariffa*, *L. capensis*, *S. melongena*, and *M. oleifera* on vitamin D, antioxidants potential and nutritional contents. Therefore, the present study examined the postharvest effects of UV-A, B and C treatments on the antioxidants potential, nutritional and vitamin D contents of six leafy vegetables.

2. Materials and Methods

2.1. Plant samples

The fresh leaves of *A. hybridus*, *B. oleracea*, *H. sabdariffa*, *L. capensis*, *M. oleifera*, and *S. melongena*, were collected from the Bodija market, Ibadan, the authentication was done at the Department of Botany Herbarium, University of Ibadan, where the voucher numbers were deposited (UIH-21131, UIH-22213, UIH-21213, UIH-22712, UIH-22913, UIH-22913 respectively). The perforated and damaged leaves were removed, the dust from the fresh leaves was cleaned with water and then air-dried. The selected vegetables were used for the experiment.

2.2. Treatment with ultraviolet lamps

The ultraviolet lamps were on for about 15 min for stabilization. The vegetable samples were irradiated with ultraviolet lamps A, B, and C in a rectangular box. Each sample received a UV radiation of 8watts lamps at a distance and dose of 70 cm and 2.217 J/m^2 respectively for 1h/day/vegetable for one week at a room temperature as described by Japelt et al. (2011), while control was not irradiated. The ultraviolet lamps A, B, and C used were of wavelengths 400, 315, and 230 nm respectively.

2.3. Plant preparation

After the irradiation, the vegetables were lyophilized, milled using a warring blender (Ultra-Turrax T25, Staufen, Germany) and refrigerated at -20^{0}C respectively. About 30 g of each sample was soaked for 24 h in distilled water with intermittent shaken. The muslin cloth was used to filter the homogenate. A rotary evaporator was used to concentrate the filtrate at 40°C and stored for analysis.

2.4. Assays for antioxidants

2.4.1. Sample's phenolic content determination

The sample's total phenolic content was estimated by using the method of Kim *et al*. (2003). Briefly, 1 mL of the sample was added to the Folin C reagent (1 mL 10%). A 3 min after the reaction, 1 mL of 15% Na_2CO_3 was added and made up to the volume with distilled water. The resulting mixture was kept in the dark with intermittent shaken for 90 min. The reading was taken at 760 nm. The standard used was gallic. Phenolic content in the sample was expressed as mg GAE/g.

2.4.2. Sample's flavonoid content determination

The sample's flavonoid content was estimated by using the method of Park *et al.* (2008). A 10 µg of the extract was mixed with $NaNO_2$ (75 µl of 5%) in 1 ml of distilled water. Also, followed by the addition of $AlCl_3.6H_2O$ (150 µl of 10%), NaOH (500 µl of 1M) and distilled water (275 µl) after 5 min. The reading was taken at 510 nm. The standard used was Quercetin. Flavonoid content in the sample was expressed as mg QUE/g.

2.4.3. Reducing power ability

The reducing power ability of the samples was determined by the method of Oyaizu (1986). Briefly, 10 µg/mL of the extract in distilled water was suspended into sterile test tubes. A phosphate buffer (2.5 mL) and K3 $[Fe(CN)_6]$ (2.5 mL) was dispensed into each of these test tubes. The mixture was incubated for 20 min at 50°C. Thereafter, 10% w/v, 1.5 mL TCA was added to stop the reaction. The mixture was subjected to centrifugation at 3000 g for 10 min. The aliquot (2.5 mL) was added to 0.5 mL of 0.1% $FeCl_3$. The reading was taken at 700 nm. The standard used was a Catechin.

2.4.4. Sample's radical scavenging activity (DPPH) determination

The method of Yen & Chen (1995) was used to estimate the DPPH radical scavenging activity of the samples. A sample extract (40 µg) was added to 1 mL of DPPH solution in 4 ml of distilled water. The resulting mixture was vortex and kept for 30 min at 25°C. The reading was taken at 517 nm. The standard treated like the extract used was catechin. The DPPH percentage inhibition was determined as follows:

$$\% \text{ DPPH scavenging ability} = \frac{Abs\ control - Abs\ sample}{Abs\ control} \times 100 \qquad 1)$$

2.4.5. Sample's hydroxyl radical scavenging activity determination

The hydroxyl radical scavenging activity of the samples was determined by the method of Halliwell *et al.* (1987). Briefly, 1 mM of EDTA, $FeCl_3$, ascorbic acid, H_2O_2 respectively and 28 mM deoxyribose were prepared in distilled water. A 0.33 mL of phosphate buffer (50 mM, pH 7.4) and 0.1 mL of 11 mM ascorbic acid were added to 1.0 mL of plant extract. The mixture was incubated for 1 h at 25^0C. The addition of 1.0 mL of 10% TCA and 1.0 mL of 0.5% TBA resulted in the development of the pink chromogen and the absorbance is taken at 532 nm. Ascorbic acid was used as the standard. The percentage of hydroxyl radical scavenging activity was calculated as follows:

Calculation

$$\% \text{ Hydroxyl radical scavenging activity} = \frac{Abs\ control - Abs\ sample}{Abs\ control} \times 100 \qquad 2)$$

2.4.6. Metal chelating ability

The metal chelating ability of the samples was determined by the method of Dinis *et al.* (1994). The reading was taken at 560 nm.

$$\% \text{ Metal chelating ability} = \frac{Abs\ control - Abs\ sample}{Abs\ control} \times 100 \qquad (3)$$

2.5. Determination of samples oxalate content

The oxalate content of the samples was determined by the method of Day & Underwood (1986). A 150 mL of 15N H_2SO_4 was added to 5 g of the sample, and the mixture was vortex carefully for 30 min and filtered by Whatman No 1 filter paper. A 25 mL of the filtrate was collected and titrated against 0.1 N $KMNO_4$ solution until a persistent faint pink colour appeared for 30 sec. The titre value was calculated to get the concentration of oxalate in the vegetable materials.

2.6. Determination of samples phytate content

The method of Reddy and Salunkhe (1980) was followed to determine the phytate content of the samples. A 50 mL of 3% trichloroacetic acid (TCA) was used to extract 1g of the sample for 30 min with intermittent shaken and then centrifuged for 30 min at 5,800 g. The aliquot that contains phytic acid was precipitated with 4 mL FeCl3 solution containing 0.2% $FeCl_3$ in 3% TCA. The precipitated ferric phytate was converted to $Fe(OH)_3$ with 3 mL of 1.5N NaOH after series of washing, heating, centrifuging and decanting of the precipitate (Wheeler & Ferrel, 1971). A 40 mL of hot 3.2 N HNO^{-3} was used to dissolve $Fe(OH)_3$ and the iron was estimated colourimetrically using 1.5 M KCN. The reading was taken at 480 nm against a reagent blank for each set of sample. From $Fe(NO_3)_3$ standard curve, the iron content was determined. The phytic acid content was estimated from the atomic ratio of iron to phosphorus (4:6) (Okon & Akpanyung, 2005).

2.7. Calcium content determination

The calcium content of the samples was determined by the method of AOAC (1990). A 2 g of each sample was heated in a crucible and ignited in a muffle furnace for 6 h at 550^0C to obtain ash content. The desiccator was used to cool the mixture and then weighed at room temperature to get the constant weight of the ash. The ash obtained was digested in a crucible with the addition of 5 mL of 2M HCl and heat to dryness on a heating mantle. Another addition of 5 mL of 2 M HCl was added, boiled and filtered by a Whatman No. 1 filter paper into a volumetric flask. Distilled water was added to the filtrate to make up the mark. Calcium concentration was read using the Flame photometer (PFP7 model). The concentration of the calcium was calculated using the formula.

$$\% \text{ Calcium} = \frac{Meter\ reading \times slope \times Dilution\ factor}{1000} \times 100 \qquad (4)$$

2.8. Phosphorus content determination

A spectrophotometric method of AOAC (1990) was employed to estimate the phosphorus content of the samples. The ash was obtained as described above for calcium. The filtrate (10 mL) was pipette into a 50 ml standard flask and immediately followed by the addition of vanadate-molybdate (10 mL) solution. The flask was made up to the mark with distilled water, and stand for 10 min for the development of yellow colour. The reading was taken at 470 nm.

$$\% \text{ Phosphorus} = \frac{Absorbance \times slope \times Dilution\ factor}{1000} \times 100 \qquad 5)$$

2.9. Determination of 7-hydrocholesterol, ergosterol vitamin D_3 and D_2

The 7-dehydrocholesterol, vitamin D_2, and D_3 contents in the selected vegetables were estimated by using the HPLC method of Japelt *et al*. (2011).

2.10. Statistical analysis

The Statistical Product and Service Solution software (Version 20) was used to analyze the data. Results were expressed as a mean ± SD. The level of significance was determined using a two-way ANOVA followed by an LSD test at $P \leq 0.05$.

3. Results

3.1. Flavonoid and phenolic contents

Figures 1 and 2 show the flavonoid and phenolic contents results in the treated and untreated vegetables. UV irradiation increased vegetables'flavonoid and phenolic contents, but a significant ($P \leq 0.05$) increase in flavonoid and phenolic contents were found in *M. oleifera* and *A. hybidus* treated with UV-A and B respectively, as compared to the control and other groups.

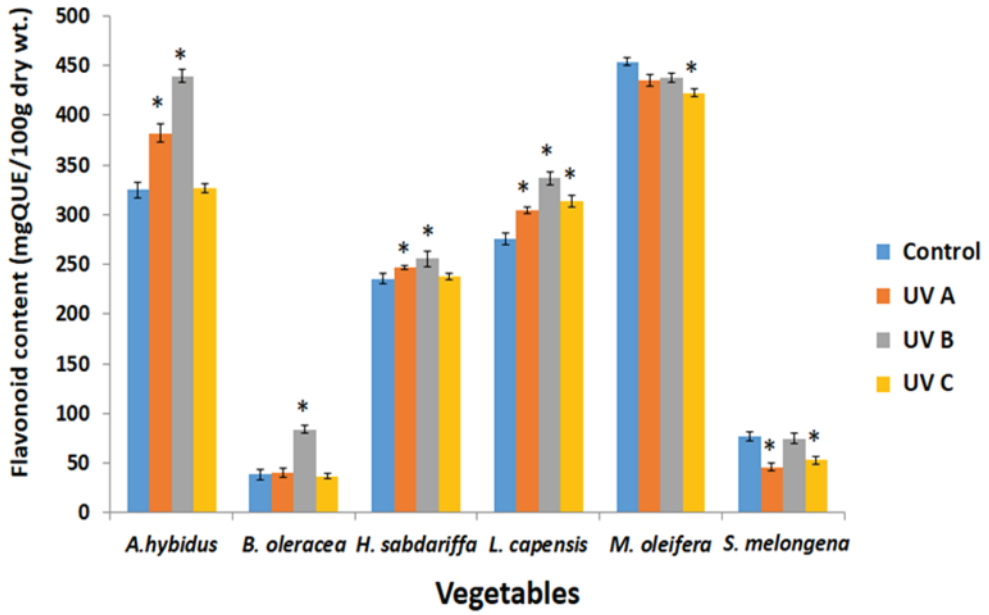

Figure 1. Postharvest effects of ultraviolet irradiation on total flavonoid content in the selected vegetables
Mean ± SD (n=3) was used for the data expression. *Significant ($P \leq 0.05$) difference from the control groups.

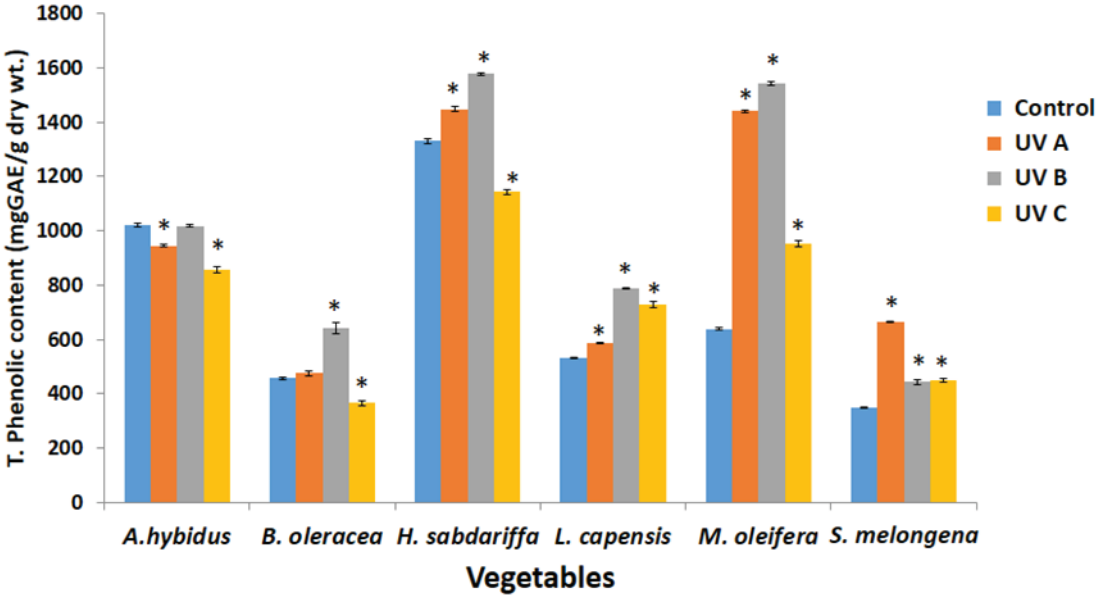

Figure 2. Postharvest effects of ultraviolet irradiation on total phenolic content in the selected vegetables
Mean ± SD (n=3) was used for the data expression. *Significant ($P \leq 0.05$) difference from the control groups.

3.2. Reducing power ability

The reducing power ability of vegetable leaves extracts is shown in Figure 3. Only the extracts of *M. oleifera* and *S. incanum* showed higher reducing power abilities in all treatments as compared to the control group. However, little or no noticeable effect of ultraviolet irradiation (A, B and C) was found on reducing power ability of other extracts when compared with the control groups.

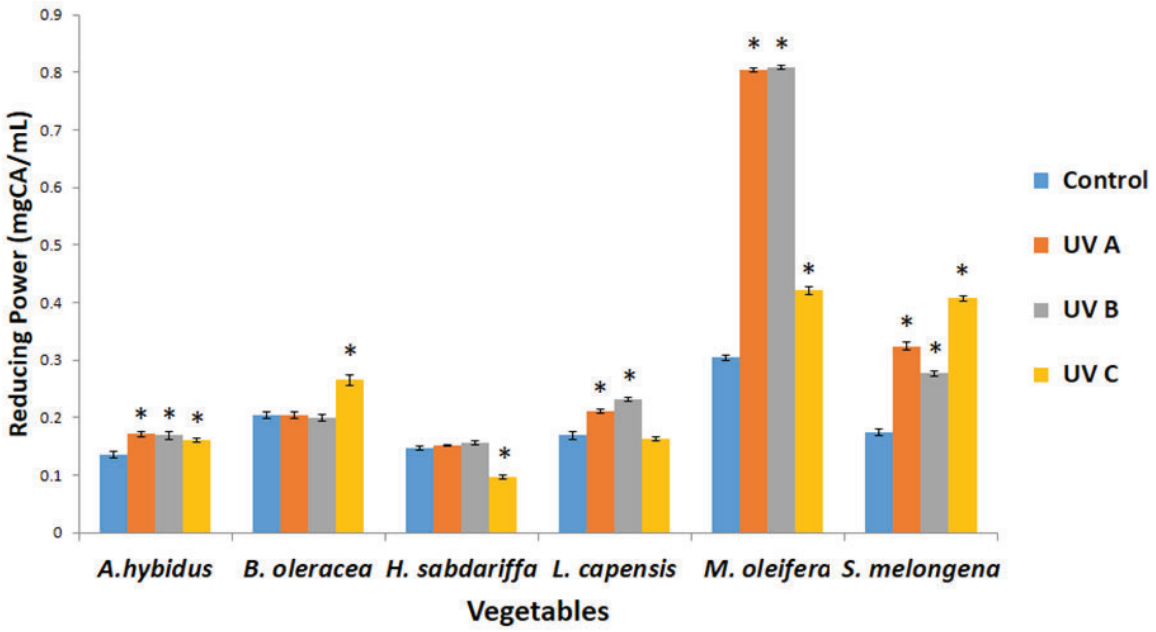

Figure 3. Postharvest effects of ultraviolet irradiation on reducing power capability in the selected vegetables. Mean ± SD (n=3) was used for the data expression. *Significant ($P \leq 0.05$) difference from the control groups.

3.3. DPPH radical and Hydroxyl scavenging activities

The DPPH radical and hydroxyl scavenging percentage inhibition of the selected vegetables are shown in Figures 4 and 5. The UV-A, B and C treated *M. oleifera* showed higher percentage inhibition of hydroxyl radical activity when compared with the control and other groups (Fig. 5). However, no significant effect of the treatments (UV-A, B and C) was found on DPPH radical scavenging activity in treated vegetables when compared with the control groups (Fig. 4).

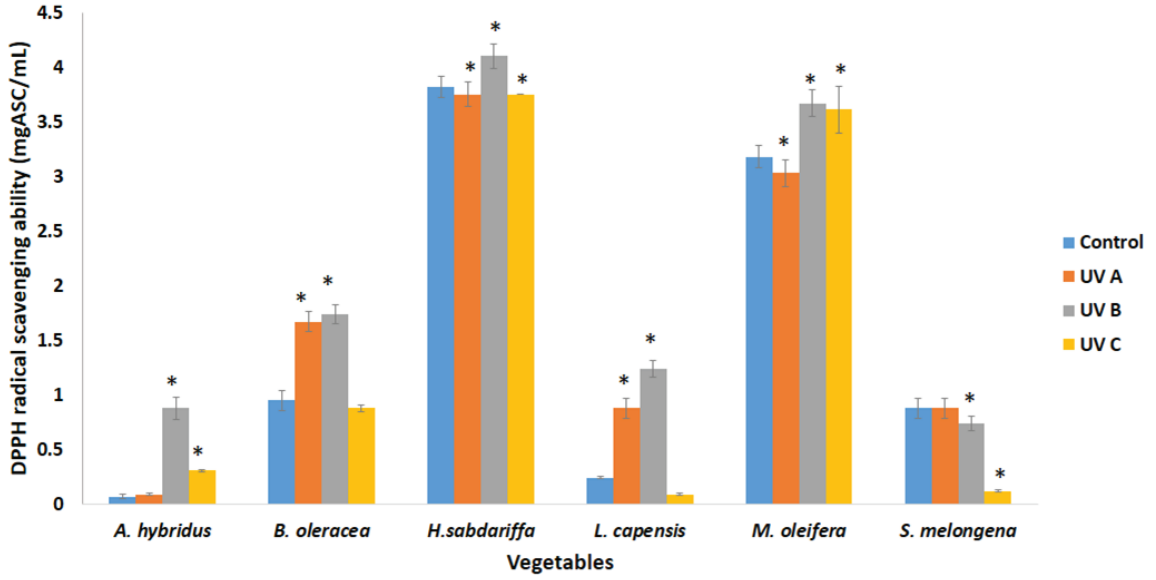

Figure 4. Postharvest effects of ultraviolet irradiation on percentage DPPH radical scavenging ability of the selected vegetables. Mean ± SD (n=3) was used for the data expression. *Significant ($P \leq 0.05$) difference from the control groups.

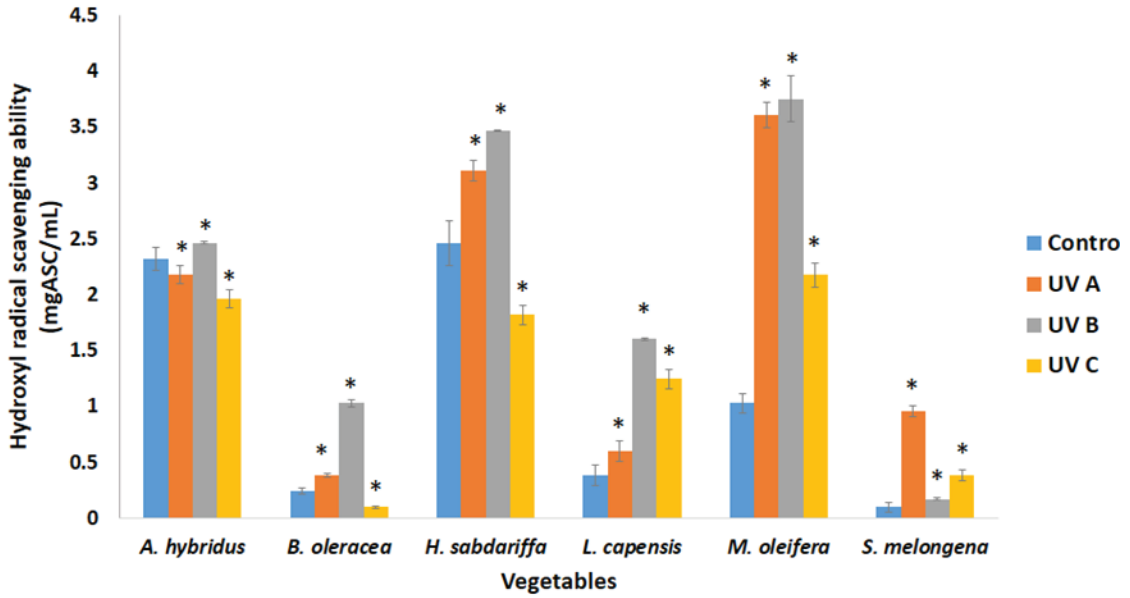

Figure 5. Postharvest effects of ultraviolet irradiation on percentage hydroxyl radical scavenging activity in the selected vegetables. Mean ± SD (n=3) was used for the data expression. *Significant ($P \leq 0.05$) difference from the control groups.

3.4. Metal (Fe^{2+}) chelating ability

The vegetable leaves extract metal chelating ability was determined, and the result was presented. Figure 6 shows that *A. hybidus* extract treated with UV-A and B has a higher metal chelating ability relative to the control group. The other extracts showed little or no effect on metal chelating ability under ultraviolet irradiation as compared to the control groups.

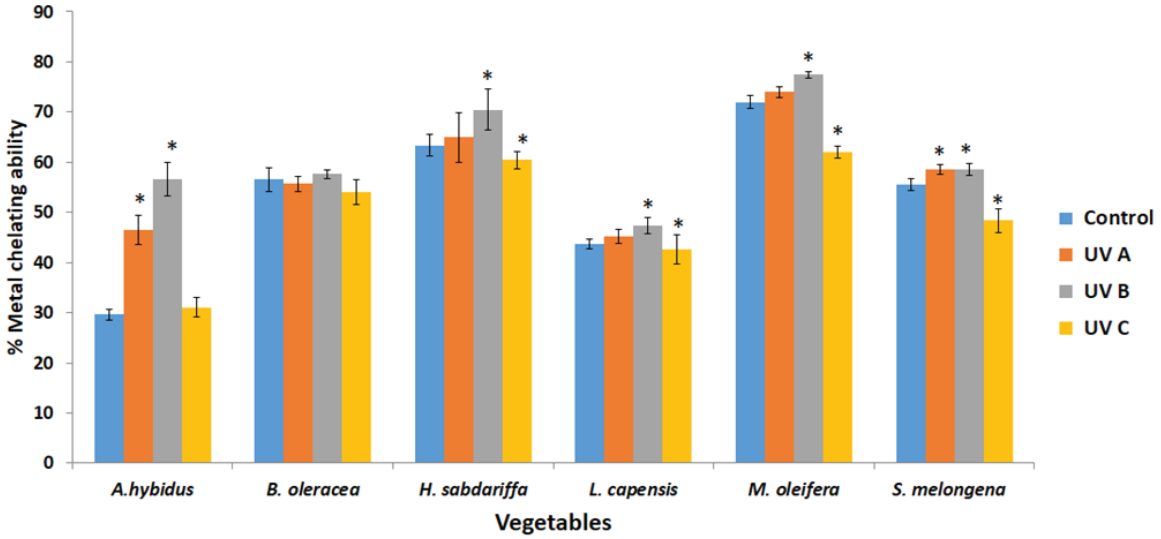

Figure 6. Postharvest effects of ultraviolet irradiation on percentage metal chelating ability in the selected vegetables. Mean ± SD (n=3) was used for the data expression. *Significant ($P \leq 0.05$) difference from the control groups.

3.5. Anti-nutrients content

As shown in Table 1, UV-A, B and C irradiation significantly ($P \leq 0.05$) reduced the oxalate content of the treated vegetables compare to their controls. On the other hand, the UV irradiation increased the vegetables'phytate content significantly ($P \leq 0.05$) except in *S. melongena*.

3.6. Minerals content

The results show that ultraviolet irradiation treated and untreated vegetable leaves extracts exhibited the same calcium and phosphorus contents as compared to the control and other groups. However, *H. sabdariffa, B. oleracea, L. capensis* and *M. oleifera* had higher calcium content (Table 1).

Table 1. Postharvest effects of ultraviolet light treatments on oxalate, phytate, calcium and phosphorus contents in the selected vegetables

Treated Veg.	UV	Ca (%)	P (%)	Oxalate (mg/g dwt)	Phytate (mg/g dwt)
A. hybridus	Control	7.35 ± 0.21	22.81 ± 0.01	0.81 ± 0.04	2.47 ± 0.02
	A	8.45 ± 0.49	23.80 ± 0.14	0.63 ± 0.01*	2.88 ± 0.04*
	B	6.96 ± 0.03	22.82 ± 0.03	0.49 ± 0.02*	3.09 ± 0.01*
	C	7.41 ± 0.01	22.80 ± 0.14	0.54 ± 0.02*	2.88 ± 0.04*
B.oleracea	Control	211.80 ± 0.31	48.80 ± 0.14	0.59 ± 0.04	2.88 ± 0.04
	A	212.90 ± 0.14	47.81 ± 0.13	0.45 ± 0.01*	2.68 ± 0.04*
	B	210.80 ± 0.11	48.74 ± 0.72	0.49 ± 0.02*	2.06 ± 0.01*
	C	214.90 ± 0.13	47.16 ± 0.13	0.48 ± 0.01*	2.67 ± 0.04*
H. sabdariffa	Control	210.70 ± 0.17	48.70 ± 0.22	1.13 ± 0.02	2.47 ± 0.02
	A	211.18 ± 0.16	47.80 ± 0.13	0.36 ± 0.01*	2.47 ± 0.02
	B	208.60 ± 0.12	48.81 ± 0.33	0.72 ± 0.02*	2.88 ± 0.04*
	C	219.02 ± 0.22	48.70 ± 0.12	0.57 ± 0.01*	2.88 ± 0.04*
L. capensis	Control	224.60 ± 0.22	50.17 ± 0.15	0.61 ± 0.01	1.47 ± 0.02
	A	220.10 ± 0.13	50.25 ± 0.35	0.43 ± 0.01*	1.81 ± 0.04*
	B	224.70 ± 0.12	50.80 ± 0.11	0.49 ± 0.02*	2.09 ± 0.01*
	C	219.10 ± 0.11	50.84 ± 0.11	0.44 ± 0.02*	1.88 ± 0.04*
M. oleifera	Control	216.58 ± 0.23	49.55 ± 0.14	2.68 ± 0.03	2.06 ± 0.01
	A	218.81 ± 0.21	47.80 ± 0.11	1.08 ± 0.01*	2.71 ± 0.08*
	B	220.65 ± 0.11	47.80 ± 0.21	1.61 ± 0.02*	2.27 ± 0.06*
	C	218.67 ± 0.12	48.55 ± 0.22	1.62 ± 0.02*	2.09 ± 0.01*
S. melongena	Control	5.55 ± 0.11	24.80 ± 0.15	0.59 ± 0.01	1.75 ± 0.01
	A	5.90 ± 0.22	25.60 ± 0.41	0.36 ± 0.02*	1.75 ± 0.01
	B	5.80 ± 0.14	24.77 ± 0.16	0.36 ± 0.01*	1.75 ± 0.01
	C	5.56 ± 0.22	25.75 ± 0.11	0.49 ± 0.02*	1.75 ± 0.01

Mean ± SD (n=3) was used for the data expression. *Significant ($P \leq 0.05$) difference from the control groups

3.7. Ergosterol, 7-dehydrocholesterol (DCH), Vitamin D_2, and D_3 contents

The results of the ergosterol, 7-dehydrocholesterol, vitamin D_2, and D_3, contents in treated vegetables were presented in Figure 7(a, b, c and d). The results show that the ergosterol and 7-DCH concentration in the UV-B treated vegetables significantly reduced relative to the control group. The concentration of 7 DCH in UV-A and C treated vegetables was reduced when compared with the control but not consistent across the treated vegetables (Fig. 7a). However, a consistent reduction was observed for ergosterol (Fig. 7c) The vitamin D_3 concentration of UV-B treated vegetables was significantly ($P \leq 0.05$) increased as compared to the control groups. The concentration of vitamin D_3 in UV-A and C treated vegetables showed no statistically significant difference from the control across the treated vegetables (Fig. 7b). The vitamin D_2 concentration was significantly ($P \leq 0.05$) increased in UV-B treated vegetables relative to the control groups. However, no statistically significant increase in vitamin D_2 concentration in UV-A and C treated vegetables relative to the control groups (Figure 7d).

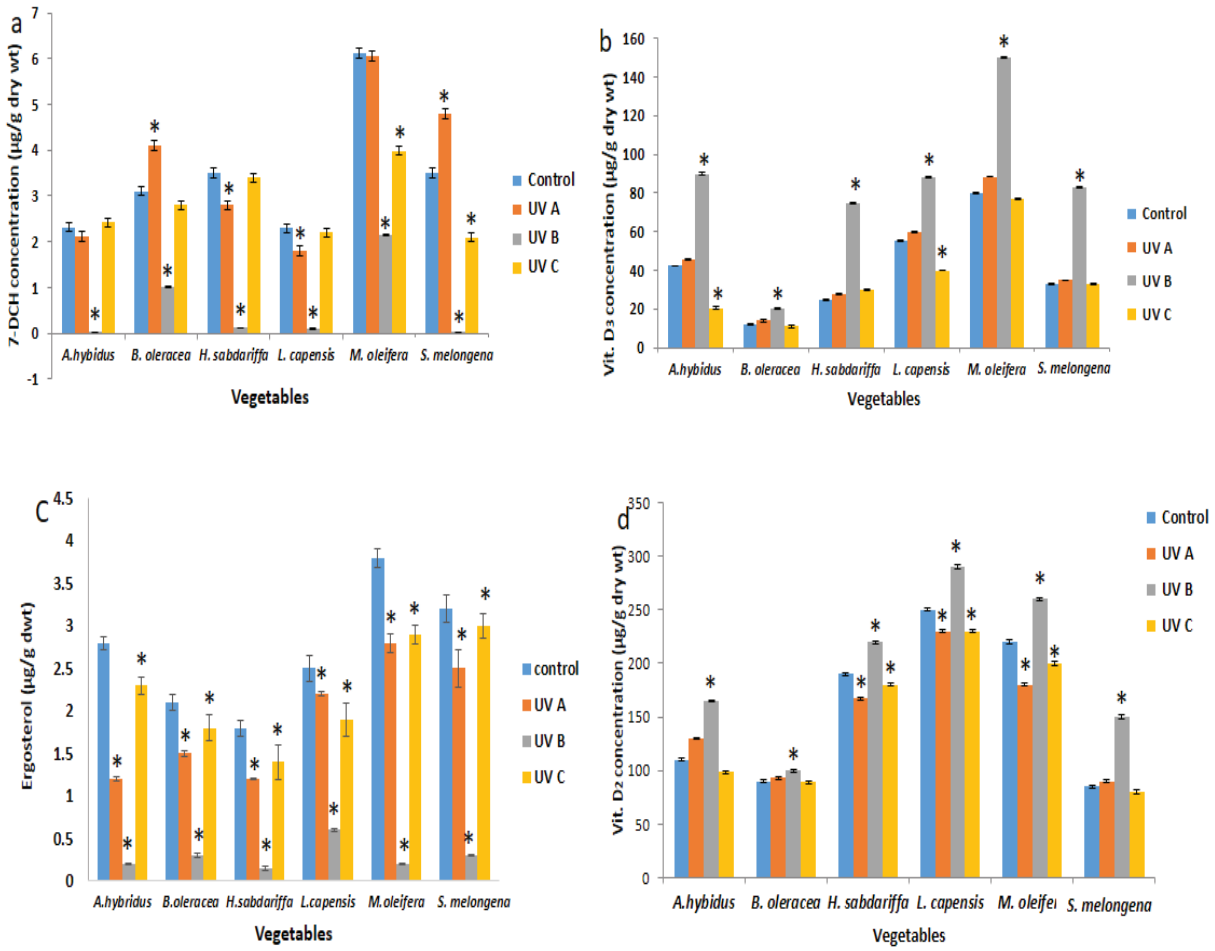

Figure 7 (a, b, c and d). Postharvest effects of ultraviolet irradiation on 7DCH, ergosterol, vitamin D_3 and D_2 contents of the selected vegetables. Mean ± SD (n=3) was used for the data expression. *Significant ($P \leq 0.05$) difference from the control groups.

4. Discussion

Ultraviolet irradiation serves as an alternative biological strategy that helps fruits and vegetables to increase their shelf-life through varying mechanisms (Shama, 2007). In response to UV irradiation, plants trigger their defense and anti-oxidative mechanism (Yun-Hee *et al.* 2007). It also serves as a germicidal agent, which readily alters the microbe's DNA and in turn affects cell division (Civello *et al*. 2006). In this work, we examined the post-harvest ultraviolet lamps irradiation effects on antioxidants properties, nutritional and vitamin D contents of six leafy vegetables. The increased phenolic and flavonoid contents observed in M. oleiferaand A. hybidus when treated with UV-A and B respectively might be a result of the phenylalanine ammonia-lyase activation, which is responsible for the synthesis of bioactive compounds (phenolic and flavonoid) in plants tissues (Papoutsis *et al*. 2016). Furthermore, the higher scavenging potential of *M. oleifera, A. hybidus,* and *S. incanum* observed under UV-ultraviolet lamps irradiation treatments in this study suggest that they are possible antioxidant sources. In this regard, the *M. oleifera* and *S. incanum* extracts reducing power was estimated by reducing iron III to iron II, while the higher reducing power was exhibited in *M. oleifera* leaf extract compared to *S. incanum* leaf extract (Fig. 3). According to the report of Islam (2013), who observed a correlation between the plant's extracts antioxidants and their capacity to reduce oxidative stress. This could also be linked to the *M. oleifera* leaf extract rich phenolic content. The metal chelating ability of *A. hybidus* under UV-A and B treatments observed (Fig. 6) under this study is in tandem with the result of Finefrock *et al.* (2003) who observed the metal chelating ability of plants with high antioxidant potentials.

In this study, there were decreased oxalate content in *M. oleifera* leaf extract under UV-A and B treatments and increased phytate content in UV-A, B and C treated *A. hybidus* (Table 1). Also, *M. oleifera* leaf treated with UV-A, B and C exhibited higher contents of calcium and phosphorus which are important minerals for bone mineralization. Ultraviolet light irradiated plant material and inert food have been shown to possess anti-rickety properties (Raghuramulu, 1996). Ultraviolet B (302 nm) enhances the synthesis of Vitamin D_2 and D_3 in irradiated vegetables. This follows the report that vitamin D_3 and D_2 are synthesized by the action of UV-B at

302 nm wavelength on the diene at the carbon 5 and 7 of the 7 dehydrocholesterol (Japelt *et al*. 2011; Mello, 2003). In addition, increased vitamin D_3 content in the vegetables with concomitant decreased 7-dehydrocholesterol after UV B treatment showed that 7-dehydrocholesterol is the precursor of vitamin D_3 in the irradiated vegetables and also that the photolytic pathway for its synthesis exists in the irradiated vegetables. This is also applicable to ergosterol and vitamin D_3 in the treated vegetables.

5. Conclusion

Medicinally and traditionally, vegetables are considered as the major sources of nutrients and antioxidants. In this study, after ultraviolet irradiation-A, B and C, all the treated vegetables still maintained many of their antioxidant capacity and physicochemical properties. The ultraviolet irradiation induced the synthesis of phenolic and flavonoid with a better-reducing power ability and antioxidant capacity in the tested vegetables. Conclusively, our results indicate that postharvest UV-A treatments significantly increased the nutritional and antioxidant properties of *M. oleifera* leaf extract, and UV-B treatment exhibited a significant increase in vitamin D_2 and D_3 levels in the leaves of all the vegetables. Enhancement of vitamin D in vegetables could be a useful dietary intervention for the management of vitamin D insufficiency and the reversal of kidney damage in patients. In this regard, *M. oleifera* leaf extract tends to be the most promising among all investigated vegetables, and thus need to be subjected to further study. Therefore, the UV-A and B treatments may be a useful biological strategy for enhancing the antioxidant and physicochemical postharvest quality of vegetables.

Conflicts of interest

No competing interest exists among the authors.

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