

Journal

J. Biol. Chem.
Environ. Sci., 2018
Vol. 13(3): 21-43
<http://biochemv.sci.eg>

EFFECT OF ULTRA VIOLET (UV-C) AND COLD STORAGE ON APPLE JUICE QUALITY

**Bazaraa^{*1}, W. A.; Shahinaz¹, A. Helmy;
H. A. Eissa² and R. M. Abd-Elhafez²**

¹*Food Science Department, Faculty of Agriculture,
Cairo University, Giza, Egypt*

²*Food Technology Department, National Research
Centre, Cairo, Egypt.*

ABSTRACT

The effect of the UV-C treatment on physico-chemical characteristics (pH, titratable acidity, TSS, color and ascorbic acid content), polyphenol oxidase activity (PPO), as well as microbial count of apple juice, compared to fresh juice was studied. The juice samples were irradiated using UV-C at 254 nm for different exposure times (15, 30, 45 and 60 min) and stored at 4±1 °C for 30 days. Treatment didn't significantly affect pH values, titratable acidity and TSS (%) in both fresh and stored samples. A negative correlation between exposure time and L* values was noted for fresh and stored samples. On the other contrary, positive relations were observed with a* and b* values. Ascorbic acid content decreased as a result of increasing exposure time where it was completely lost after 5 days for samples treated for 30, 45 and 60 min., 10 days for samples treated for 15 min. and 15 days for control one. PPO was partially deactivated by either treatments (76.8 % loss of its initial activity after 60 min. of UV exposure) or during storage (at slower rate). Total bacterial count as well as yeast and mold numbers were negatively affected by increasing the UV exposure time. It was obvious, the higher UV resistance of yeasts and molds than bacteria. The sensory characteristics, i.e. odor, color, taste, consistency and overall acceptability didn't change as a result of UV treatment up to 30 min. and significantly decreased thereafter.

Key words: apple juice, cold storage, polyphenol oxidase, sensory characteristics, UV-C.

INTRODUCTION

Fruit juices are important trade commodities in most countries (**Vasavada 2003**). Fruit juices provide nutrients that are beneficial for human health and are in high and continually increasing demand (**Ashurst 2005**). Apple juice is consumed by people around the world, mainly in single-strength, reconstituted or concentrated form, in blends for new flavor, in beverages as well as other products (**Noci et al. 2008**). Generally, the shelf life of fresh apple juice is restricted by enzymes and microbial activities. Spoilage of fruit and vegetable juices is mainly due to the presence of osmophilic microflora (**Tahiri et al. 2006**). These microflora (mostly yeasts) cause fermentation and produce a buttermilk-like off-flavour (**Tournas et al. 2006**). Presently, thermal pasteurization is considered the most effective technology in inactivating microorganisms and enzymes to extend product's shelf life (**Noci et al. 2008**). However, the used temperature can affect the overall quality of juice by changing its nutritional and biochemical properties (**Sanchez-Vega et al. 2009**). In response to this limitation, ultraviolet (UV) irradiation, which is a non-thermal technology, was introduced to overcome the problems associated with heating and to obtain a product that has similar quality attributes to the fresh juice (**Mertens and Knorr 1992**).

Ultraviolet (UV) radiation covers a small part of the electromagnetic spectrum, which also includes radio waves, microwaves, infrared radiation, visible light, X-rays and γ -radiation (**Diffey 2002**). Ultraviolet radiation involves the use of radiation from the electromagnetic spectrum from 100 to 400 nm. The UV radiation is categorized to three areas: UV-A (320–400 nm), UV-B (280–320 nm) and UV-C (200–280 nm) as mentioned by **Guerrero-Beltrán and Barbosa-Cánovas (2004)**. UV radiation technology has been utilized in food industry for decades to disinfect water and effectively destroy microorganisms on surfaces using 254 nm at low temperature (**Bintsis et al. 2000**). The other advantages associated with UV-C treatment are: no known toxic by-products are formed during the treatment, certain organic contaminants may be removed, no off flavor or off odor is formed and it requires very little energy compared to thermal pasteurization processes (**Koutchma et al. 2009**).

Shortwave UV irradiation (200–280 nm) induces the crosslinking of neighboring pyrimidine nucleoside bases in the same DNA strand,

blocking DNA transcription and replication and eventually causing cell death (**Guerrero-Beltrán and Barbosa-Canovas 2004**). In addition to microbial spoilage, reactions facilitated by inherent enzymes such as polyphenol oxidase can also adversely affect shelf life and consumer acceptance (**Tomás-Barberán and Espín 2001**). Polyphenol oxidase (PPO) is a copper containing enzyme, which occurs in many fruits (**Falguera et al. 2012**). The enzyme catalyzes the oxidation of various phenolic substrates, whose polymerization leads to the formation of undesirable brown pigments and therefore has to be inactivated by processing to enhance the shelf life of the juice (**Chisari et al. 2011**).

Most of the studies concerning UV irradiation of fruit juices have been carried out in order to assess its effect on microbial inactivation (**Falguera et al. 2012**). Nevertheless, there are few references about the influence of UV on some enzyme activities that are important in this kind of fruit derivatives (**Jiang et al. 2004; Gayan et al. 2013; Falguera et al. 2014**). Similarly, little is known about the storage quality of UV treated fruit juices (**Forney et al., 2004; Franz et al. 2009; Koutchma et al., 2009; Lu et al. 2010; Fredericks et al. 2011**). Therefore, the aim of this work was to evaluate the effect of UV-C treatment at 254 nm at room temperature for different exposure times and storage (30 days at $4 \pm 1^{\circ}\text{C}$) on the quality of apple juice which includes microbial load, pH, TSS, titratable acidity, color characteristics, ascorbic acid content, polyphenol oxidase activity (PPO) and sensory criteria.

MATERIALS AND METHODS

1-MATERIALS

Apple fruits (red delicious variety) at maturity stage, were purchased from local market during the fall and winter seasons of 2016 – 2017. The fruits were stored at 4°C until needed. Plate count agar (PCA), potato dextrose agar (PDA), were obtained from Sisco Research Laboratory, catechol, 2,6-dichlorophenolindophenol sodium salt, sodium hydroxide, ascorbic acid were purchased from Sigma Chemical Company (St. Louis, Missouri, USA).

2-METHODS

a-Preparation of apple juice

Apple fruits were rinsed with tap water, sectioned to longitudinal slices and juice was extracted using a juicerator (Braun, model K700, Germany) and filtered through a stainless filter. Apple juice was collected in a beaker containing 0.5 g ascorbic acid / 1000 ml juice with stirring. The added ascorbic acid was to prevent browning (Liao *et al.* 2018).

b-Ultra violet (UV-C) treatment and storage conditions

The UV-C treatments were carried out in a stainless steel chamber (50 x 35 x 30 cm), equipped with one UV-C germicidal lamp (254 nm), mercury low pressure (Phillips, model T8, Holland) as shown in **Fig.(1)**. In each experiment, a 200 mL of fresh apple juice was placed in an in covered glass petri dish (27 x 2 cm) forming a film thickness of 5-7 mm under continuous stirring. Temperature was controlled at $25 \pm 1^{\circ}\text{C}$. The distance between the surface of the juice and the lamp was 7 cm and the exposure was for the periods of 15, 30, 45, and 60 min. After irradiation process, the samples were placed in sterile capped test tubes (25 mL) and stored at $4 \pm 1^{\circ}\text{C}$. Samples were randomly withdrawn for each dose at 0, 5, 10, 15 and 30 days for analysis.

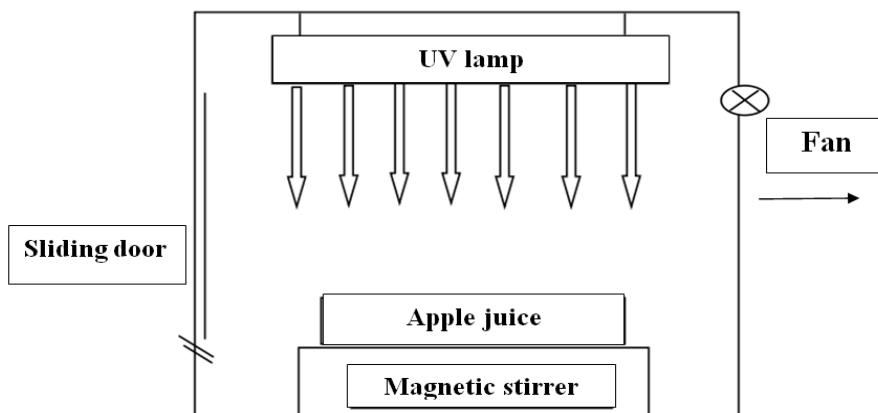


Fig. (1): Diagram of UV chamber

c-pH

The pH values of apple juice samples were measured using a digital pH-meter (HANNA, HI 902 meter, Germany).

d-Total soluble solids (°Brix)

The percent of total soluble solids (TSS), expressed as °Brix, was determined with a hand refractometer (ATAGO, Japan). Measurements were performed at 20 °C as recommended by **Ranganna (1986)**.

e-Titratable acidity (TA)

Juice sample (10 ml) was titrated with 0.1 N sodium hydroxide to the end-point in the presence of phenolphthalein indicator. Results were expressed as milligrams of malic acid per 100 ml apple juice (**Tung-Sung *et al.* 1995**).

f-Ascorbic acid

Ascorbic acid content was determined according to **AOAC (2005)** using 2,6 dichlorophenolindophenol sodium salt by titration.

g-Color measurement

The color of juice samples was measured using Hunter Lab color system (Hunter, Lab Scan XE - Reston VA, USA). The instrument was calibrated using a white tile ($L^* = 92.46$; $a^* = -0.86$; $b^* = -0.16$). Color values were expressed as L^* (lightness or brightness/ darkness), a^* (redness/greenness) and b^* (yellowness/blueness) according to **Feng *et al.* (2013)**.

h-Polyphenol Oxidase (PPO) activity

One ml of apple juice (diluted when needed) was mixed with 2 ml of catechol solution (0.2 M) prepared in a phosphate buffer solution (pH 7, 0.2 M). PPO activity was determined by spectrophotometrically measuring the increase in absorbance at 420 nm at 25°C. The absorbance values were recorded every 30 s for 3 min. The enzyme activity was calculated on the basis of the slope of the linear portion of the curve plotted of A_{420} against time. One unit of PPO activity was defined as $0.001 \Delta A_{420} / \text{min}$ under the assay conditions (**Ozoglu and Bayndrl 2002**).

i-Microbiological analysis

Total plate count as well as total yeasts and molds were determined using pour plate technique on plate count agar and potato dextrose agar, respectively (**Hatcher *et al.* 1992**). Juice samples were serially diluted using sterile saline (0.85% NaCl) and the appropriate dilution was then plated. The plates for total count were incubated for 48 h at 35 °C, whereas the plates for yeasts and molds were incubated for 5 days at 28 °C. Colonies were then counted and expressed as log₁₀ colony forming unit per milliliter of juice (log₁₀ CFU.ml⁻¹).

j-Sensory analysis

Juice samples were given three digit codes and organoleptically evaluated by 10 untrained panelists from Food Technology Department, National Research Centre. All samples were evaluated for color, odor, taste, consistency and overall acceptability on a ten point's hedonic scale on which score of ten represented attributes most liked, 5 represented attributes at an unacceptable margin and 1 represented attributes most disliked. Samples (20 ml, each) were served in clear plastic cups at room temperature and compared with a fresh control. Water and neutral wafers were also served for cleaning palate between samples.

k-Statistical analysis

Data were statistically analyzed using one-way analysis of variance ANOVA (**Silva and Azevedo, 2009**). All data were the averages of 3 experiments unless otherwise stated.

RESULTS AND DISCUSSION

a-Effect of UV-C and cold storage on the pH of apple juice

The value of pH is one of the important quality characteristics that describe the stability of bioactive compounds in fruit juices (**Sanchez-Moreno *et al.* 2006**). **Table (1)** shows the effect of UV at different exposure times and storage on the pH values of apple juice. Results indicated no significant changes in pH values of the untreated juice compared to the treated one. At zero time, the pH values were 4.31, 4.29, 4.28, 4.26 and 4.20 for samples exposed for different times (0, 15, 30, 45 and 60 min., respectively). Obtained results are in agreement with those of **Bhat *et al.* (2011)**, **Caminiti *et al.* (2012)** **Feng *et al.* (2013)** and **Shamsudin *et al.* (2014)**, who reported no

significant changes in pH values of different types of fruit juices treated with different of UV dosages. Similarly, no statistical differences in pH values were noticed during storage for 30 days at 4°C for all treatments. These results are also in the same line with a study of **Del Caro *et al.* (2004)**, who indicated no significant changes in pH of orange juice during 15 days of storage at 4°C and values ranged from 3.34 (zero time) to 3.43 (after 15 days). In contrast, **Cortes *et al.* (2008)** reported a significant increase in pH value of fresh orange juice during storage for 4 weeks at 2°C. However, **Unluturk and Atilgan (2015)** reported a significant decrease in pH value during storage of grape juice.

Table (1): Effect of UV-C treatment and storage (30 day, 4°C) on pH values of apple juice

Exposure time (min.)	Storage (days)				
	0	5	10	15	30
0	*4.31 _a ±0.004	4.26 _a ±0.006	4.22 _a ±0.001	4.25 _a ±0.005	4.28 _a ±0.010
15	4.29 _a ±0.005	4.27 _a ±0.006	4.23 _a ±0.005	4.25 _a ±0.004	4.25 _a ±0.040
30	4.28 _a ±0.005	4.26 _a ±0.005	4.23 _a ±0.005	4.27 _a ±0.003	4.23 _a ±0.010
45	4.26 _a ±0.005	4.24 _a ±0.006	4.23 _a ±0.001	4.21 _a ±0.003	4.20 _a ±0.010
60	4.20 _a ±0.005	4.23 _a ±0.005	4.20 _a ±0.005	4.21 _a ±0.004	4.22 _a ±0.060

*Means followed by different superscripts (within columns) and different subscripts (within rows) are significantly different ($p \leq 0.05$).

b-Effect of UV-C and cold storage on titratable acidity of apple juice

The obtained results for the effect of UV-C treatment on titratable acidity are summarized in the following points. The titratable acidity of fresh apple juice was 0.336 mg malic acid.100 ml⁻¹ juice. No significant change in such value was noted in juices treated at the different UV exposure times. Similarly, the storage for 30 days at 4°C didn't significantly affect the titratable acidity value obtained at zero time. Obtained results are in agreement with those of **Chisari *et al.* (2011)**; **Pala and Toklucu (2011)**; **Caminiti *et al.* (2012)**; **Shamsudin *et al.* (2014)** and **Kaya and Ünluturk (2015)**, who

reported that UV didn’t significantly affect the titratable acidity of treated juices during refrigerated storage.

c-Effect of UV-C and cold storage on TSS of apple juice

Total soluble solids (TSS) are routinely employed to measure the approximate sugar levels in fruit juice (Bhat, 2016). Therefore, TSS was measured for all treated samples compared with control sample and the results are presented in Fig. (2). Data revealed that TSS values for control and the UV- treated samples at zero time ranged between 12 to 12.8 with no significant differences between them. Such values persisted with no changes during storage (30 days, 4°C). These results are in harmony with those of Noci *et al.* (2008), Bhat *et al.* (2011); Feng *et al.* (2013) and Falguera *et al.* (2013) where they reported no significant differences in the TSS% of fruit juice samples treated with UV irradiation.

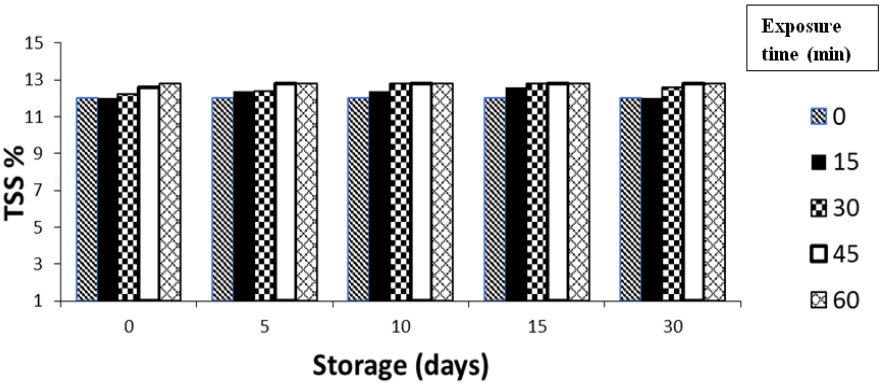


Fig. (2): Effect of UV-C treatment and storage (30 days, 4°C) on TSS (°Brix) of apple juice

d-Effect of UV-C and cold storage on the color of apple juice

The color of the juice is an important visual criterion which has received top attention in food industries and consumers. Color changes in fruit juices can serve as an indicator of microbiological and enzymatic qualities as well as bad processing (Flaguera *et al.* 2011a). Therefore, color characteristic of apple juice samples were measured to determine the effect of different UV treatments as well as cold storage time at 4°C up to 30 days on it. The results are summarized in Table (2). The L* value measures the lightness and ranges from 0 (black) to 100 (white). The a* value measures the redness and ranges

from $-a^*$ (greenness) to $+a^*$ (redness). Lastly, b^* measures the yellowness and ranges from $-b^*$ (blueness) to $+b^*$ (yellowness). Data revealed that the L^* values were inversely proportional to exposure time. Where L^* values recorded 30.07, 28.86, 26.87, 22.85 and 21.50 for samples treated for 0, 15, 30, 45 and 60 min., respectively. On the other hand, a^* values were directly proportional to UV exposure time, where, it recorded -2.43,

-1.13, 0.98 and 3.98, respectively, compared to -2.98 of the control. Similar to a^* values, b^* values showed the same trend where values significantly increased by increasing UV exposure time and the recorded data were 14.92, 17.84, 20.05 and 25.75 for samples treated for 15, 30, 45 and 60 min, respectively, compared to 13.59 of the control sample before storage.

Obtained results are similar to those reported by **Manzocco et al. (2009)**; **Falguera et al. (2013)** and **Müller et al. (2014)**, who confirmed the reduction in L^* values (lightness) of apple and grape juices and the increase in a^* and b^* values of the UV treated juices. Therefore, the apple and grape juices became darker, redder and more yellow. **Müller et al. (2014)** reported that both a^* and b^* values of untreated apple juice significantly increased from day 3 during the 18 days of storage and such changes were referred to the activity of PPO.

Regarding storage for 30 days at 4°C, data are summarized in **Table (2)**. In control and treated apple juice, an increase in 'L' value with significant differences ($p \leq 0.05$) was observed from zero time to 30 days. The color of the apple juice became lighter during storage for 30 days. Similar trend was also observed with a^* and b^* values during storage for 30 days at 4°C. For example, a^* and b^* values of fresh apple juice was -2.98 and 13.59 for control samples, while it was -1.03 and 22.35 after 30 days of storage, respectively. **Donahue et al. (2004)** reported a decrease in L^* values of apple cider and referred such results to the enzymatic and non-enzymatic browning.

Table (2): Effect of UV-C treatment and storage (30 day, 4°C) on color characteristics of apple juice.

▲CP	■Ex.time (min)	Storage (days)				
		0	5	10	15	30
L*	0	30.07 ^a ±0.01	34.05 ^c ±0.05	34.83 ^c ±0.06	35.46 ^a ±0.02	36.33 ^a ±0.04
	15	28.86 ^c ±0.04	28.42 ^b ±0.20	30.89 ^b ±0.08	31.15 ^a ±0.07	31.24 ^a ±0.03
	30	26.87 ^c ±0.30	27.83 ^b ±0.40	28.47 ^c ±0.40	28.77 ^c ±0.20	28.80 ^c ±0.10
	45	22.85 ^d ±0.10	22.51 ^d ±0.08	23.07 ^c ±0.20	23.70 ^b ±0.10	25.92 ^d ±0.01
	60	21.50 ^d ±0.01	21.85 ^d ±0.04	22.52 ^c ±0.10	23.86 ^b ±0.02	24.14 ^e ±0.03
a*	0	-2.98 ^d ±0.01	-1.45 ^c ±0.07	-1.16 ^b ±0.02	-1.12 ^b ±0.07	-1.03 ^e ±0.05
	15	-2.43 ^d ±0.06	1.90 ^c ±0.06	4.24 ^c ±0.05	5.05 ^b ±0.03	6.24 ^a ±0.02
	30	-1.13 ^c ±0.09	3.30 ^b ±0.06	5.31 ^b ±0.25	6.33 ^a ±0.03	6.60 ^c ±0.05
	45	0.98 ^b ±0.06	5.31 ^a ±0.06	6.03 ^b ±0.03	6.84 ^a ±0.13	7.61 ^a ±0.05
	60	3.98 ^a ±0.01	5.85 ^c ±0.05	6.00 ^b ±0.08	6.63 ^a ±0.09	8.87 ^a ±0.05
b*	0	13.59 ^d ±0.08	20.65 ^d ±0.05	20.71 ^c ±0.20	21.37 ^b ±0.30	22.35 ^c ±0.10
	15	14.92 ^d ±0.08	22.96 ^d ±0.10	24.48 ^b ±0.20	25.37 ^a ±0.09	26.34 ^b ±0.06
	30	17.84 ^d ±0.10	24.51 ^c ±0.10	24.49 ^b ±0.30	25.81 ^b ±0.10	27.38 ^a ±0.20
	45	20.05 ^b ±0.07	24.52 ^b ±0.10	24.37 ^a ±0.20	25.54 ^a ±0.10	27.72 ^a ±0.20
	60	25.75 ^a ±0.03	25.30 ^c ±0.10	25.30 ^b ±0.09	25.00 ^b ±0.40	27.57 ^a ±0.08

▲Color parameters and ■Exposure time.

Means followed by different superscripts (within coulms) and different subscripts (within rows) are significantly different at the (P≤0.05), L (lightness), a* (redness) and b* (yellowness).

e-Effect of UV-C and cold storage on ascorbic acid content of apple juice

Ascorbic acid was determined in apple juice samples immediately after UV-C treatment and during storage time for 30 days at 4±1°C and the results are presented in **Fig. (3)**. The obtained results indicated that ascorbic acid recorded 2.75 mg.100 ml⁻¹ in control (zero time). Meanwhile, it decreased by 81.8% after exposure to UV-C (254 nm) for 15 min. where, it recorded 0.5 mg.100 ml⁻¹. Also, it decreased to 0.25 mg.100 ml⁻¹ as a result of increasing the exposure time to 30 min, then it persisted at 45 and 60 min of exposure. These results are in harmony with those found by **Bradshaw et al. (2001)** and **Falguera et al. (2014)** who indicated a significant decrease in ascorbic acid content as a result of exposure to UV-C irradiation in pear juices.

A complete degradation of ascorbic acid was noted after 5 days of storage for samples treated for 30, 45 and 60 min., 10 days for samples treated for 15 min., while 15 days were needed for the control. This result is in harmony with that observed by **Feng et al. (2013)** who stated that no ascorbic acid remained in watermelon juice

by the end of storage period at 4°C. The degradation of ascorbic acid during storage has been attributed to atmospheric oxygen (**Odrizola-Serrano *et al.* 2008**). Also, various factors such as light exposure, hydrogen peroxides, storage temperature, type of processing packaging materials, and enzymes present such as ascorbate oxidase and peroxidase could affect the degradation of ascorbic acid (**Davey *et al.* 2000** and **Ayhan *et al.* 2001**).

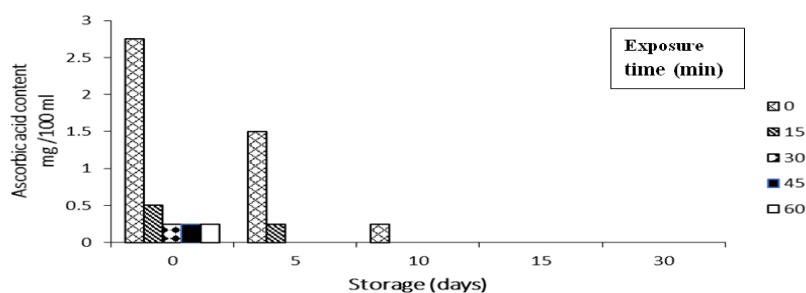


Fig (3): Effect of UV exposure time and storage at 4 °C for 30 days on ascorbic acid content of apple juice.

f-Effect of UV-C and cold storage on PPO activity of apple juice

Enzymatic browning causes color change in fruits and vegetables and such changes in color result from the action of polyphenol oxidase (PPO) on the phenolic compounds in fruits and vegetables in the presence of oxygen (**Manzocco *et al.* 2009**).

Table (3) indicates the effect of UV exposure time on the PPO activity in apple juice stored up to 30 days at 4°C. Results indicated a significant decrease ($p \leq 0.05$) in PPO activity by increasing exposure time. The activity was 54.67 (u.ml⁻¹) for the control sample then gradually decreased to be 12.67 (u.ml⁻¹) after 60 min. of exposure to UV light with 76.8% reduction of the total activity. However, the 45 min. treatment resulted in higher PPO activity than the 60 min, it is of interest to report that there was no significant difference between both of them and therefore, the 45 min. treatment was recommended. Accordingly, similar trend in the PPO activity reduction was noticed during storage for 30 days at 4 °C, but with a slower rate. On the other hand, almost constant values (with no significant differences, $p \leq 0.05$) were obtained in case of the 45 and 60 min UV-C treatments.

Enzymes deactivation was reported to occur generally due to photo-oxidation *via* two routes: direct absorption of radiation by protein or bound chromophore or *via* indirect oxidation by singlet oxygen (Davies and Truscott, 2001).

Barbosa-Cánovas and Guerrero-Beltrán (2006) and Falguera *et al.* (2011b) reported a reduction of PPO activity in different juices after treatment with UV at 25°C. Manzocco *et al.* (2009) ascertained the need for a longer treatment in case of juices than model system due to the low transmittance of UV-C light through the suspended and soluble solids in juice.

Table (3): Effect of UV-C treatment and storage (30 day, 4°C) on PPO activity (u.ml⁻¹) in apple juice.

Exposure time (min)	Storage (days)				
	0	5	10	15	30
0	*54.67 _a ^{A*}	28.33 _b ^A	15.33 _c ^A	17.33 _c ^A	13.33 _c ^A
15	44.67 _a ^B	16.67 _b ^B	13.33 _b ^A	16.67 _b ^{AB}	12.00 _b ^A
30	28.00 _a ^C	14.67 _b ^{BC}	13.67 _{bc} ^A	14.67 _b ^{AB}	13.05 _c ^A
45	15.67 _a ^D	12.67 _a ^{BC}	11.33 _a ^A	12.00 _a ^{BC}	12.00 _a ^A
60	12.67 _a ^D	9.67 _a ^C	10.67 _a ^A	8.67 _a ^C	10.00 _a ^A

*Means followed by different superscripts (within columns) and different subscripts (within rows) are significantly different at the (p≤0.05).

g-Effect of UV-C and cold storage on microbial quality of apple juice

UV-C radiation is routinely used in the food industry as non-thermal treatment for inhibiting microbial growth on surfaces, in air and in liquids. It is most effective at 254 nm since energy at that wavelength can induce formation of pyrimidine dimers that distort the DNA and block cell replication (Bintsis, 2000; Lado and Yousef 2002; Guerrero-Beltrán and Barbosa-Cánovas 2004).

The effect of both UV treatment and storage period (30 day at 4°C) on the total bacterial load in apple juice was indicated in **Table (4)**. A negative correlation between UV exposure time and the total bacterial count was noted. At zero time, slight decrease with no significant differences were noticed in bacterial count between the control, 15 and 30 min. samples and the reduction was from 2.48 to 2.39 and 2.22 log₁₀CFU, respectively. A significant reduction (31.7%)

in number was achieved upon using a treatment of 45 min. On the other hand, a 100% reduction was achieved when 60 min. exposure was used. The storage for 30 day at 4°C for the control resulted in significant increase in total bacterial count. No growth at all was noted in 60 min. treatment during the storage period. The highest increase was for the untreated sample and an increase of 0.92 log₁₀CFU was noted. The lowest increase was for the 45 min. treatment sample and an increase of 0.18 log₁₀CFU was achieved. In all cases, the bacterial growth was very well controlled since the maximum obtained bacterial count was 3.4 log₁₀CFU and such number is much lower than that listed as the onset of bacterial spoilage of 10⁶ CFU.ml⁻¹ (Mirrazavi, 2011). Such low number was expected since the pH values of the juice didn't exceed 4.3 and at such low pH most of the bacterial genera can't grow (Hatcher *et al.* 1992).

The Saudi Arabian Standards (3081 / 1434) for fresh juices limited the total bacterial number to (5x10³ CFU.ml⁻¹). Therefore, the tested juice, even after 30 days of storage at 4°C is bacteriologically accepted.

Table (4): Effect of UV-C treatment and storage (30 day, 4°C) on the total plate count (log₁₀CFU.ml⁻¹) of apple juice

Exposure time (min.)	Storage (days)				
	0	5	10	15	30
0	*2.48 _c ^A	2.91 _b ^A	2.99 _b ^A	3.25 _a ^A	3.40 _a ^A
15	2.39 _c ^A	2.75 _b ^A	2.90 _a ^A	2.95 _a ^B	3.00 _a ^B
30	2.22 _d ^{AB}	2.46 _c ^B	2.63 _b ^B	2.77 _{ab} ^C	2.85 _a ^B
45	1.79 _b ^B	1.74 _b ^C	1.82 _b ^C	1.92 _a ^D	1.97 _a ^C
60	0.00 _a ^C	0.00 _a ^D	0.00 _a ^D	0.00 _a ^E	0.00 _a ^D

*Means followed by different superscripts (within columns) and different subscripts (within rows) are significantly different at the (p≤0.05).

h-Effect of UV-C and cold storage on total yeasts and molds of apple juice:

The effect of UV on the total yeast and mold counts in apple juice was indicated in **Table (5)**. The increase in exposure time resulted in sharp decline in yeast and mold numbers where decreased from 2.61 (control) to 1.44 log₁₀ CFU.ml⁻¹ (60 min treatment) with the exception of the 15 and 30 min. treatments where no significant

differences were obtained. During storage, number of yeasts and molds persisted with almost no big differences. On the other hand, the untreated sample (control) was considered to be microbially spoiled since total yeast and mold numbers exceeded the onset of spoilage of 10^6 after 13 days of storage at 4°C. All tested UV treatments controlled the growth of yeast and mold successfully. The Saudi Arabian Standards (3081 / 1434) specified 100 cells.gm⁻¹ as the maximum acceptable number of yeasts and molds in juice. Obtained results indicated that the 60 min. treatment succeeded to lower yeasts and molds number to meet with the Saudi Arabian Standards limits even after storage for 30 days at 4°C (1.85 log₁₀ CFU. ml⁻¹).

It is of interest to report that in all cases the tested juices didn't exceed the microbial onset of spoilage of 10⁶ CFU.ml⁻¹ (**Mirrazavi 2011**).

Unlike the effect of UV on bacteria, the 60 min treatment didn't completely destroy yeasts and molds and a surviving value of 56.% was obtained at zero time. The main reason for yeast and mold to exhibit higher UV resistance than bacteria could be attributed to their lower content of pyrimidine nucleosides where lower chance for the formation of thymine dimers is expected. Additionally, the chemical composition and thickness of the cell wall of yeast and mold are different than bacteria, which render them to be UV resistant (**Miller et al. 1999**).

Keyser et al. (2008), Feng et al. (2013), Unluturk and Atilgan (2015) and Bhat (2016) reported the effectiveness of UV-C in deactivation of bacteria, yeasts and molds in different juices. Such inhibition was intensity dependent. **Chia et al. (2012)** reported an improvement of 7 weeks in the shelf life of pineapple juice treated with UV (53.4 J.cm⁻²) and stored at 4°C. **Kaya et al. (2015)** extended the microbial shelf life of lemon-melon juice blend (4°C) by 28 days utilizing UV-C treatment at 2.461 J.ml⁻¹. This treatment was successfully eliminated the entire microbial population present in the fresh form.

Table (5): Effect of UV-C treatment and storage (30 day, 4°C) on yeast and mold counts ($\log_{10}\text{CFU.ml}^{-1}$) in apple juice

Exposure time (min.)	Storage (days)				
	0	5	10	15	30
0	*2.61 _c ^A	4.02 _c ^A	5.45 _b ^A	6.32 _a ^A	7.54 _a ^A
15	2.54 _c ^A	2.59 _c ^B	2.61 _{bc} ^B	2.80 _{ab} ^B	2.85 _a ^B
30	2.46 _b ^A	2.49 _b ^B	2.58 _{ab} ^B	2.61 _{ab} ^B	2.71 _a ^C
45	1.91 _c ^B	2.06 _b ^C	2.17 _a ^C	2.18 _a ^C	2.17 _a ^D
60	1.44 _c ^C	1.65 _b ^D	1.72 _b ^D	1.77 _b ^D	1.85 _a ^E

*Means followed by different superscripts (within columns) and different subscripts (within rows) are significantly different ($p \leq 0.05$).

i-Effect of UV-C treatment on sensory evaluation of apple juice:

From the consumer point of view, fruit juice color, odor, taste and consistency are very significant for determining its marketability. The effect of UV exposure times (15, 30, 45 and 60 min) on the sensory attributes (color, odor, taste, consistency and overall acceptability) of apple juice compared to control is indicated in **Table (6)**. Results indicated that color scores didn't significantly ($p \leq 0.05$) changed, compared with control sample until 30 min of exposure followed by significant decrease thereafter. Similar trend was observed for data obtained for both odor and taste scores.

On the other hand, statistical analysis revealed no significant differences ($p \leq 0.05$) for consistency scores for all tested samples compared to control. Also, the highest overall acceptability scores were for the control and sample treated for 15 min. with no significant differences between them. The increase of exposure time up to 30 min. resulted in a significant decrease in overall acceptability.

Obtained results are in harmony with those reported by **Harrington and Hills (1968)**, who indicated that apple cider exposed to UV light for 120 sec. exhibited no significant differences in sensory criteria compared with fresh control apple cider. Also, our results are in the same line with those reported by **Donahue et al. (2004)** who used UV light (254.7 nm) as a low-cost alternative technique for pasteurizing of apple cider. They ascertained that treatment with UV irradiation didn't affect the sensory attributes of apple ciders compared to control one.

Our results are also in agreement with those reported by **Caminiti *et al.* (2012)** who treated apple juice with different UV energy dosages (5.31 to 53.10 J.cm⁻²). They indicated that samples exposed to 5.31 and 10.62 J.cm⁻² exhibited acceptability of color, odor, flavor and overall acceptability while at higher dosage (26.55 J.cm⁻²), odor was negatively affected, meanwhile the dosage of 53.1 J.cm⁻² was needed to decrease color scores.

Therefore, it could be concluded that UV treatment up to 30 min didn't affect the sensory attributes of apple juice.

Table (6): Effect of UV-C treatment on sensory attribute of apple juice

Exposure time (min.)	Sensory criteria				
	color	odor	taste	consistency	Overall acceptability
0	*8.10 ^a ±1.70	8.20 ^{ab} ±1.40	8.35 ^a ±1.50	8.30 ^a ±1.40	8.40 ^a ±1.70
15	8.10 ^a ±1.10	8.50 ^a ±0.85	8.40 ^a ±1.07	8.35 ^a ±1.40	8.50 ^a ±1.20
30	7.10 ^{ab} ±0.88	7.50 ^{ab} ±0.97	7.30 ^{ab} ±0.95	7.75 ^a ±1.20	7.40 ^{ab} ±1.07
45	5.80 ^b ±1.50	6.80 ^{bc} ±1.20	6.40 ^b ±1.50	7.00 ^a ±1.80	6.30 ^{bc} ±1.80
60	5.50 ^b ±1.60	6.00 ^c ±1.60	6.10 ^b ±1.80	6.70 ^a ±2.06	5.10 ^c ±1.85

*Means followed by different superscripts within each columns are significantly different (p≤0.05).

REFERENCES

- A.O.A.C (2005).** Official Methods of Analysis of Association of Official Analytical Chemists.18th ed. Gaithersburg, Maryland 20877-2417, USA.
- Ashurst, P. R. (2005).** Chemistry and Technology of Soft Drinks and Fruit Juices. p. 1-14. (Ed). Blackwell Publishing Ltd. UK.
- Ayhan, Z.; H.W. Yeom; Q. H. Zhang, and D. B. Min (2001).** Flavor, color, and vitamin C retention of pulsed electric field processed orange juice in different packaging materials. Journal of Agriculture Food Chemistry, 49:669–674.
- Barbosa-Cánovas, J. A. and G. V. Guerrero-Beltrán (2006).** Inactivation of *Saccharomyces cerevisiae* and polyphenol oxidase in mango nectar treated with UV light. Journal of Food Protection, 69: 362–368.

- Bhat, R (2016).** Impact of ultraviolet radiation treatments on the quality of freshly prepared tomato (*Solanum lycopersicum*) juice. Food Chemistry, 213: 635–640.
- Bhat, R.; S. Ameran; C. V. Han; A. A. Karim and M. T. Liong (2011).** Quality attributes of starfruit (*Averrhoa carambola* L.) juice treated with ultraviolet radiation. Food Chemistry, 127:641–644.
- Bhat, R. and R. Stamminger (2015).** Impact of Ultraviolet radiation treatments on the physicochemical properties, antioxidants, enzyme activity and microbial load in freshly prepared hand pressed strawberry juice. Food Science and Technology International, 21: 354–363.
- Bintsis, T.; E. Litopoulou-Tzanetaki and R. Robinson (2000).** Existing and potential applications of ultraviolet light in the food industry—A critical review. Journal of the Science of Food and Agriculture, 80: 637–645.
- Bradshaw, M. P.; P. D. Prenzler and G. R. Scollary (2001).** Ascorbic acid-induced browning of (+)-catechin in a model wine system. Journal of Agriculture Food Chemistry, 49: 934–939.
- Caminiti, I.; I. Palgan; A. Muñoz; F. Noci; P. Whyte; D. Morgan; D. Cronin and J. Lyng (2012).** The effect of ultraviolet light on microbial inactivation and quality attributes of apple juice. Food Bioprocess Technology, 5: 680–686.
- Chia, S. L.; S. Rosnah; M. A. Noranizan and W. D. Wan Ramli (2012).** The effect of storage on the quality attributes of ultraviolet-irradiated and thermally pasteurised pineapple juices. International Food Research Journal, 19(3): 1001–1010.
- Chisari, M.; R. N. Barbagallo; G. Spagna and F. Artés (2011).** Improving the quality of fresh-cut melon through inactivation of degradative oxidase and pectinase enzymatic activities by UV-C treatment. International Journal of Food Science and Technology, 46(3): 463–468.
- Cortes, C.; M. J. Esteve and A. Frigola (2008).** Color of orange juice treated by high intensity pulsed electric fields during refrigerated storage and comparison with pasteurized juice. Food Control, 19: 151-158.

- Davey, M.W.; M. V. Montagu; D. Inze; M. Sanmartin; A. Kanellis; N. Smimoff; L. J. J. Benzie; J. J. Strain; D. Favell and J. Fletcher (2000).** Plant L-ascorbic: chemistry, function, metabolism, bioavailability and effects of processing. *Journal of the Science of Food and Agriculture*, 80 (7):825–860.
- Davies, M. J and R. J. W. Truscott (2001).** Photo-oxidation of proteins and its role in cataractogenesis. *Journal of Photochemistry and Photobiology B: Biology*, 63:114–125.
- Del Caro, A.; A. Piga; V. Vacca and M. Agabbio (2004).** Changes of flavonoids, vitamin C and antioxidant capacity in minimally processed citrus segments and juices during storage. *Food Chemistry*, 84: 99-105.
- Diffey, B. L. (2002).** Sources and measurement of ultraviolet radiation. *Methods*, 28:4–13.
- Donahue, D. W.; Nazife Canitez and A. A. Bushway (2004).** UV inactivation of *E. coli* O157:H7 in apple cider : quality, sensory and shelf-life analysis. *Journal of Food Processing and Preservation*, 28: 368–387.
- Falguera, V.; J. Pagan; S. Garza; A. Garvín and A. Ibarz (2011a).** Ultraviolet processing of liquid food: a review. Part 1: Fundamental engineering aspects. *Food Research International*, 44(6): 1580-1588.
- Falguera, V.; J. Pagan and A. Ibarz (2011b).** Effect of UV irradiation on enzymatic activities and physicochemical properties of apple juices from different varieties. *LWT - Food Science and Technology*, 44: 115-119.
- Falguera, V.; J. Pagan; S. Garza; A. Garvín and A. Ibarz (2012).** Inactivation of polyphenol oxidase by ultraviolet irradiation: Protective effect of melanins. *Journal of Food Engineering*, 110: 305–309.
- Falguera, V.; S. Garza; J. Pagan; A. Garvín and A. Ibarz (2013).** Effect of UV Vis irradiation on enzymatic activities and physicochemical properties of four grape musts from different varieties. *Food Bioprocess Technology*, 6: 2223-2229.
- Falguera, V.; A. Garvín; A. Garza; J. Pagán and A. Ibarz (2014).** Effect of UV-Vis photochemical processing on pear juices from six different varieties. *Food Bioprocess Technologies.*, 7: 84-92.

- Feng, M.; K. Ghafoor; B. K. S. Yang and J. Park (2013).** Effects of ultraviolet-C treatment in Teflon -coil on microbial populations and physico-chemical characteristics of watermelon juice. *Innovative Food Science and Emerging Technologies*, 19:133–139.
- Franz, C. M. A. P.; I. Specht; G. S. Cho; V. Graef and M. R. Stahl (2009).** UV-C-inactivation of microorganisms in naturally cloudy apple juice using novel inactivation equipment based on Dean Vortex technology. *Food Control*, 20(12): 1103–1107.
- Forney, L. J.; J. A. Pierson and Z. Ye (2004).** Juice irradiation with Taylor–Couette Flow: UV inactivation of *Escherichia coli*. *Journal of Food Protection*, 67(11): 2410–2415.
- Fredericks, I. N.; T. M. du and M. Krügel (2011).** Efficacy of ultraviolet radiation as an alternative technology to inactivate microorganisms in grape juices and wines. *Food Microbiology*, 28(3): 510–517.
- Guerrero-Beltrán, J. A. and G. V. Barbosa-Cánovas (2004).** Review: Advantages and limitations on processing foods by UV light. *Food Science and Technology International*, 10: 137–148.
- Gayán, E.; M. J. Serrano; S. Monfort; I. Alvarez and S. Condon (2013).** Pasteurization of apple juice contaminated with *Escherichia coli* by a combined UV-mild temperature treatment. *Food Bioprocess Technology*, 6: 3006-3016.
- Hatcher, Jr. W. S.; J. L. Weihe; D. F. Splittstoesser; E. C. Hill and M. E. Parish (1992).** Fruit beverage. P. 953-960. In: Vanderzant, C. and D. F. Splittstoesser (Eds). *Compendium of Methods for the Microbiological Examination of Foods*, 3rd ed. American Public Health Association. Washington, D.C. USA.
- Harrington, W.O. and C.H. Hills (1986).** Reduction of the microbial population of apple cider by ultraviolet irradiation. *Food Technology*, 22: 117–120.
- Jiang, Y.; X. Duan; D. Joyce; Z. Zhang and J. Li (2004).** Advances in understanding of enzymatic browning in harvested litchi fruit. *Food Chemistry*, 88: 443–446.
- Kaya, Z. and S. Ünlütürk (2015).** Processing of clear and turbid grape juice by a continuous flow UV-C system. *Innovative Food Science and Emerging Technologies*, 33: 282–288.

- Kaya, Z.; S. Yildiz and S. Ünlütürk (2015).** Effect of UV-C irradiation and heat treatment on the shelf life stability of a lemon-melon juice blend: Multivariate statistical approach. *Innovative Food Science and Emerging Technologies*, 29: 230–239.
- Keyser, M.; I. A. Muller; F. P. Cilliers; W. Nel and P. A. Gouws (2008).** Ultraviolet radiation as a non-thermal treatment for the inactivation of microorganisms in fruit juice. *Innovative Food Science and Emerging Technologies*, 9(3): 348–354.
- Koutchma, T.; S. Keller; S. Chirtel and B. Parisi (2009).** Ultraviolet disinfection of juice products in laminar and turbulent flow reactors. *Innovative Food Science and Emerging Technologies*, 5 (2): 179–189.
- Lado, B.; and A. Yousef (2002).** Alternative food-preservation technologies: efficacy and mechanisms. *Microbes and Infection*, 4: 433–440.
- Liao, H.; L. Jianga; Y. Chenga; X. Liaob and R. Zhanga (2018).** Application of nisin-assisted thermosonication processing for preservation and quality retention of fresh apple juice. *Ultrasonics - Sonochemistry*, 42: 244–249.
- Lu, G.; C. Li; P. Liu; H. Cui; Y. Xia and J. Wang (2010).** Inactivation of microorganisms in apple juice using an ultraviolet silica-fiber optical device. *Journal of Photochemistry and Photobiology B: Biology*, 100: 167–172.
- Manzocco, L.; B. Quarta and A. Dri (2009).** Polyphenol oxidase inactivation by light exposure in model systems and apple derivatives. *Innovative Food Science and Emerging Technologies*, 10(4): 506–511.
- Mertens, B. and D. Knorr (1992).** Developments of non thermal processes for food preservation. *Food Technology*, 46(5), 124–133.
- Miller, R.; W. Jeffrey; D. Mitchell and M. Elasri (1999).** Bacterial responses to ultraviolet light. *ASM News-American Society for Microbiology*, 65: 535–541.
- Müller, A.; L. Noack; R. Greiner; M. R. Stahl and C. Posten (2014).** Effect of UV-C and UV-B treatment on polyphenol oxidase activity and shelf life of apple and grape juices. *Innovative Food Science and Emerging Technologies*, 26: 498–504.
- Mirrazavi, F. (2011).** New science and technology achievements. *European Journal of Operational Research*, 137(1):1–9.

- Noci, F.; J. Riener; M. Walkling-Ribeiro; D. A. Cronin; D. J. Morgan and J. G. Lyng (2008).** Ultraviolet irradiation and pulsed electric fields (PEF) in a hurdle strategy for the preservation of fresh apple juice. *Journal of Food Engineering*, 85: 141–146.
- Odriozola-Serrano I.; I. Aguiló-Aguayo; R. Soliva-Fortuny; V. Gimeno-Anó and O. Martín-Belloso (2008).** Lycopene, vitamin C, antioxidant capacity of tomato juice as affected by high-intensity pulsed electric fields critical parameters. *Journal of Agriculture Food Chemistry*, 55 (22):9036–9042.
- Ozoglu. H. and A. Bayndrl (2002).** Inhibition of enzymic browning in cloudy apple juice with selected antibrowning agents. *Food Control*, 13: 213–221.
- Pala, Ç. U. and A. K. Toklucu (2011).** Effect of UV-C light on anthocyanin content and other quality parameters of pomegranate juice. *Journal of Food Composition and Analysis*, 24(6):790–795.
- Plaza, L.; C. Sanchez-Moreno; P. Elez-Martinez; B. Ancos; O. Martin-Belloso and M. P. Cano (2006).** Effect of refrigerated storage on vitamin C and antioxidant activity of orange juice processed by high-pressure or pulsed electric fields with regard to low pasteurization. *European Food Research and Technology*, 223: 487–493.
- Ranganna, S. (1986).** *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. 2nd ed. New Delhi: Mc Graw Hill, 9-80.
- Sanchez-Moreno, C.; L. Plaza; B. D. Ancos and M. P. Cano (2006).** Nutritional characterization of commercial traditional pasteurized tomato juices: Carotenoids, vitamin C and radical scavenging capacity. *Food Chemistry*, 98: 749-756.
- Sanchez-Vega, R.; H. Mujica-Paz; R. Marquez-Melendez; M. O. Ngadi and E. Ortega-Rivas (2009).** Enzyme inactivation on apple juice treated by ultrapasteurization and pulsed electric fields technology, *Journal of Food Processing and Preservation*, 33(4): 486-499.
- Shamsudin, R.; M. N. Adzahan; P. Y. Yap and A. Mansor (2014).** Effect of repetitive ultraviolet irradiation on the physico-chemical properties and microbial stability of pineapple juice. *Innovative Food Science and Emerging Technologies*, 23: 114–120.

- Silva, F. A. and C. A. Azevedo (2009).** Principal Components Analysis in the Software Assistat-Statistical Attendance. In: 7th World Congress on Computers in Agriculture, 22-24 June, Reno, Nevada, USA; American Society of Agricultural and Biological Engineers.
- Tahiri, I.; J. Makhlouf; P. Paquin and I. Fliss (2006).** Inactivation of food spoilage bacteria and *Escherichia coli* O157:H7 in phosphate buffer and orange juice using dynamic high pressure. Food Research International, 39(1): 98–105.
- Tomás-Barberán, F. A. and J. C. Espín (2001).** Phenolic compounds and related enzymes as determinants of quality in fruits and vegetables. Journal of the Science of Food and Agriculture, 81(9): 853–876.
- Tournas, V. H.; J. Heeres and L. Burgess (2006).** Moulds and yeasts in fruit salads and fruit juices. Food Microbiology, 23(7): 684–688.
- Tung-Sung, C.; M. Siddiq; N. Sinha and J. Cash (1995).** Commercial pectinase and the yield and quality of Stanley plum juice. Journal of Food Processing Preservation, 19: 89–101.
- Unluturk, S. and M. R. Atilgan (2015).** Microbial safety and shelf life of UV-C treated squeezed white grape juice. Journal of Food Science, 80: 1831–1841
- Unluturk, S. K.; H. Arastoopour and T. Koutchma (2004).** Modeling of UV dose distribution in a thin-film UV reactor for processing of apple cider. Journal of Food Processing, 65(1): 125–136.
- Vasavada, P.C. (2003).** Microbiology of fruit juice and beverages. p. 95-123. In: Foster, T. and P. C. Vasavada (Eds). Beverage Quality and Safety, CRC Press. USA.

تأثير الأشعة فوق البنفسجية قصيرة الموجة والتخزين تحت تبريد علي جودة عصير التفاح

وائل أحمد بازرعه¹ - شاهيناز أحمد حلمي¹ - هشام أمين عيسى²

– رمضان محمد عبد الحافظ²

¹ قسم علوم الأغذية – كلية الزراعة – جامعة القاهرة – الجيزة – مصر

² قسم الصناعات الغذائية – المركز القومي للبحوث – القاهرة – مصر

تم دراسة تأثير الأشعة فوق البنفسجية (UV-C) علي الخصائص الفيزيوكيميائية (pH ، الحموضة ، المواد الصلبة الذائبة ، اللون ، محتوى حمض الأسكوربيك) وكذلك نشاط البولي فينول أوكسيداز (PPO) بالإضافة إلي العد الميكروبي في عصير التفاح مقارنة بالعصير الطازج. تم تشيع عينات العصير باستخدام الأشعة فوق البنفسجية (254 نانومتر) لأزمنة مختلفه (15، 30، 45، 60 دقيقة) ، وتم تخزين العينات علي $4 \pm 1^\circ \text{C}$ لمدة 30 يوما. لم تؤثر المعاملة بالأشعة فوق البنفسجية بشكل كبير علي قيم pH ، الحموضة ، المواد الصلبة الذائبة في كل من العينات الطازجة والمخزنة. لوحظ وجود علاقة عكسية بين زمن التعرض وقيم L^* (درجة السطوع) للعينات الطازجة والمخزنة. على العكس من ذلك ، لوحظ وجود علاقة طردية بين زمن التعرض مع قيم a^* وقيم b^* . انخفض محتوى حمض الأسكوربيك بزيادة زمن التعرض حيث فقد بالكامل بعد 5 أيام للعينات المعاملة بالأشعة فوق البنفسجية لمدة 30 ، 45 ، 60 دقيقة و بعد 10 أيام للعينات المعاملة لمدة 15 دقيقة و 15 يوماً للينة الطازجة. تم تثبيط نشاط إنزيم PPO جزئياً عن طريق المعاملة بالأشعة فوق البنفسجية (حيث تم فقد 76.8% من نشاطه بعد 60 دقيقة من التعرض للمعاملة) وكذلك أثناء التخزين (ولكن بمعدل أبطأ). تأثر عد البكتيريا الكليه وكذلك أعداد الخمائر والفطريات سلبا عن طريق زيادة زمن التعرض للأشعة فوق البنفسجية. وكان من الملاحظ أن الخمائر والفطريات كانت أكثر مقاومة للأشعة فوق البنفسجية من البكتيريا. كما لم تتغير الخصائص الحسية (الرائحة ، اللون ، الطعم ، التجانس ، القبول العام) نتيجة المعاملة بالأشعة فوق البنفسجية لمدة تصل إلى 30 دقيقة، ثم انخفضت بعد ذلك بشكل معنوي.

الكلمات الدالة: الأشعة فوق البنفسجية ، عصير التفاح ، البولي فينول أوكسيداز ، الخصائص الحسية ، التخزين تحت تبريد.