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Assessing the Impact of Non-Thermal and Thermal Treatment on The Shelf-Life of Onion Juice

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Abstract

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Onion (*Allium cepa* L.) juice is a marinating agent for meat and fish marination and readily usable sauce for any meal that has onion in its formulation. This study aims to assess the microbiological and physicochemical changes in the onion juice processed by UV-C irradiation (0.5 mm sample depth, 30 min exposure time, 7.5 mW/cm^2 UV incident intensity) and conventional heat treatment (74.5°C, 12 min) during its storage. Microbiological results showed processing by UV-C irradiation or heat treatment under optimum conditions extended the microbial shelf-life of untreated onion juice by minimum 6-times. Total colour change of heat-treated samples was lower than that of untreated and UV-C treated samples for 12 weeks. Also, pH, total titratable acidity, total soluble solids content, turbidity, NEBI and total phenolic content were monitored for 12 weeks. The results of this study will form scientific infrastructure for onion juice manufacturers to decide on the processing method with respect to its shelf-life.

Keywords: heat treatment; marination; food quality; UV-C irradiation

Onion (*Allium cepa*) ranks third in the world production among seven major vegetables (onion, garlic, cauliflower, green pea, cucurbit, tomato and green bean) (Mitra *et al.* 2012). It is one of the most consumed vegetables both in European (especially in England, Holland and Spain) and Asian (China, India and Japan) countries (Li *et al.* 2016) with the Asian production share of 62.9% (FAOSTAT 2017). Twenty percent of the produced onion was discarded as waste in European countries mainly in the UK, Holland, Italy and Spain (Gonzales-Saiz *et al.* 2008). In recent years, thanks to its underlined positive health effects and popularity in ethnic cuisines, the consumption of onion has been increased by 25% worldwide. Onion juice is one of the products that can add value to these surplus onions which has use as; marinating agent for fish and meat marination, flavouring sauce and component of some blended vegetable juices after the assurance of food safety during its storage.

Low-acid (pH > 4.6) vegetable juices, such as onion juice (pH 5–5.5) require high-temperature (above 100°C) sterilization to prevent the product from spoilage. On the other hand, to reduce the negative effect of high temperature on the sensorial and nutritional quality of vegetable juices, acidification (pH < 4.6) of juice by an organic acid is commonly preferred that enables use of pasteurization (below 100°C) norms (Wu & Chen 2011). Therefore, in this study, onion juice was acidified (pH < 4.6) using citric acid to allow

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pasteurization as previously applied to carrot juice (Ferrario *et al.* 2017). However, studies showed that even pasteurization at mild temperatures may cause problems such as discoloration, off-flavour or off-taste formation or loss of vitamin in juices (Tran & Farid 2004). At this point, non-thermal processing of juices emerged as alternative processing methods. Among these methods, UV-C irradiation, which has germicidal effect on microbial populations, gained the attention as a pasteurization process for onion juice due to its previously reported minimal negative impact toward quality of products (Shah *et al.* 2016). UV-C (200–280 nm) light being a part of UV band (100–400 nm) is absorbed by genetic material of the cell resulting in mutagenic and cytotoxic lesions in DNA. However, depending on the UV processing dose and specific nutrients, UV light was reported to have varying effect on nutritional, enzymatic and physicochemical properties of juice which should not be overlooked (Turtoi & Borda 2013).

The objective of this study was to assess the effect of conventional heat treatment and UV-C irradiation on the microbiological and physicochemical quality of onion juice during its storage.

MATERIAL AND METHODS

Preparation of onion juice. Mature, yellow and undamaged onions (*Allium cepa* L.) with approximately 10 cm body diameter were purchased from wholesale market hall of Osmaniye (Turkey). After hand peeling, onions were washed with tap water and dried by paper towel. Onion juice was extracted by a home-type juice extractor (Braun J700) and centrifuged (Hettich Universal 320 R) at + 4°C and 3000 rpm for 15 min and supernatant was acidified using 10% (w/v) citric acid (ACS grade, Merck) until it reaches pH ~ 4.3.

Microbial analyses. Total aerobic mesophilic count (TAMC) and total yeast and mould count (TYMC) was determined according to Herceg *et al.* (2012) and Tran and Farid (2004), respectively.

UV-C irradiation and conventional heat treatment. Apparatus is equipped with two pairs of 20 W low mercury UV lamps (Mineralight, UVP XX-20) at 254 nm wavelength and orbital platform shaker (IKA KS 260) placed on a sliding flat platform to adjust distance of the sample to the light source. Samples in Petri dishes covered with a cylindrical black tube were placed under UV light source and shaken at 50 rpm. A radiometer (UVP Inc. UVX) with UVX-25 sensor was used by placing at a similar distance as the onion juice samples. The apparatus was disinfected using 70% (v/v) ethanol solution and UV lamps were opened at least 30 min before treatment. The depth of the sample was calculated from the ratio of the sample volume and the surface area of a Petri dish. Onion juice samples with 0.5 mm sample depth were UV-C treated for 30 min at 7.5 mW/cm^2 UV incident intensity (preoptimized conditions).

Heat treatment was performed by placing capped test tubes filled with 9.8 ml onion juice into water bath at 74.5°C for 12 min (preoptimized conditions). A K-type thermocouple replaced in one of the test tubes was used to monitor cold spot temperature. Following the heat treatment, tubes were cooled to room temperature by immediately immersing into ice-bath.

Physicochemical analyses. Density (g/cm^3) of the onion juice samples were measured by a digital density meter (Kyoto DA650) at 20°C. Turbidity was measured by turbidimeter (HACH 2100N). Samples were filled into quartz glass containers and immediately inserted into the instrument after turning upside down for 3-times. Results were given as nephelometric turbidity unit (NTU). CIE L^* (lightness), a^* (redness) and b^* (yellowness) colour parameters were determined in triplicate using a chromometer (Konica Minolta CR 400 Chromometer). Total colour change (ΔE) values of the samples were calculated by Equation 1 and untreated onion juice was taken as the reference.

Total titratable acidity (expressed in % anhydrous citric acid (ACA)), total soluble solids content (°Brix) and pH of the samples were determined and calculated according to Delgado-Adamez *et al.* (2013). The non-enzymatic browning index (NEBI) was determined by adding 5 ml of ethyl alcohol to 5 ml of sample, centrifuging for 20 min at 800 *g* and the absorbance of the supernatant was read at 420 nm in a spectrophotometer. Total phenolic content of the onion juice samples was analysed according to Vázquez-Gutiérrez *et al.* (2014) using Folin-Ciocalteau colorimetric assay.

Storage. Untreated (freshly prepared), UV-C treated or heat-treated onion juice samples were stored at room temperature for 12 weeks after being processed. UV-C treatment (0.5 mm sample depth, 30 min irradiation, 7.5 mW/cm^2 UV incident intensity) and heat treatment (74.5°C, 12 min) were applied

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under the determined optimum conditions. Then 125 ml of untreated or treated samples were aseptically bottled into amber bottles. Randomly selected 3 bottles for each kind were opened at 2 weeks interval for microbiological and physicochemical analysis.

RESULTS AND DISCUSSION

Microbiological changes. Untreated, UV-C treated (0.5 mm sample depth, 30 min exposure time, 7.5 mW/cm^2 UV incident intensity) and heat-treated (74.5°C, 12 min) onion juice samples were aseptically collected in amber bottles and monitored for 12 weeks under room conditions (22 ± 2°C). Figure 1 shows the effect of storage time on total aerobic mesophilic count (TAMC) and total yeast and mould count (TYMC) of untreated, UV-C and heat-treated onion juice. The initial microbial load of onion juice was determined as 1.65 ± 0.05 log CFU/ml TAMC and 0 log CFU/ml TYMC. However, by the end of 2nd week, TAMC and TYMC reached the levels of 5.14 ± 0.60 log CFU/ml and 5.33 ± 0.38 log CFU ml, respectively (Figure 1). This result indicated that the shelf life of fresh onion juice was only 2 weeks with respect to microbial load. Similarly, Unluturk and Atilgan (2015) also reported that lactic acid bacteria, yeast and total aerobic count of untreated fresh white grape juice reached to 4 log CFU/ml at the end of 2nd week (14th day). On the other hand, TAMC and TYMC levels were zero for UV-C or heat-treated onion juice samples throughout the storage period (Figure 1). These results also pointed out that UV-C or heat treatment under the studied processing conditions improved the microbial shelf-life of the untreated onion juice by minimum 6-times.

Physicochemical changes. Along with the microbial quality, physicochemical properties of untreated, UV-C treated, and heat-treated onion juice samples were also monitored for 12 weeks. According to Figure 2A, total colour change (ΔE) of UV-C treated onion juice increased dramatically on the 2nd week and varied between 9.5 and 11.6 throughout the 12-weeks of storage period. Total colour changes of untreated onion juice increased gradually until the 6th week and changed in the range of 11.9 to 13.1 between the 6th and 12th weeks of the storage. These results indicated the colour of both untreated and UV-C treated samples changed noticeably after the 2nd week which were classified as 'great change' (Cserhalmi *et al*. 2006). However,

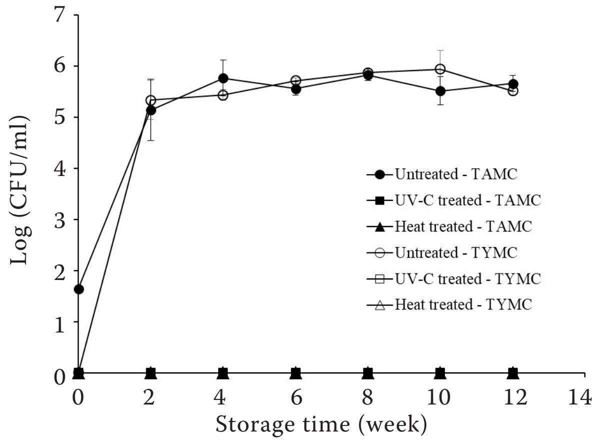

Figure 1. Effect of UV-C and heat treatment on total aerobic mesophilic count (TAMC) and total yeast and mold count (TYMC) of onion juice during storage (error bars are standard deviation of the mean of three experiments; where error bars are not displayed, they are smaller than the graph symbol)

ΔE values of heat-treated samples were generally lower than that of untreated and UV-C treated samples for 12 weeks and ranged between 5.5 and 9.0.

At the beginning of storage, the comparison of total colour changes between UV-C or thermal treatment showed that thermal treatment lead to relatively low total colour change. Lee & Parkin (1998) have explained this by the formation of pink pigments in the disrupted *Allium* tissues. In the first step, endogenous alliin alkyl sulfenate-lyase (E.C. 4.4.1.4, cysteine sulfoxide lyase or CS-lyase) enzyme is acting on isoalliin and other alk(en)yl-*L*-cysteine sulfoxide(s) (ACSO) that causes the formation of ether-soluble organosulfur components (thiosulfinates). Isoalliin is the major free amino acid found in onion (Kubec *et al.* 2004). These enzymatic reactions were followed by the non-enzymatic reactions between various amino acids and carbonyl compounds and the formed thiosulfinates, yielding green to red coloured pigments. The pH range of the pigment formation reactions was given as pH 2.2–5.5 by Lee and Parkin (1998) which matches with the pH (4.3) of the acidified onion juice in the current study. It was also reported that the enzymes taking place in this discoloration process in the disrupted onion tissues such as alliin alkyl sulfenate-lyase and the thiosulfinates are thermally sensitive (Lee & Parkin 1998). Consequently, it is thought that the thermal

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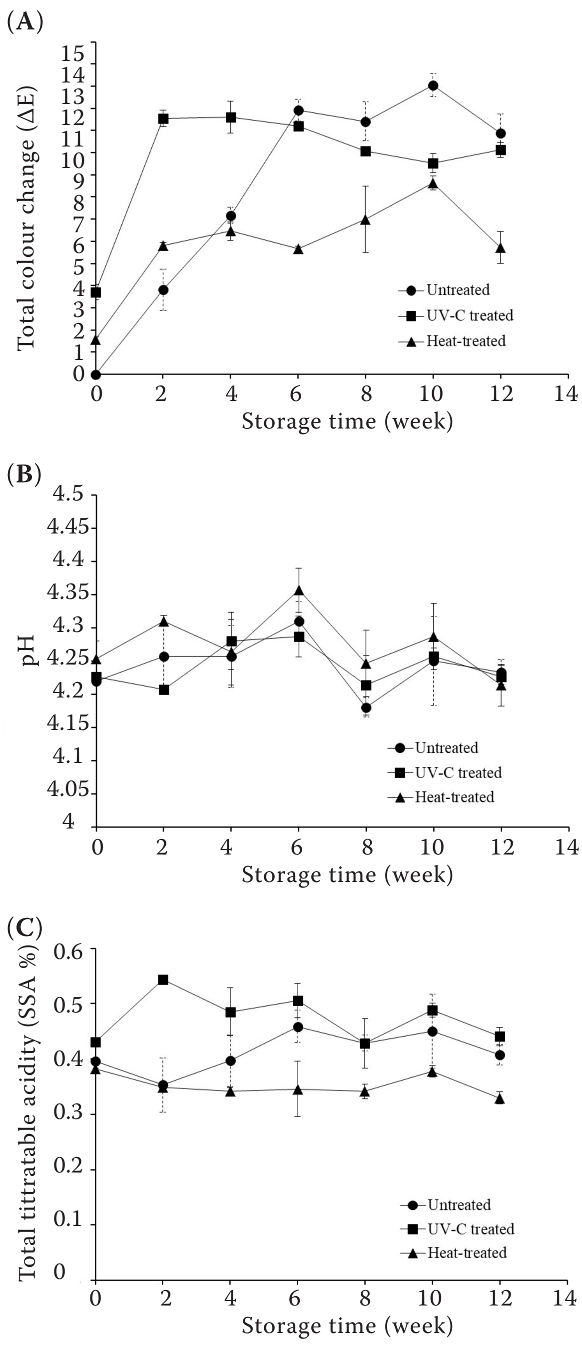

Figure 2. Changes in (**A**) total colour change; (**B**) pH; (**C**) total titratable acidity in untreated, UV-C treated and heat-treated onion juice during storage (error bars are standard deviation of the mean of three experiments, where error bars are not displayed, they are smaller than the graph symbol)

treatment of onion juice may have denatured the enzymes taking role in the discoloration process and reduced the formation of pink colour resulting in the relatively low ΔE values in the thermally treated onion juice samples. Therefore, the total colour change of thermally treated onion juice samples was lower than the UV-C treated ones during the storage period.

Figure 2B showed that pH values of all investigated samples were generally in the range between 4.1 and 4.3 with a slight reduction on the 8th week. Similarly, total titratable acidity of these samples did not show variability for 12 weeks and ranged between 0.3–0.54% ACA (Figure 2C).

Initial total soluble solids content (°Brix) of untreated onion juice was 6.63 ± 0.05 °Brix, whereas a gradual decrease for 12 weeks ended with a significantly low value i.e. 2.07 ± 0.12 °Brix. The reduction in total soluble solids content was proposed to be because of microbial activity and fermentation of sugar content of fruit juices (Rosen & Gothard 2010; Chia *et al.* 2012). It was reported that 100 g of a large onion contains 11 g carbohydrate (Mitra *et al.* 2012). Additionally, carbohydrate content (total wet base) of onion consist of 2% glucose, 0.9% fructose and 3.2% saccharose (Breu 1996). Therefore, in line with the increment of microbial load (Figure 1), fermentation of the above mentioned nutritional elements is thought to reduce the total soluble solids content of untreated onion juice significantly. On the other hand, total soluble solids contents of UV-C treated, and heat-treated onion juice samples was not reduced for 12 weeks (Figure 3A), which is thought to be a result of no microbial activity (Figure 1). Parallel to this finding, turbidity of the untreated samples was also ascended (Figure 3B) due the increase in number of bacteria, yeast and mould (Figure 1). Turbidity of UV-C treated, and heat-treated onion juice did not change significantly throughout the 12-week storage period.

Non-enzymatic browning, i.e. Maillard reactions, causing a change in colour due to browning of fruit or vegetable juice (Chia *et al.* 2012). Non-enzymatic browning index (NEBI) of untreated onion juice samples were lower than that of UV-C treated ones until the 8th week of storage period (Figure 3C) and continued in parallel to other samples until the end of storage period. NEBI values of heat-treated onion juice samples which had the lowest values among the investigated ones, did not show any significant change for 12 weeks and ended with a slight decline (Figure 3C). This is somewhat contrary to expectations from literature where the heat treatment was reported to accelerate Maillard reactions leading to non-enzymatic browning of juices (Bharate & Bharate 2012). The NEBI values obtained for

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untreated, UV-C treated and heat-treated onion juices were relatively higher than that of Chokanan mango juice reported by Santhirasegaram *et al.* (2015). NEBI values of Chokanan mango juice were 0.06 ± 0.00, 0.07 ± 0.01, and 0.13 ± 0.01 for control, UV treated (30 min) and heat-treated juice, respectively. Studies on fruit juices have shown that UV treatment may cause non-enzymatic browning on the juice as a result of photodegradation (Ibarz *et al.* 2005; Santhirasegaram *et al.* 2015).

According to Figure 3D, total phenolic content of UV-C treated and heat-treated onion juice samples in the 6th week and untreated samples in the 8th week increased dramatically. Also, a sharp decrement in the 10th week was observed for all types of onion juice samples. In the similar studies on fruit juices, increase in total phenolic content was referred to be a result of microbial activity, however in the current study there was no microbial activity in UV-C treated and heat-treated onion juice samples (Figure 1). Increase in TPC of fruit juices during storage was also attributed to the reactions between oxidized polyphenols and formation of new compounds of antioxidant character (Castro-López *et al.* 2016). In addition, the dramatic changes in TPC (Figure 3D) were thought to be arisen from the changes in pH of these samples (Figure 2B). It was also foreseen that, phenolic compounds in the onion juice having different solubility at different pH values might have cause variation in the total phenolic content of the samples during the storage period. The fluctuation of TPC during the storage (Figure 3D) was similarly reported in many studies (Klimczak *et al.* 2007; Chia *et al.* 2012). In summary, the increment on total phenolic compound at the 6th and 8th weeks were followed by a reduction until the end of storage period and ended with an approximate level of 210 mg/ml (eqv. GA).

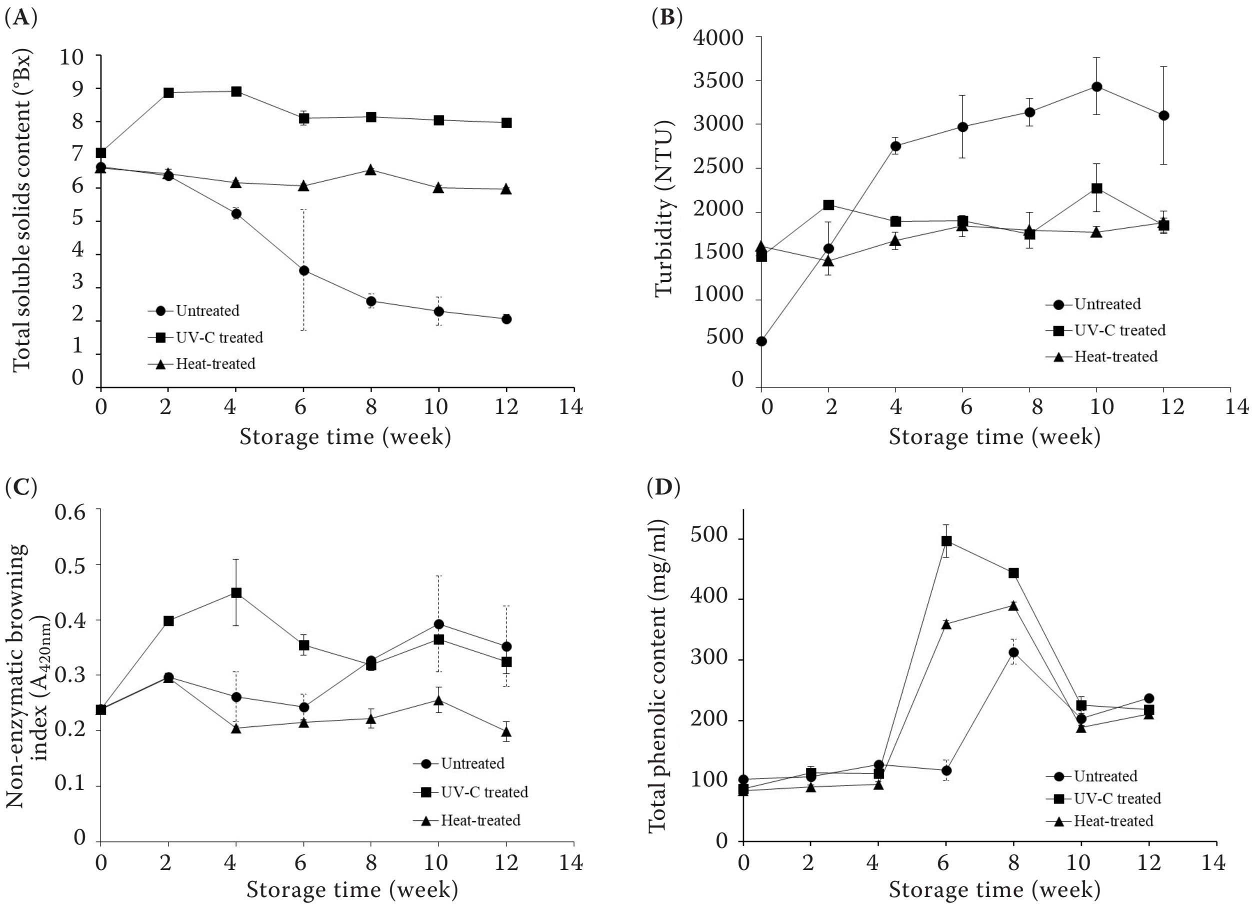

Figure 3. Changes in (**A**) total soluble solids content; (**B**) turbidity; (**C**) non-enzymatic browning index and (**D**) total phenolic content in untreated, UV-C treated and heat-treated onion juice during storage (error bars are standard deviation of the mean of three experiments; where error bars are not displayed, they are smaller than the graph symbol).

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CONCLUSIONS

In this study, onion juice processed by UV-C and heat treatment was assessed by investigating the microbiological and physicochemical changes during its storage. Microbial shelf-life of untreated onion juice at room temperature was extended by minimum 6-times by both using UV-C and heat treatment under the optimized conditions. The results of the physicochemical analyses suggested that heat treatment preserved some of the quality attributes of onion juice (ΔE, titratable acidity, etc.) better than UV-C treatment during storage. UV-C treatment did not provide any additional physicochemical benefits to the onion juice compared to heat treatment. Further research also needs to be done on the degradation kinetics of health promoting bioactive compounds of thermal or non-thermal pasteurized onion juice and formation of toxic compounds during its storage at different temperatures.

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