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Comparison of UV-C and thermal pasteurisation for the quality preservation of pineapple-mango juice blend

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Abstract

Massive grow in the juice industry promotes the development of the new flavour juice by blending two or more different types of fruits. Application of ultraviolet-irradiation of light spectrum C (UV-C) on single juice already widely explored whereas limited study was done on juice blend. Thus, the effect of ultraviolet-irradiation (UV-C) on physicochemical and antioxidant properties of pineapple-mango juice blend was investigated. Pineapple and mango juice blended together at blending ratio of 70 pineapple: 30 mango (volume/volume). Physicochemical properties of pH, total titratable acidity, total soluble solid and turbidity of pineapple-mango juice blends UV-C (UV-C dosage of 8.38mJ/cm²) and thermally (90°C, 5 mins) treated were significantly changes ($p<0.05$) during 9 weeks of storage at 4°C. Antioxidant qualities namely ascorbic acid, total phenolic compounds (TPC), and total antioxidant (as DPPH assay scavenging activities) of UV-C treated pineapple-mango juice blend shows higher values throughout the storage period. A Pearson correlation showed that ascorbic acid is the main contributor in antioxidant properties of pineapple-mango juice blend as decreased in ascorbic acid content caused degradation in TPC during storage. Present study proved that UV-C treatment better in nutritional and heat sensitive component retention compared to conventional thermal pasteurisation.

1. Introduction

Natural juice products are obtained from one fruit species, while mixed fruit products obtained from mixing two or three juices of different fruit species with or without the addition of sugar (Lozano, 2006). Juice blends able to improve the nutritional contents of juices compare to single fruit juice. Juice blending also promotes the development of new products with benefits of pleasant taste that has been encouraging by the food industry and well accepted by the consumer (De Carvalho *et al.,* 2007).

Pineapple (*Ananas cosmosus* L.) is a perennial, herbaceous monocot of the family *Bromeliaceae* which are planted extensively in the tropical and subtropical region (Shamsudin *et al.,* 2007*)*. Malaysia plant several varieties of pineapple includes *Sarawak*, *Maspine*, *Yankee*, *Gandul*, *Josapine*, *N36*, *Golden Sweet (MD2)* and *Moris*. The variety used in this present study is *Josapine*. *Josapine* variety is a hybrid between the '*Johor variety*' ('*Singapore Spanish*' hybrid with '*Smooth Cayenne*') and the *Sarawak* variety ('*Smooth Cayenne'*). Mango (*Mangifera indica* L.) regards as the queen of tropical fruit. There are several varieties of mangoes grown in Malaysia; the better-known cultivars are "*Golek*" (MA162), "*Masmuda*" (MA204), "*Maha65*" (MA165), and *Chok Anan* (MA224) (Khaliq *et al*., 2016). *Chok Anan* mango selected to be used in the present study as the variety having a large stock annually with three harvests time in May, June, and August (Santhirasegaram *et al*., 2015a). Pineapple juice tends not to be suitable to drink alone (Jan and Masih, 2012) without any added sugar or additives due to the strong taste of the juice. In contrast, mango juice was viscous in nature if extracted without the addition of water. Thus, blending together pineapple and mango into juices promotes the enhancement of juice quality and overall organoleptic and sensorial properties.

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Thermal pasteurisation is known to be effective in juice preservation. However, preservation treatment using heat caused tremendous nutritional degradation (Rahman, 2007) especially the heat sensitive components such as ascorbic acid and colour pigment. Various non-thermal technologies such as high-pressure processing (HPP), sonication, pulsed electric field (PEF), and ultraviolet irradiation (UV-C) has been explored in order to prevent the detrimental effect of thermal pasteurisation (Sulaiman *et al.,* 2015; Sulaiman *et al.,* 2017). In the present study, UV-C treatment was used as preservation treatment of pineapple-mango juice blend.

The UV-C treatment is known to be more ecologically friendly and free from chemical and waste effluent (Gómez-López *et al.,* 2012). Mechanism of UV-C treatment involved with the photochemical reaction which the UV light of C region (also known as short-wave region with wavelength ranges from 254 to 264) exhibit germicidal effects through penetration of the UV-C light into the outer membrane of microorganism cells leading to massive damage of the DNA (Choudhary and Bandla, 2012). Heat sensitive nutrition such as vitamin C and B well retain after UV-C treatment. Despite, the sensitivity of vitamin C towards UV light, the degradation effect is minimal compared to thermal pasteurization (Chia *et al*., 2012; Shamsudin *et al*., 2014; Mohd-Hanif *et al*., 2016b;).

Reported studies of UV-C treatment on tropical juice blend includes on guava-pineapple (Keyser *et al*., 2008), and lemon-melon (Kaya, Yildiz, and Ünlütürk, 2015). These studies proved that UV-C has a positive implication on retaining the nutritional and appearance properties of juice blends. However, as far as our concern no study had been done on pineapple-mango juice blend UV-C treated. Thus, the aim of the present study was to investigate the effect of UV-C treatment on the quality attributes of pineapple-mango juice blends at a blending ratio of 70% pineapple and 30% mango. The quality accessed in this study includes the colour, physicochemical (pH, titratable acidity, °Brix, and turbidity) and antioxidant properties (ascorbic acid, total phenolic and total antioxidant) during 9 weeks of storage time at 4°C. A comparison was made with conventional thermal pasteurisation.

2. Materials and methods

2.1 Pineapple-mango juice blend preparation

Josapine pineapple and *Chok Anan* mango originated from Muar, Johor, Malaysia and Bidor, Perak, Malaysia respectively at commercial maturity were obtained from the local retailer in Selangor, Malaysia. The extraction of pineapple and mango juice was done separately using juice extractor (Power Juice, Smart Shop TM, US). Centrifugation process was added in the juice processing to minimize the opacity of the juice as a highly opaque liquid will be poorly treated with UV-C as the penetration depth of the UV-light was the main limitation in UV-C treatment. A slight modification was done by centrifugation process of mango juice. Previously, Santhirasegaram *et al.* (2013), Santhirasegaram *et al.* (2015b), and Santhirasegaram *et al.* (2016) centrifuged mango juice at 12,000 rpm for 10 mins at 4°C, whereas in the present study mango juice was centrifuged at 9000 rpm for 10 mins (Benchtop Centrifuge, Universal 320/320 R, Hettich Zentrifugen, Germany) due to the limitation of the centrifuge used in present study. For pineapple juice, the centrifugation process was not reported in any literature. Taking the processing of mango juice as a reference, pineapple juice was centrifuged at 8000 rpm for 5 mins (the processing parameter was decided on the basis of preliminary trials in which the quality of physicochemical properties of pineapple juice was not significantly different from the uncentrifuged juice). Since pineapple juice was originally clearer than mango juice the centrifugation needed was lower. The juice of pineapple and mango mixed together at blending ratio of 70:30 (pineapple: mango). Kamarul Zaman *et al.* (2016) stated that blending ratio of 70% pineapple and 30% mango (v/v) resulted with the best nutritional quality of vitamin C and total phenolic with good colour properties.

2.2 Thermal and UV-C treatments

2.2.1 Thermal pasteurization

Pasteurisation process was done using batch pasteurizer (P9000, Elecrem, France) at 90°C for 5 mins. To minimize the effect of thermal treatment the pasteurization was done by submerging the pineapple-mango juice bottled in a sterilized glass bottle of 200 ml volume, tightly capped inside the container filled with water (Hounhouigan *et al*., 2014).

2.2.2 UV-C treatment

UV-C pasteurizer unit (Malaysia patent PI201203186) used in this study was similar to the previous study by Mansor *et al*. (2017), Mohd-Hanif *et al*. (2016a) and Shah *et al*. (2014). The unit consists of 6 low-pressure mercury lamps (28 mm diameter and 915 mm length vertically arranged) quartz sleeved which 5 of it coiled with polyfluoroalcoxy (PFA). The uncoiled lamp was located in the middle. In the present study, one coiled lamp and the middle lamp was used for the UV-C treatment. The schematic diagram of the UV-C pasteurizer unit used illustrated in Figure 1. The pineapple-mango juice blend was treated by flowing the liquid juice inside the coiled PFA tube which portrayed a dean vortex technology. In dean vortex technology the UV-C treatment was proved to be more efficient as the homogeneity of the flow was enhance resulted in greater exposure towards the UV-light source. The UV-C dosage of pineapple-mango juice was obtained by setting the pump flow rate at 40 Hz resulted in 8.38mJ/cm² of UV-C dosage. Residence time distribution and Irradiance intensity of 8.65 seconds and 0.9225mW/cm² (obtained from the installed UV radiometer at each lamp) were used to calculate the UV-C dosage following equation (1) as indicated by (Mansor *et al*., 2017).

$$Dose\ \left(\frac{mJ}{cm^2}\right) = Irradiance\ intensity\ \left(\frac{mW}{cm^2}\right) \times Residence\ time\ distribution\ (s) \qquad (1)$$

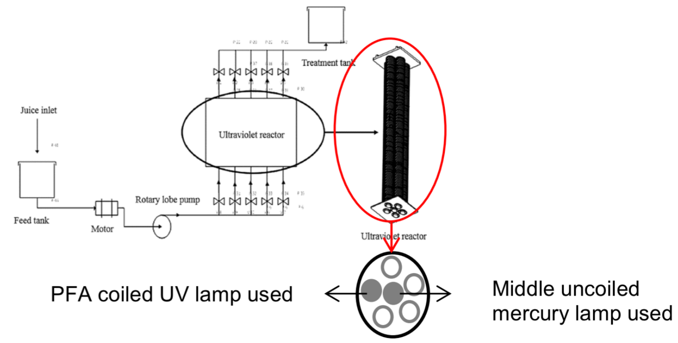

Figure 1. Schematic diagram of the ultraviolet reactor

2.3 Experimental design

2.3.1 Colour parameter

Spectrophotometer UltraScan Pro (D65 Hunter Lab, USA) was used to obtain parameter L*, a*, and b* which was then used to calculate the colour saturation and degree of dullness denoted as hue angle (h) and chroma (C*) respectively (Fernández-Vázquez *et al*., 2011). Below, equations (2), (3), and (4) was used to define hue, chroma and total colour difference (ΔE) respectively.

$$C = \sqrt{a*^2 + b*^2} \qquad (2)$$

$$h = \arctan\left(\frac{b^*}{a^*}\right) \qquad (3)$$

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \qquad (4)$$

NEBI denoted as the quality index in food quality as it contributes to colour changes, off-flavours and nutritional losses in food products (Caminiti *et al*., 2011). A total of 5 mL of 95% ethanol was added to 5 mL of pineapple-mango juice blends. The solution was centrifuged at 2500 rpm for 15 mins (Benchtop Centrifuge, Universal 320/320 R, HettichZentrifugen, Germany). The supernatant absorbance was measured using UV spectrophotometer (Ultraspec, 3100, Amersham) at 420 nm (Cohen *et al*. (1998). All measurement was done in triplicate.

2.3.2 Physicochemical analysis

2.3.2.1 pH and titratable acidity

Measurement of pH is important in determining the stability of food. pH of pineapple-mango juice blends measured using pH meter (pH 200, HM Digital, Korea) in triplicate. Titratable acidity (TA) measured the organic acid available in food. The TA of pineapple-mango juice blend measured by a standard method of AOAC, 1995 method in which 10 mL of juice sample was diluted with 40 mL of distilled water. A total of three drops of phenolphthalein added into the diluted sample and titrated with 0.1 mol/L of sodium hydroxide (NaOH) until a visible pink colour persisted for 1 min. TA was expressed as a percentage of malic acid, Equation (5):

$$\%malic\ acid = \frac{ml\ NaOH\ used \times 0.1\ N\ NaOH \times 0.067 \times 100}{grams\ of\ sample} \qquad (5)$$

2.3.2.2 Total soluble solids

Total soluble solids indicate the amount of sugar available in the fruit juice (Mohd-Hanif *et al.,* 2016a). Digital refractometer (AR-2008, Krus Germany) was used and the reading taken in triplicate expressed as unit °, Brix.

2.3.2.3 Turbidity

Turbidity affects the efficiency of UV light penetration due to light scattering and shading effect of microbe inside juice sample (Shah *et al*., 2014). Amount of cloudiness in pineapple-mango juice blend as expressed as turbidity in unit NTU was measured using Turbidimeter (TN-100, Eutech, Singapore). Calibration of the turbidimeter was done with 800, 100, 20 and 0.02 NTU standard solution.

2.3.3 Antioxidant content

2.3.3.1 Ascorbic acid

Ascorbic acid in pineapple-mango juice blend measured using AOAC 967.21 method (Hernandez *et al*., 2006). Three different solutions were prepared for the ascorbic acid analysis which was, metaphosphoric acid-acetic acid solution, ascorbic acid standard solution (prepared fresh each time) and 2, 6-dichlorophenolindophenol dye solution. Sample titration was done by titrating mixture of 5 mL metaphosphoric acid-acetic acid solution and 2 mL of juice with 2,6-dichlorophenolindophenol. Equation (6) then used to calculate the mg ascorbic acid per mL of pineapple-mango juice blend.

$$\frac{mg\ ascorbic\ acid}{ml} = (X - B) \times \left(\frac{F}{E}\right) \times \left(\frac{V}{Y}\right) \qquad (6)$$

$$Titer, F = \frac{mg\ ascorbic\ acid\ in\ volume\ standard\ solution\ titrated}{(average\ ml\ dye\ used\ to\ titrate\ standard - average\ ml\ dye\ used\ to\ titrate\ blank)}$$

Where X = average mL for sample titration; B = average mL for sample blank titration; F = titer of dye (= mg ascorbic acid equivalent to 1.0 mL indophenol standard solution); E = mL assayed (= 2 mL); V = volume of initial assay solution (= 7 mL); and Y = volume of sample aliquot titrated (= 7 mL)

2.3.3.2 Total phenolic content (TPC)

The UV-spectrophotometry method as described by Škerget *et al.* (2005) was used for TPC determination with slight modification. The juice sample of 0.5 mL diluted with 2.5 mL distilled water and added with Folin-Ciocalteu reagent (R&M Marketing, Essex, UK) that already diluted 10 times with distilled water. 2 mL of 7.5% (w/v) sodium chloride (Na_2CO_3) mixed into the solution and incubated at ambient temperature for 1 hr before the absorbency measured at 765 nm using UV-spectrophotometer (Ultraspec, 3100, Amersham) with a gallic acid of 1 µM was used as a control. The total phenolic content in pineapple-mango juice blends was expressed as mg gallic acid equivalent (GAE/L).

2.3.3.3 DPPH assay

The radical scavenging ability of pineapple-mango juice blends was analysed on the basis of the radical scavenging effect on the DPPH free radical (Ramadan *et al.,* 2008). 1 mL of fruit juice sample was added to 3 mL of 0.1mM DPPH solution. The solution then mixed and kept in dark for 30 mins at ambient temperature. Absorbance then measured at 517 nm using UV spectrophotometer (Ultraspec, 3100, Amersham). The scavenging activity of the juices was calculated as follow, Equation (7):

$$DPPH\ Scavenging\ activity\ (\%) = \frac{A-B}{A} \times 100 \qquad (7)$$

Where A=absorbance of DPPH; B=absorbance of DPPH and fruit juice combination.

2.4 Statistical analysis

The experiment was done in triplicates and one-way analysis of variance (ANOVA) used to evaluate the performance of UV-C irradiation treatment on pineapple-mango juice blends using SPSS Version 21.0 Software (SPSS Inc., USA) as statistical analysis tools. Duncan test was then used to further analyse the different effect of thermal and UV-C treatment on pineapple-mango juice blends during storage. A significant level of differences denoted as $p<0.05$.

Sigmaplot 12.0 (Systat Software. Inc.) software was used for Pearson correlation ($P<0.05$) in antioxidant properties to analysed the correlation between ascorbic acid, total phenolic and total antioxidant properties of pineapple-mango juice blend during storage.

3. Results and discussion

3.1 Physicochemical analysis

3.1.1 Effectiveness of ultraviolet irradiation and thermal pasteurization on pineapple-mango juice colour parameter

Table 1 shows the colour changes of UV-C and thermal treated pineapple-mango juice blends during 9 weeks of storage at 4°C. Appearance in juice is important to determine the quality of the juice as well as the degree of deterioration of fruit juice. L*, a*, and b* of pineapple juice for all treatment conditions were significantly reduced during the storage time. Colour properties of thermally treated pineapple-mango juice blend degrade greater compared to UV-C treated juice. The negative value of a* parameter indicates the colour shift toward more green. Throughout the storage time, the yellow colour (b*) of pineapple-mango juice blends become less yellow and changes towards brownish. Similarly, lemon-melon juice blend b* parameter degrade significantly after UV-C and heat treatment which is believed to be the effect of carotenoid degradation (Kaya *et al.*, 2015). The changes in the colour of the present study were supported by the increment of hue angle and decrement of chroma. Hue angle and chroma give information on colour saturation and degree of hue colour difference compared to the grey colour of the same lightness (quantitative attributes of colour) respectively (Fernández-Vázquez *et al.*, 2011). Increase in hue indicate more yellow colour (Esteve *et al*., 2005) of pineapple-mango juice blend, but closer to brown as low chroma indicate dullness colour properties.

ΔE of pineapple-mango juice blend significantly ($p<0.05$) changed during storage for all treatment conditions. According to Bhat (2016), ΔE ranging from 0 to 0.5, 0.5 to 1.5, 1.5 to 3.0 and 3.0 to 6.0 were denoted as not noticeable, slightly noticeable, noticeable and well noticeable respectively. UV-C irradiated pineapple-mango juice blend shows slight colour changes after treatment (week 0). Similarly, orange-carrot juice blend also resulted in slightly noticeable ΔE after UV-C treatment (Caminiti *et al.*, 2012). However, greater colour changes observed in thermally treated pineapple-mango juice blend ($1.5< \Delta E <3.0$). Lemon-melon juice blend showed a similar trend of higher ΔE value of thermally treated juice as compared to UV-C treated juice sample (Kaya et al., 2015). During storage ΔE of UV-C and heat treated pineapple-mango juice blend well noticeable ($3.0<\Delta E<6.0$) at week 5 and 3 respectively.

Another parameter to support the colour changes in pineapple-mango juice blend was NEBS. NEBI denoted as a quality index in food quality as it contributes to colour changes, off-flavours and nutritional losses in food products (Caminiti *et al*., 2011). The NEBI of UV-C treated pineapple-mango juice blend was not

Table 1. Colour changes of pineapple-mango juice blends stored at 4°C.

Treatment	Week	L*	a*	b*	Hue angle	Chroma	ΔE	NEBI
Fresh	0	39.95±0.53^{a}	-0.48±0.01^{c}	1.59±0.07^{a}	73.27±0.36^{d}	1.66±0.07^{d}	-	0.27±0.02^{c}
	1	39.53±0.35^{a}	-0.47±0.02^{c}	1.58±0.07^{ab}	73.62±0.39^{d}	1.64±0.07^{d}	2.46±1.10^{e}	0.28±0.01^{c}
	3	35.48±0.73^{b}	-0.36±0.06^{b}	1.48±0.04^{b}	76.33±2.40^{c}	1.53±0.03^{c}	4.46±0.47^{d}	0.25±0.00^{cd}
	5	32.08±0.11^{c}	-0.29±0.04^{ab}	1.48±0.03^{b}	79.08±1.32^{b}	1.51±0.04^{c}	7.87±0.62^{c}	0.60±0.01^{b}
	7	25.58±0.41^{d}	-0.24±0.01^{a}	1.26±0.04^{c}	79.21±0.52^{b}	1.28±0.03^{b}	14.37±0.16^{b}	0.56±0.00^{b}
	9	19.70±0.36^{e}	-0.23±0.04^{a}	1.09±0.03^{d}	78.32±1.66^{a}	1.12±0.03^{a}	20.25±0.22^{a}	0.46±0.00^{a}
UV-C	0	36.71±0.26^{f}	-0.37±0.02^{e}	1.63±0.02^{a}	77.13±0.51^{d}	1.68±0.02^{d}	1.04±0.37^{f}	0.24±0.01^{c}
	1	35.67±0.16^{e}	-0.42±0.02^{d}	1.54±0.04^{b}	74.65±0.81^{e}	1.60±0.04^{d}	3.37±1.00^{e}	0.23±0.00^{c}
	3	31.51±0.05^{d}	-0.31±0.02^{c}	1.13±0.01^{c}	76.72±0.83^{d}	1.35±0.01^{c}	4.67±0.32^{d}	0.24±0.00^{c}
	5	29.05±0.75^{c}	-0.24±0.01^{b}	1.24±0.03^{d}	79.05±0.39^{c}	1.26±0.03^{b}	7.67±0.53^{c}	0.30±0.00^{b}
	7	25.58±0.08^{b}	-0.17±0.01^{a}	1.14±0.05^{e}	81.65±0.45^{b}	1.15±0.05^{a}	11.15±0.18^{b}	0.32±0.00^{b}
	9	19.27±0.35^{a}	-0.14±0.05^{a}	1.03±0.04^{f}	82.15±0.17^{a}	1.05±0.04^{a}	17.47±0.42^{a}	0.42±0.00^{a}
Heat	0	33.70±0.15^{a}	-0.34±0.02^{c}	1.57±0.02^{a}	77.72±0.73^{c}	2.83±0.05^{e}	1.64±0.16^{a}	0.52±0.02^{a}
	1	32.07±0.08^{b}	-0.32±0.02^{c}	1.47±0.02^{b}	77.89±0.64^{c}	2.50±0.04^{d}	2.57±0.20^{b}	0.54±0.01^{d}
	3	30.69±0.29^{c}	-0.26±0.03^{b}	1.22±0.04^{c}	78.09±1.51^{c}	1.75±0.07^{c}	5.41±0.61^{c}	0.21±0.00^{c}
	5	25.39±0.31^{d}	-0.24±0.02^{b}	1.23±0.02^{c}	78.84±0.55^{cd}	1.76±0.03^{c}	8.32±0.45^{d}	0.24±0.01^{c}
	7	22.56±0.08^{e}	-0.15±0.02^{a}	1.06±0.04^{d}	82.13±0.59^{b}	1.27±0.09^{b}	11.15±0.13^{e}	0.45±0.00^{b}
	9	17.64±0.17^{f}	-0.12±0.01^{a}	1.04±0.03^{d}	83.60±0.25^{a}	1.20±0.06^{a}	16.07±0.03^{f}	0.50±0.00^{a}

Values are expressed as the mean ± standard deviation of triplicate (*n=3*). Values followed by the same small letter in a column are not significantly different from each other ($p>0.05$) for each different treatment of fresh, UV-C and heat. ΔE and NEBI are the colour difference and non-enzymatic browning index respectively

significantly different until 3rd weeks of storage and starts to increase afterward ($p<0.05$). The increment of NEBI in UV-C treated juice might due to the photo-degradation effect promoting Maillard reaction to occur (Santhirasegaram *et al*., 2015a). In contrast, thermally treated juice shows fluctuation in NEBI, as the value sharply decreased at week 3 (0.21±0.00) and increased significantly afterward ($p<0.05$). Prior study on apple-cranberry juice blends resulted with no significant change of NEBI after heat treatment at 72ºC, 26s (Caminiti *et al*., 2011). This shows that NEBI effect increased with increasing temperature and treatment time of heat pasteurisation. Overall, colour properties of pineapple-mango juice blend were retained better after UV-C treatment compared to thermal pasteurization, but improvement will be needed on the UV-C dose induced to obtain better results.

3.1.2 Effectiveness of ultraviolet irradiation and thermal pasteurization on pineapple-mango juice physicochemical properties

pH in fruit juice gives information on the bioactive compound stability in fruit juice. Previously, no significant changes observed in pH of single pineapple juice after the heat and UV-C treatment (Chia *et al*., 2012; Pala and Toklucu, 2013b). The present study deviates from the trend as the pH of pineapple-mango juice blends was significantly changed ($p<0.05$) after UV-C and thermal treatment. Significant increment ($p<0.05$) of pH values during the 9 weeks of storage were observed in untreated and UV-C treated pineapple-mango juice blends as shown in Table 2. In contrast, prior study shows that pH of lemon-melon juice blend thermally and UV-C treated was not significantly changed during storage of 30 days (Kaya *et al*., 2015). In the present study, heat treated pineapple-mango juice blend pH was not significantly different until the 5th week of storage. Result obtained indicated pH of heat treatment was more stable compared to the UV-C treatment. pH associated with microbiological activities of fruit juice which correlated to the shelf-life of a product and act as the quality indicator of juice.

Table 2 shows the titratable acidity (TA) of UV-C and thermal treated pineapple-mango juice blends was not significantly different ($p>0.05$) during the first 3 weeks of storage. Koutchma *et al.* (2016) stated that the TA parameter was not significantly affected by UV-C treatment. Increase in TA associated with the organic acid in fruit juice, which will eventually result in lower pH as stated by Chia et al. (2012). Present study deviates from the trend as TA and pH increased together. Deviation might due to blending effect in which the fruit juice matrix was changed. According to Ibrahim (2016) types of fruits, biochemical reaction and microbial activities contribute to the changes. Islam *et al.* (2016) added that high TA value will not necessarily result with low pH.

Total soluble solids (TSS) was measured as unit ° Brix. Soluble solids content determination in fruit juice was important as an indicator of sugar content which later affects the organoleptic preference of fruit juice. TSS of UV-C treated pineapple-mango juice blend (13.57±0.49°Brix) at week 0 was lower in value compared to thermal pasteurised juice (14.50±0.5°Brix) as shown in Table 2 which in agreement with a prior study on lemon-melon juice blend (Kaya *et al.,* 2015). Jafari *et al*. (2017) reported that high TSS values were frequently observed at thermal pasteurisation process higher than 85°C. Similarly, Chia *et al.* (2012) observed

Table 2. Physicochemical changes of pineapple-mango juice blends stored at 4°C.

Treatment	Week	pH	TA	TSS	Turbidity
Untreated	0	3.97±0.02^{f}	0.70±0.02^{c}	13.67±0.21^{a}	402.67±5.03^{f}
	1	4.14±0.02^{e}	0.77±0.03^{b}	12.37±0.06^{b}	450.33±0.58^{e}
	3	4.20±0.01^{d}	0.77±0.04^{b}	12.17±0.06^{c}	473.67±1.00^{d}
	5	4.29±0.00^{c}	0.92±0.03^{a}	11.63±0.06^{d}	562.00±2.08^{c}
	7	5.18±0.01^{b}	0.52±0.03^{d}	11.03±0.06^{e}	661.00±3.46^{b}
	9	5.43±0.01^{a}	0.50±0.02^{d}	10.77±0.06^{f}	719.00±1.73^{a}
UV-C	0	4.18±0.01^{f}	0.60±0.03^{b}	13.57±0.49^{c}	423.67±2.08^{e}
	1	4.14±0.02^{e}	0.61±0.09^{b}	11.43±0.06^{c}	462.33±0.58^{d}
	3	4.20±0.01^{d}	0.59±0.04^{b}	10.37±0.06^{b}	458.00±1.00^{d}
	5	4.29±0.00^{c}	0.77±0.10^{a}	9.97±0.06^{b}	540.67±2.08^{c}
	7	5.18±0.01^{b}	0.76±0.05^{a}	9.53±0.06^{ab}	610.67±10.97^{b}
	9	5.42±0.01^{a}	0.73±0.05^{a}	9.00±0.00^{a}	655.67±2.89^{a}
Heat	0	4.22±0.01^{d}	0.57±0.04^{a}	14.50±0.50^{a}	407.33±1.53^{f}
	1	4.21±0.02^{cd}	0.63±0.07^{ba}	12.83±0.12^{b}	433.33±2.31^{e}
	3	4.28±0.02^{c}	0.59±0.05^{a}	12.43±0.06^{cd}	460.33±1.53^{d}
	5	4.31±0.01^{bc}	0.68±0.06^{b}	12.77±0.06^{bc}	493.67±0.58^{c}
	7	4.34±0.02^{b}	0.80±0.02^{a}	12.27±0.06^{de}	527.00±5.29^{b}
	9	4.48±0.03^{a}	0.68±0.03^{b}	12.00±0.00^{e}	594.00±2.65^{a}

Values are expressed as the mean ± standard deviation of triplicate (*n=3*). Values followed by the same small letter in a column of similar treatment are not significantly different from each other ($p>0.05$)

pineapple juice of UV-C treated decrease in TSS while heat treated was constant throughout storage time which may due to microorganism activity. TSS correlated with pH of juice as soluble solid content illustrate the balance of sugars and acid content in the fruit juice matrix subsequently affect the fruit juice taste (Fundo *et al*., 2017).

Table 2 shows that the turbidity of untreated pineapple-juice blends increases significantly ($p<0.05$) during storage while UV-C treated juice was constant until week 5 of storage. In the meanwhile, an increment of turbidity of heat pasteurised pineapple-mango juice blends was lower compared to UV-C. Turbidity in fruit juice associated with microbial reoccurrence in fruit juice. The greater turbidity of juice was results of high suspended solids in juice causing low penetration consequently reduce the ultraviolet irradiation treatment (Kaya and Unluturk, 2016). Increase in turbidity after ultraviolet irradiation of fresh grape juice believed to be the effect of yeast and bacteria causing particle sedimentation contributing to juice cloudiness (Unluturk and Atilgan, 2014). Minimal increment observed in heat pasteurised pineapple-mango juice blends. Heat pasteurisation increased the turbidity of juice as an effect of protein-polyphenol interaction during the degradation of pectin (Kaya *et al*., 2015). Overall, physicochemical properties of pineapple-mango juice blends were significantly changed ($p<0.05$) during storage of 9 weeks regardless the different treatment induced.

3.1.3 Effectiveness of ultraviolet irradiation and thermal pasteurization on pineapple-mango juice antioxidant properties

Ascorbic acid (vitamin C) act as protection against free radical and often account as juice nutritional and quality indicator. The significant decrement of vitamin C content was observed in both UV-C and thermal treated pineapple-mango juice blend as shown in Figure 2. The decrease in vitamin C was associated with the oxidation process and peroxidase enzyme activities (Davey *et al.*, 2000). However, degradation after treatment (week 0) was greater in thermally pasteurised pineapple-mango juice blend with 52.5% ascorbic acid loss compared to only 22% in UV-C treatment. The results in agreement with a prior study in which minimum degradation of ascorbic acid was observed un UV-C treated juice compared to thermal pasteurised juice (Pala and Toklucu, 2013b; Santhirasegaram *et al*., 2015a). Ascorbic acid in pineapple-mango juice blend decreased significantly ($p<0.05$) for all treatment condition throughout 9 weeks of storage, with greater degradation observed in thermally treated juice. According to La Cava and Sgroppo (2015), degradation of ascorbic acid after UV-C treatment during storage may be the effect of co-occurrence between maximum absorption and the peak emission of UV-C lamp during processing. Based on the present study, UV-C treatment proved to give better retention of ascorbic acid content in pineapple-mango juice blend compare to thermal treatment.

Phenolic compound is denoted as secondary metabolites found in plants acts as a natural antioxidant (Santhirasegaram *et al*., 2015b) beneficial to health and promotes better juice quality includes appearance and sensorial quality. Total phenolics compound (TPC) at all treatment condition (untreated, UV-C and thermal pasteurization) of pineapple-mango juice blend, significantly decrease ($p<0.05$) throughout the storage

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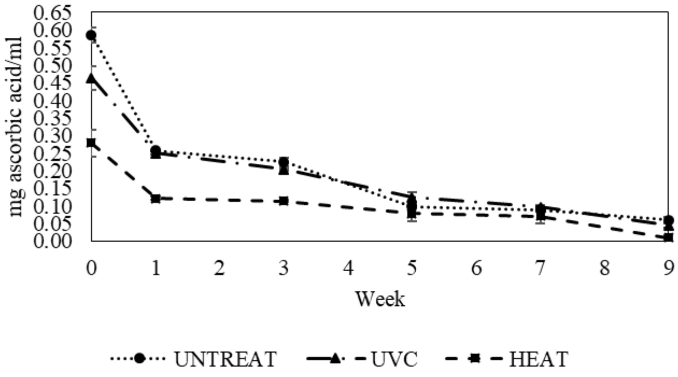

Figure 2. Ascorbic acid of pineapple-mango juice blend during 9 weeks of storage

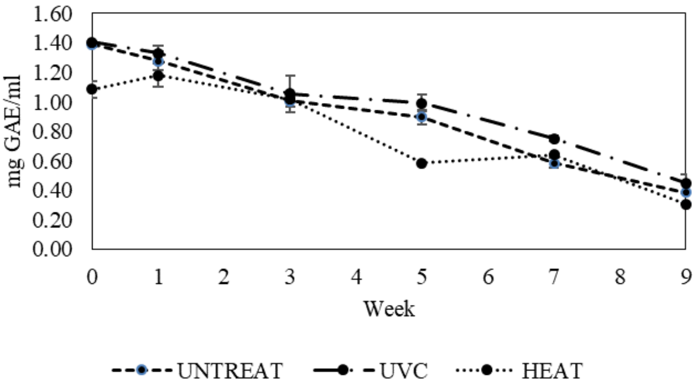

Figure 3. Total phenolic content (TPC) of pineapple-mango juice blend during 9 weeks of storage

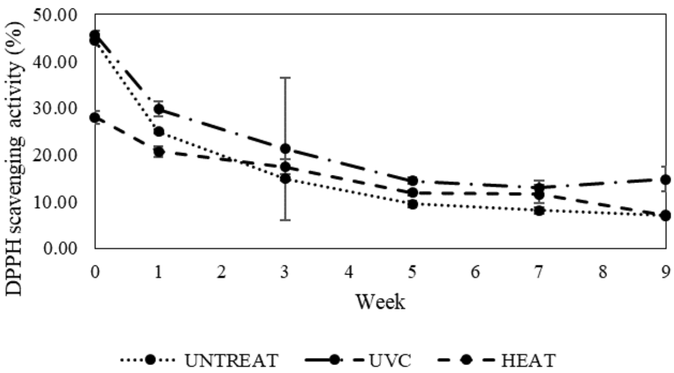

Figure 4. DPPH antioxidant activity of pineapple-mango juice blend during 9 weeks of storage

time as shown in Figure 3. However, TPC of UV-C treated juice retained higher values ranges from 0.45±0.06 to 1.41±0.00 mg GAE/ml compared to thermally treated pineapple-mango juice blend (0.31±0.00 to 1.18±0.08 mg GAE/ml). Similarly, TPC in UV-C treated apple juice was not significantly differed from control ($p>0.05$) and more stable compared to heat treated apple juice (Islam *et al*., 2016). Thermal pasteurisation reduces the TPC content of pineapple-mango juice blend up to 22.3% after treatment and reaches more than 50% reduction at week 5. Processing affects the bio-accessibility of phenolics compounds from drinks in which processing involved the use of heat cause loss of thermo-labile phenols from polymerization (Rodríguez-Roque *et al*., 2015). Thus, UV-C treatment is a promising alternative treatment for juice processing which minimised the alteration of the food matrix.

Antioxidant activity in fruit juice differs depending on the type of fruits. Production of fruit juice involved with a different process such as crushing, clarification, filtration and thermal treatment, which indirectly affect the antioxidant properties of fruit juice (Wern *et al.,* 2016). Total antioxidant activities of DPPH assay of pineapple-mango juice blends at different treatment condition was decreased significantly throughout the storage periods of 9 weeks as indicated in Figure 4. At week 0, DPPH values of untreated (44.46±1.01%) pineapple-mango juice blend increased after treatment with UV-C (45.74±0.76%). The result obtained was in agreement with Santhirasegaram *et al.* (2015a), DPPH radical scavenging assay in *Chok Anan* mango juice recorded 91.2% inhibition after treatment of 30 mins with UV-C. Similarly, the antioxidant activity of grape increased after treatment with ultraviolet irradiation which might be contributed to phenolic accumulation during light exposure during treatment (Pinto *et al.,* 2016). Present result shows that phenolic at week 0 (Figure 3) also increase contributing to increment in DPPH value. However, orange juice treated with UV-C dose of 12.03 kJ/L (4.65 µmol Trolox equivalent/ml) shows no significant difference of antioxidant activity analysed as Trolox equivalent/ml compared to control (4.71 µmol Trolox equivalent/ml) and heat treatment at 90°C for 2 mins (4.41 µmol Trolox equivalent/ml) (Pala and Toklucu, 2013b). This indicates the antioxidant activity may vary depends on the reaction of fruit juice component towards designated treatment. Decreases in antioxidant activity in fruit juice after processing contribute to the oxidation of bioactive components such as vitamin C and phenolics compounds.

The correlation between ascorbic acid, TPC and DPPH scavenging activity was analysed by Pearson correlation as tabulated in Table 3. Based on the obtained data, TPC shows good correlation with ascorbic acid content in pineapple-mango juice blend with correlation values for untreated, UV-C and thermal pasteurised sample of 0.842, 0.856 and 0.745 respectively. TPC content in pineapple-mango juice blend decreased with decreasing ascorbic acid content during storage of 9 weeks. Similarly, DPPH scavenging activities also highly correlated with ascorbic acid with the correlation coefficients of untreated, UV-C and thermally pasteurised pineapple-mango juice blend were 0.986, 0.968 and 0.960 respectively with $p<0.05$.

In short, antioxidant properties of pineapple-mango juice blend were directly affected by ascorbic acid

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Table 3. Pearson correlation of antioxidant properties of pineapple-mango juice blend

	Treatment	Vit C		TPC		DPPH	
		Corr. Coeff.	P-value	Corr. Coeff.	P-value	Corr. Coeff.	P-value
Vit C	Untreated			0.842	0.04	0.986	0.000
	UV-C			0.856	0.030	0.968	0.002
	Heat			0.745	0.089	0.960	0.002
TPC	Untreated	0.842	0.036			0.854	0.030
	UV-C	0.856	0.003			0.812	0.050
	Heat	0.745	0.089			0.890	0.017
DPPH	Untreated	0.986	0.000	0.854	0.030		
	UV-C	0.968	0.002	0.812	0.050		
	Heat	0.960	0.002	0.890	0.017		

TPC and DPPH are total phenolics content and DPPH scavenging activity respectively. Corr. Coeff and P-value are correlation coefficient and Pearson value respectively.

content, as decreased in vitamin C content relatively, contribute to decrement in TPC and DPPH assay. Pineapple-mango juice UV-C treated maintains the higher antioxidant content of ascorbic acid, TPC and DPPH compare to thermally treated juice throughout the storage.

4. Conclusion

Application of UV-C light on single fruit juices has been studied for years on varieties of fruits, whereas limited research was done on juice blend to evaluate the effectiveness of such treatments which highlighting the novelty of present study on pineapple-mango juice blend. Based on the obtained data, ultraviolet irradiation treatment on pineapple-mango juice blend was better in colour properties with minimal colour degradation compared to thermal pasteurized juice. In addition, all physicochemical properties of pineapple-mango juice blends were significantly changed ($p<0.05$) during storage of 9 weeks with minimal degradation of ascorbic acid, TPC and DPPH were observed in UV-C treated juice. The non-thermal UV-C treatment proved to be better in nutritional properties retention in pineapple-mango juice blend compared to conventional thermal pasteurisation. Further study on the shelf-life of pineapple-mango juice blend through microbiological analysis will be needed to explore the effectiveness of UV-C treatment in term of microbiological safety.

Declaration of interest

All authors declare that they do not have any conflict of interest.

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