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Effect of Ultraviolet Irradiation (UV-C) on Quality Attributes of Pineapple-Mango Juice Blend Compare with Thermal Pasteurization

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Abstract– This intended paper was done to give an early overview of the expected quality attributes of pineapple-mango juice blend treated with ultraviolet irradiation (UV-C) and thermal pasteurisation. *Josapine* pineapple (*Ananas comosus* L.) and *Chokanan* mango (*Mangifera indica* L.) is the popular tropical fruits in Malaysia with unique taste and constant availability. The blend of pineapple-mango juice predicted to have good overall quality attributes as proved by prior studies on orange-pineapple, lemon-melon, pineapple-carrot-orange and carrot-apple-banana juice blends. Conventional thermal pasteurisation widely implemented in juice industry but resulted in massive quality degradation. Thus, research on the non-thermal technology of UV-C widely studied to overcome such drawbacks of thermal pasteurisation. Effect of UV-C and thermal pasteurisation on pineapple-mango juice blend will be evaluated in terms of physicochemical (pH, titratable acidity, total soluble solids, turbidity and colour), antioxidant (ascorbic acid, total phenolics content and total antioxidant DPPH assay) and microbiological properties. UV-C treated pineapple-mango juice blend believed to have better retention of heat sensitive ascorbic acid and other quality compared heat pasteurised juice with minimal distinctive characteristic compared to fresh juice.

Keywords: pineapple, mango, juice blend, ultraviolet irradiation, quality attributes

Introduction

Fruit juice rich in antioxidant and health benefit quality which regain popularity among consumers. Fruit juice defined by Codex Stan 247, as a fermentable and unfermentable liquid that obtained from the edible part of matured or ripe fresh fruit that process with means of maintaining its important physical, chemical, organoleptic and nutritional quality of fruit juice(Codex, 2005). Juice obtained by extraction processed of fruit pulp or flesh. British Soft Drinks Association (BSDA) (2016) defined juice as directly extracts without additional processed of reconstitution form juice concentrate as direct juice. Fruit juice processed using single fruit type denoted as single fruit juice (Lozano, 2006) whereas, the combination of different types of fruit species producing mixed fruit juice or juice blend (Bhardwaj and Mukherjee, 2011). Juice blends also define as a mixture of two or more puree juices (Bates and Morris, 2001) as tabulated in Table 1.

Juice blend combines the individual qualities of different types of fruit blended. De Carvalho et al. (2007) stated that juice blends able to meet the consumer demands for a new taste and flavour with nutritional benefit. Bates and Morris (2001) further added that some flavourful juice may not be fully balanced nutritionally or lacking in several nutrients includes vitamins, minerals and nutraceuticals content in which blending of different types of juice acts as carriers in enhancing such qualities. Prior studies on juice blends proved the quality attributes of fruit juice shows increment in physicochemical, antioxidant and appearance quality. Carrot and apple juice blended at the ratio of 30% carrots and 70% apple shows greater vitamin C content (21.07±0.67 mg/100ml) compare to the respective single juice of carrot (5.54±0.54mg/100ml) and apple (18.08±0.62mg/100ml) (Leahu et al., 2013). Pineapple: carrot: orange (60:10:30) juice blend quality of pH, total soluble solid, acidity, vitamin C and beta-carotene shows minimal changes after blended together(Jan and Masih, 2012).

Table 1: Designation of juice

Term	**Criteria**	**Remarks**
Pure juice 100%	All juice	No additional content, not concentrated
Freshly squeezed	Not pasteurized	Refrigerated, concern about food safety
Chilled, RTS	All juice	Refrigerated, process from concentrate or pasteurized juice
Not from concentrate	Single strength	Reconstituted and pasteurized
From concentrate	From concentrate	Reconstituted and pasteurized
Juice blend	All juice	A mixture of puree juice
Puree	Pulp containing juice	High viscosity, 100% from fruit

(Adapted from Bates and Morris (2001))

Tropical fruit gaining vast interest as fruit juice due to its health benefit properties. However, due to its strong extensive taste, it tends not suitable to drink alone, thus tropical fruits mixed as juice blend. Pineapple (*Ananas comosus* L.) of family *Bromeliaceae* is among popular tropical fruit that widely planted in the tropical and subtropical region (Australian Government, 2008). The market of pineapple fruit in Malaysia expected to arise to 700, 000 metric ton in the year 2020 with plantation area of 23, 000 hectare as supported by Thalip et al. (2015). *Josapine, Moris, N36, Sarawak, Moris Gajah, Yankee, Gandul, Maspine* and MD2 are varieties of pineapples planted widely in Malaysia. Pineapple fruit **often** utilized into canned products and juice (either single strength or concentrates or blends with other fruit) (Shamsudin et al., 2009). Variety used for present study is *Josapine* which in general having pH, titratable acidity and total soluble solids of 3.81, 0.90% and 13.42°Brix respectively (Shamsudin et al., 2009). Treatment of pineapple juice with heat resulted in nutritional and organoleptic properties degradation as the effect of non-enzymatic browning due to Maillard reaction (Hounhouigan et al., 2014).

Mango fruit regards as queen of tropical fruit with a sweet taste and captivating colour. Mango said to be originated from India (Cruz and Garcia, 2005) and planted widely around the Caribbean, Africa, South-East Asia and Australia (Mukherjee, 1972). Popular species of mango around the world includes *Alphonso, Baganpalli, Chausa, Dasheri, Langra, Totapuri and Keasar* (De La Cruz Medina & Garcia, 2002). In Malaysia, the local varieties of mango as *Golek* (MA162), *Masmuda* (MA204), *Maha65* (MA165) and *Chokanan* (MA224) (Ding and Mijin, 2013). Variety to be used in present research study is due to its constant availability as *Chok Anan* mango yield off-season flowering with 3 harvesting times in May, June, and August (Santhirasegaram et al., 2015). *Chok Anan* is sweet in taste with total soluble solid content ranging from 14 to 16°Brix (Santhirasegaram et al, 2013), and rich in pre-biotic dietary fibre, vitamin C, polyphenols and carotenoids (Bhardwaj & Pandey, 2011) made it suitable to be processed into juice.

The effectiveness in disinfection of pathogenic microorganism of thermal pasteurisation made it as the most favourable method in extending juice product shelf-life (Walkling-Ribeiro et al., 2008). Cloudy, puree and clear type of fluid product well treated using the combination of high-temperature short time (HTST) (Shah et al., 2016) which cause fatality to microorganism as an effect of shock due to high temperature induced. Despite the effectiveness of thermal pasteurization in microbial inactivation, pasteurisation by means of heat caused the loss in nutritional content (Sanchez-Vega et al., 2009) especially heat sensitive compound such as vitamin C (Van Opstal et al., 2006). Chia et al. (2012) found that treatment of pineapple juice at 80°C for 10 minutes greatly degraded vitamin C and total phenolics compound inside the juice. Therefore, alternative non-thermal treatment such as ultraviolet irradiation (UV-C) gaining much interest to minimize the quality degradation as well as meet the consumer demands for fresh like products.

Santhirasegaram et al. (2015) stated that non-thermal technology able to maintain juice quality, and safely inactive microorganism activities in fruit juice. UV-C using the effect of a photon of light penetration at germicidal wavelength ranges from 254 to 264 nm able to cause cell death due to disability to replicate which render food spoilage (Koutchma, 2009). Prior research on the effect of UV-C on single pineapple and mango juice has been done. Goh et al. (2012) found that ascorbic acid value of pineapple juice was higher retained after UV-C treatment (76.8%) compare to thermal pasteurization (61.6%) from its initial value of 16.4 mg/100g. The well retains ascorbic acid in pineapple juice together with other physicochemical properties was also found in the study by Chia et al. (2012) and Shamsudin et al. (2014). UV-C treated mango juice shows no significant difference in caffeoyl and moonogalloyl and glucose, with increased individual phenolics compound content (quinic acid, ellagic, quercetin, gallic acid, kaempferol, mangiferin and tannic acid) (Santhirasegaram et al., 2015) showing antioxidant compound in juice minimally reduced with UV-C.

Thus, this forecast review intended to predict the quality attributes of tropical juice blend from pineapple and mango treated with UV-C as an alternative to thermal pasteurisation. From this review, promising results of colours, physicochemical properties, microbiological inactivation and product shelf-life of pineapple-mango juice blend UV-C treated can be forecasted. Besides, information gathered through this paper may give future prospect in fruit juice processing in Malaysia with the implementation of non-thermal technology.

Materials and methods

Juice extraction and preparation

Pineapple and mango of *Josapine* and *Chok Anan* variety respectively obtained from the local retailer in Selangor. Pineapple skin peeled and the eye removed then, cleaned and cut into smaller pieces before introduced into the juice extractor. Mango fruit washed and peeled. The flesh separated from the seed and extracted using the same juice extractor (Power Juice, Smart ShopTM, US). Both juices extracted separately and filter using a muslin cloth. In order to reduce the juice opacity, both juice further filtered using centrifuge (Benchtop Centrifuge, Universal 320/320R, Hettich Zentrifugen, Germany). After that, pineapple and mango juice will be mixed together following the blending ratios as indicated in Table 2:

Table 2: Pineapple and Mango juice blending ratios

Ratio	Pineapple	Mango
100:0	100	0
70:30	70	30
50:50	50	50
30:70	30	70
0:100	0	100

(Adapted from Kamarul Zaman et al., (2016)

Ultraviolet irradiation and thermal pasteurization treatment

UV-C treatment will be done for the selected blending ratio that exhibits the best quality of pineapple-mango juice blend. Dean vortex ultraviolet pasteurizer unit of Malaysia patent (PI202203186) consists of 6 mercury lamps (5 coiled lamps and one uncoiled middle lamp) will be used for this study. The flow rate of the fluid flows inside the unit controlled by the pump frequency (ranging from 20 to 45Hz). The determination of UV-C dosage of ultraviolet treatment adapted from prior studies that using the same unit (Mansor et al., 2014; Shamsudin et al., 2014 and Mohd-Hanif et al., 2016). Several flow rates tested to obtain best UV-C dosage that able to effectively inactive microorganism in pineapple-mango juice blend to meet the FDA regulation of 5 log reduction of pertinent microorganism. A comparison will then made with thermal pasteurisation at 90°C for 5 minutes using batch pasteurizer unit (P9000, Elecrem, France).

Quality attributes analysis

Physicochemical properties of pH, titratable acidity (TA), total soluble solids (TSS), turbidity, colour (lightness, L*, hue, chroma, colour different (ΔE) and browning index) and antioxidant properties (ascorbic acid, total phenolic, total antioxidant) of juice blend will be analyzed. pH, TSS, and turbidity will be measured using pH meter (Metler Toledo, USA), a digital refractometer (AR-2008, Krus, Germany) and turbidimeter (TN-100, Eutech, Singapore) respectively. TA analysed using titration method as indicated by AOAC 1995 (Islam et al., 2014). TA and TSS expressed as % of malic acid and °Brix respectively.

Colour spectrophotometer (UltraScanPro D65, Hunter Lab, USA) give lightness (L*), redness (a*) and yellowness (b*) colour spectrums. The obtained values then inserted into the following equation 1, equation 2 and equation 3 for determination of hue angle (H), chroma (Luvonga et al., 2010) and browning index (BI) (Rolstad, 2007) respectively:

$$() = {}^{-1}({}^{*}/ \quad {}^{*}) \qquad \text{Equation (1)}$$

$$h \; , = \sqrt{{}^{*2} + {}^{*2}} \qquad \text{Equation (2)}$$

$$= \frac{-0.31}{0.172 \times 100} \qquad \text{Equation (3)}$$

Where: $= ({}^{*} + 1.75 \; {}^{*}) / (5.64 \; {}^{*} + {}^{*} - 3.012 \; {}^{*})$

Ascorbic acid will be analysed using AOAC 967.21 titration method and expressed as ascorbic acid/100 ml juice. Total phenolics evaluate using method of Folin-Ciocalteu and expressed as gallic acid equivalent (GAEmg/100ml) (Nayak et al., 2015). In the meanwhile, the total antioxidant in pineapple-mango juice determines using DPPH free radical scavenging assay method (Alothman et al., 2009).

Microbiological analysis

Plate count method will be used in the microbiological analysis for the pineapple-mango juice blend. *E. coli* O157: H7 obtained from the Bacteriological Food Safety Laboratory, Food Science and Technology Faculty, University Putra Malaysia will be serially diluted and inoculated (at inoculums of 10^{-8}) into pineapple-mango juice blend of **best** blending ratios. The initial count of *E. coli* O157: H7 obtained through plating on Sorbitol McConkey Agar (SMAC) (Difco^{TM}, Dickinson and Company, USA) and incubated for 24 hours. Yeast and mould (YM) and total plate counts (TPC) will be also counted. YMC will be done through plating on Dichloron rose Bengal Chloramphenicol (DRBC) agar and incubated at 37°C for 5 days, while TPC plating will be done on plate count agar (Merk, Germany) and incubated at 25°C±2°C for 2 days (Santhirasegaram et al, 2013).

Results and Discussion

Juice blend proved to be more nutritious compared to single juice as supported by the previous study on several juice blends combination as indicated in Table 3. Thus, a blending of pineapple and mango expected to shows minimal changes or increment in its nutritional values and physicochemical qualities. Table 3 summarised the effect of blending on the overall physicochemical properties of pH, total soluble solids, titratable acidity and turbidity of prior studies on juice blend at treatment condition of thermal pasteurization, ultraviolet-irradiated and untreated (fresh). Based on the reported studies, it is believe that juice blend of pineapple and mango will exhibit similar results or relatively closer to the previous study done.

Physicochemical properties evaluate the quality of food products in sensorial and food texture which provides the information on food quality during its final stage of production (Bengtsson, 2009). Referring to Table 3, juice blend of orange and pineapple increased the total solid content from 11.95% (single orange juice) to 15.68% with pH value turned to be more acidic from 3.97 (single orange juice) to 3.68 (pineapple-orange juice blend) (Akusu et al., 2016). More acidic fruit juice is more favourable as it has higher resistant towards microbial activities. Mixing more than 2 types of different fruit varieties caused chemical reaction between the organic acid components. Single carrot, apple, peach and banana juice had pH of 5.98, 3.11, 4.1 and 4.86 respectively. The blending combination consists of different pH ranging from more acidic to less acidic (apple>peach>banana>carrot) (Leahu et al., 2013) in which juice blend combination from the mention fruits increased in pH and decreased in titratable acidity with increasing carrot volume ratios in the blend as shown in Table 3. In the meanwhile, kinnow mandarin-annola juice blend show no significant difference of titratable acidity with increasing total solid (Bhardwaj & Mukherjee, 2011) compared to their respective single juice. Pineapple: carrot: orange juice blend shows similar trends of titratable acidity increment with increment of total solid content after blended together (Jan and Masih, 2012). According to Mansor et al. (2014), the increment in pH relatively affects the titratable acidity content due to the decrement in acid concentration of fruit juice (respected to predominant acid in juice).

Table 3: Physicochemical properties of juice blends (a is mg malic acid/100ml)

Juice blend	**pH**	**Total solid**	**Titratable acidity**	**Turbidity**	**References**
Orange: 30 Pineapple:70	3.68±0.04	15.68±0.04	0.7±0.01		(Akusu et al., 2016)
Carrot: 30 Apple: 70	3.69±0.03	10.57	0.12±0.01a		(Leahu et al., 2013)
Carrot: 50 Apple: 30 Peach: 20	4.10±0.01	10.43	0.12±0.01a		
Carrot: 50 Apple: 30 Banana: 20	5.51±0.01	10.21	0.13±0.01a		
Lemon: 12 Melon: 88	3.93±0.01	8.51±0.11	0.50±0.00	292.75±0.96	(Kaya et al., 2015)
Kinnow: 95 Anola: 5		12.00	0.80		(Bhardwaj and Mukherjee, 2011)
Pineapple: 60 Carrot: 10 Orange: 30	4.09		0.97		(Jan and Masih, 2012)

In the meanwhile, total solid of single orange and pineapple juice increase from 10.30±0.14% and 14.88±0.11% respectively to 15.68±0.04% after blending (Akusu et al., 2016). Similarly, juice blend of carrot and apple had total solid content of 10.57% after mixed together. Single mandarin kinnow juice initially having low value of total solid (11.5°Brix) content, but the blend of mandarin kinnow with anola increased the juice total solid to 12.0°Brix (Leahu et al., 2013). Total solid measured the total sugar and can be used to represent the sweet taste of fruit juice. Thus, it is predicted that pineapple-mango juice blend will resulted with better physico-chemically if blended at the right blending ratios.

Apart from that, UV-C treatment of juice blend showed the physicochemical properties minimally affected after treatment giving insight on the application of UV-C on pineapple-mango juice blend. Prior study on UV-C treated lemon-melon juice blend resulted in no significant changes in pH, titratable acidity and total solid with the decrement in juice turbidity after treatment. The turbidity of lemon-melon juice blend of UV-C treated lower compared to thermal pasteurization (342.50±0.71 NTU) (Kaya et al., 2015). Thus, it can be concluded that juice blend able to enhance the physicochemical qualities of single fruit juice as well as minimally affected by UV-C treatment. Therefore, the used of UV-C as pasteurisation treatment on pineapple-mango juice blend predicted to be excellent in quality compared to thermal pasteurisation.

Table 4: The Antioxidant content of juice blend

Juice blend	**Treatment condition**	**Vitamin C(mg/100ml)**	**Total phenolic (mg GAE/100ml)**	**Other antioxidant**	**References**
Carrot-apple (30:70)	Fresh	21.07±0.67	158.3±10.5		Leahu et al. (2013)
Carrot-apple-peach (50:20:30)		42.1±0.31	110.3±10.5		
Carrot-apple-banana (50:30:20)		48.5±0.62	95.2±3.21		
Kinnow-anola (95:5)	Thermal pasteurized at 75°C for 15 min	45.70			Bhardwaj & Mukerjee (2011)
Pineapple-carrot-orange (60:10:30)	Thermal pasteurized at 90°C for 25 sec	41.30		Beta-carotene (1107.0)	Jan & Masih (2012)

Anti-carcinogenic effect of antioxidant in fruit juice such as vitamin C, vitamin E or beta-carotene (Pyo et al., 2014) beneficial to consumer health. Antioxidant also act as preservatives that lengthen the shelf life of the product by preventing oxidation effects (which can cause discolouration and rancidity) (Kaur and Kapoor, 2001). Table 4 shows the prior studies on antioxidant content of vitamin C, total phenolics and beta-carotene in juice blends. Based on Table 4, vitamin C content of carrot-apple-peach and carrot-apple-banana juice blends was higher than, only carrot-apple juice blends.

This shows that more type of different fruit blended together the antioxidant properties will be higher. Besides, vitamin C content of kinnow and anola juice blend increased from 21.15 mg/100ml and 45.70 mg/100ml respectively to 45.70 mg/100ml after mixed together (Bhardwaj and Mukherjee, 2011). Jan and Masih (2012) also found a similar trend of vitamin C increment after blending together pineapple, carrot and orange juice. However, antioxidant capacity such as vitamin C and vitamin B relatively heat sensitive compound which easily degrades at high temperature. Thus, UV-C treatment believed to have positive effects on the antioxidant retention in fruit juice.

Since minimal studies available in juice blend UV-C irradiated, single fruit juice was taken to give insight on the effectiveness of UV-C treatment on fruit juice. Prior studies on single fruit juice UV-C irradiated shows minimal changes in antioxidant and physicochemical properties with promising microorganism reduction after treatment as shown in Table 5. UV-C irradiated apple juice of *Golden*, *Straking* and *King David* varieties had no significant changes in physicochemical properties but show vitamin C degradation after UV-C (Falguera et al., 2011). Similarly, pomegranate juice also decreased in vitamin C content after UV-C treatment despite the well-maintained pH, titratable acidity and soluble solid content (Pala and Toklucu, 2011). The decrement of vitamin C content in fruit juice was related to the UV-C dosage induced by the treatment. Pala and Toklucu (2013) added that the higher the UV-C dosage, the greater degradation in vitamin C content will be observed. Shah et al. (2016) stated that vitamin C was an excellent UV light absorber and light sensitive in which too much exposure to light will degrade the amount of vitamin C in juice. In the meanwhile, pomegranate juice which rich in anthocyanin content showed minimal losses after UV-C treatment. Anthocyanin easily degraded and caused undesirable colour changes and browning with heat treatment in which such drawbacks was minimized through alternative UV-C treatment.

Table 5: Ultraviolet irradiation effects on fruit juice (TA, TPC, TSS is titratable acidity, total phenolics content and total soluble solid respectively)

Juice	Treatment	Effects	References
Apple	UV-C dosage: 3.88×10-7 E/min Time: 120 minutes	pH, sugar, TPC, TSS not significantly different. Lightness increase with less red colour. Vitamin C loss 7.5 to 70%	(Falguera et al., 2011)
Pomegranate	UV-C dose: 12.5 to 62.35mJ/cm² Flow rate: 20.21 m/s	pH, TA, TSS, TPC not significantly different. Anthocyanin losses 3.98 to 8.4%. Reduced 53.4 and 74.4% of aerobic plate count and yeast and mould counts respectively (at 62.35mJ/cm²).	(Pala and Toklucu, 2011)
Orange	UV-C dose:12.03 to 48.12 kJ/L Flow rate: 0.02L/s	pH, TA, TSS not significantly different. Vitamin C degraded higher at a	(Pala and Toklucu, 2013)

		higher dosage. Reduced 91 and 20.2% total aerobic and yeast and mould respectively. 5.72 log reduction of *E. coli* ATTC 25922	
White Grape	UV-C dose: 0 to 489 mJ/cm² Time: 0 to 15 minutes	5.5 log reduction of *A. acidoterrestris* spore at 489mJ/cm².	(Baysal et al., 2013)

Microbiological studies give information on the food safety and shelf-life. Thermal pasteurization well recognized as trusted technology in inactivation of pathogenic bacteria in food. Based on Table 5, the effect of UV-C treatment on single fruit juice was comparable to thermal pasteurization. *E. coli* ATTC 25992 in orange juice inactivated completely after treatment at a UV-C dosage of 60.15kJ/L (after 5 cycles), with 91% total aerobic count reduction (UV-C dosage of 48.12kJ/L). However, yeast and mould unable to be completely inactivated at 48.12kJ/L which due to bigger DNA structure of yeast and more resistant towards UV light (Shah et al., 2016). (çiĝdem U. Pala & Toklucu, 2013) and however, found deviated results in which yeast highly inactivated compared to total plate count in pomegranate juice. Baysal et al. (2013) found that white grape able to inactive spore of *A. acidoterrestris* at highest dosage of 498mJ/cm². In short, the effectiveness of microbial inactivation using UV-C treatment depends greatly on UV-C dosage. Thus, it can be predicted that effect of UV-C on pineapple-mango juice blend microbial inactivation (*E. coli* O157:H7) will be promising with suitable UV-C dosage induced.

Conclusion

Juice blending from different fruits proved to be promising in quality improvements, which give an insight into pineapple-mango juice blend. The blend of pineapple and mango at best blending ratio will result with great juice quality attributes of physicochemical, antioxidant and microbiological properties. Ultraviolet irradiation treatment able to maintain most of the nutritional content compared to thermal pasteurization. Thus, UV-C treatment on pineapple-mango juice blend will be greater in quality compared to thermally treated juice. This overview of the expected outcome of pineapple-mango juice blend ultraviolet irradiated will give new prospect in juice processing using non-thermal technology with enhancement of product quality.

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