

## UV-C effect on microbial disinfection of pineapple-mango juice blend using Dean-vortex technology

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### Abstract

This study intended to evaluate the effect of ultraviolet irradiation (UV-C) treatment of Dean-vortex technology on pineapple-mango juice blend microbial safety. Non-thermal alternative treatment of UV-C known to be promising in juice processing but low penetration depth in opaque liquid resulted in enhancement of treatment using dean vortex. Dean vortex promotes mixing in helically arranged treatment tube. Two pump frequency was selected (40 and 45Hz) to be performed on pineapple-mango juice blend at blending ratio of 70%pineapple and 30% mango. The flow regimes inside the polyfluoroalcoxy (PFA) tube behave as turbulence as the effect of dean vortex for both flow rates of the pump which brought the targeted microorganism closer towards light source relatively improve treatment efficiency. Pathogenic *E. coli* O157: H7 that can cause fatality was inoculated into pineapple-mango juice blends. This study shows that at a UV-C dosage of 8.38mJ/cm<sup>2</sup> able to reduce *E. coli* O157: H7 more than 5 log reduction. Although UV-C treatment unable to fully disinfect yeast and mould counts in pineapple-mango juice blend, the detection colony was still under the permissible limit (1.26 log CFU/mL). These proved that UV-C treatment with the implementation of dean-vortex technology able to meet the microbial load safety limit comparable to commercialize practice using thermal pasteurization.

## 1. Introduction

*Josapine* pineapple (*Ananas comosus*) and *Chok Anan* mango (*Mangifera indica*. L.) are among popular tropical fruit that widely planted in Malaysia. Due to the strong taste of pineapple, pineapple often blends together with other fruit (Jan and Masih, 2012) consequently, promoting new juice product. In contrast, mango is known for its sweet but easily deteriorate as an effect of storage and temperature (Raymundo *et al.*, 2009; Khaliq *et al.*, 2016). *Chok Anan* mango is a seasonal fruit but can be obtained almost throughout the year with harvesting time in May, June and August (Santhirasegaram *et al.*, 2013; Santhirasegaram *et al.*, 2015). The blending of pineapple and mango will results in new product development and reduce the dependency of seasonal stock.

Juice is defined as a product of direct consumption that obtained either by pressing or diffusion methods of fruits (British Soft Drinks Association, 2016). Whereas,

fruit juice blend define as mixture of different species of puree juices with or without the addition of sugar (Bates *et al.*, 2001; Lozano, 2006). Bhardwaj and Pandey (2011) added that juice blend extracted from two or more different types of fruits, puree or the edible part of fruit or any concentration still denoted as juice. Thus, any combination of liquid extracted from different species of fruits will be denoted as fruit juice as long as it meets the properties of fruit juice. At early years fruit juice intended as fresh consumption, but due to several outbreaks, FDA regulates that a 5 log reduction of pertinent microorganism must be achieved in fruit juice product (Kahraman *et al.*, 2017). *E. coli* O157: H7 is the most reported outbreak in unpasteurised fruit juice (Aneja *et al.*, 2014). Due to the arising awareness of food safety, it is mandatory for fruit juice to be pasteurized either by thermal or non-thermal means of juice processing. Thermal pasteurization is the most common method used commercially worldwide in manufacturing fruit juice products due to its broad ability in preserving

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Table 1. Non-thermal treatments on fruit juice blend

Non-thermal treatment	Juice blend	Processing conditions	Key finding (s)	References
Pulsed electric field (PEF)	Apple-cranberry	18Hz; 34 kV/cm; 1µs; 20°C	<i>E. coli</i> (K 12 DSM 1607) reduce to 4 log reduction	Palgan et al. (2011)
	Carrot-orange	18Hz; 24 kV/cm; 1µs; 89µs;<49°C	PME not fully inactive (14% of inactivation)	Caminiti et al. (2012)
High hydrostatic pressure	Apple-beetroot-carrot-ginger-lemon	400 to 600 MPa; 0 to 300 s; 11°C	Patulin decrease 45 ppb (0.29 µM) treated at 600 MPa for 300 s	Hao et al. (2016)
	Apple-mint-pineapple	400 to 600 MPa; 0 to 300 s; 11°C	Patulin decrease 48 ppb (0.31 µM) treated at 600 MPa for 300 s	Hao et al. (2016)
	Jucara-mango	600 MPa; 5 min; 25°C	No changes in anthocyanin content	Moreira et al. (2017)
	Orange-sweet pepper	550 MPa; 5 min; ~25°C	4 log reduction of total aerobic bacteria, yeast and molds	Xu et al. (2015)
Sonication	Blueberry-orange-pomegranate	130 W; 60%; 20 kHz; 4 and 6 min; <40°C	Inactivation of yeast <i>W. anomalous</i> (DSM 70130)	Bevilacqua et al. (2014)
	Mango-papaya	400 W, 24 kHz; 100%; 20 and 160 s	84% to 91% retention of ascorbic acid and higher carotenoid content	Carbonell-Capella et al. (2016)
Ultraviolet light	Carrot-orange	10.62 J/cm <sup>2</sup> ; 1 min	18% PME inactivation	Caminiti et al. (2012)
Pulsed light	Apple-cranberry	1.213 J/cm <sup>2</sup>	3 and 4 log reduction of <i>E. coli</i> (K 12 DSM 1607) and <i>P. fermentans</i> (DSM 70090) respectively	Palgan et al. (2011)
	Carrot-orange	3.3 J/cm <sup>2</sup> ; 360µs;<30°C	113% PME residual activity	Caminiti et al. (2012)
Manothermosonication	Apple-carrot	100 to 300 kPa; 15-75 s	5 log reduction of <i>E. coli</i> O157:H7 in 30 s for treatment at 60°C	Kahraman et al. (2017)

fruit juice (Goh et al., 2012). However, the quality of fruit juice such as the bioactive compound, nutrients and sensorial properties greatly degrade after thermal pasteurization as the effect of temperature (Kaya et al., 2015). Thus, alternative non-thermal treatment such as high-pressure processing, pulsed electric field, sonication and ultraviolet irradiation (Polydera et al., 2003; Moody et al., 2014; Koutchma et al., 2016; Roobab et al., 2018) was widely explored and studied to minimized the drawbacks of thermal pasteurization. Table 1 summarized the used of non-thermal technology on fruit juice blend. In term, of microbial inactivation high pressure processing (HPP) on orange-sweet pepper juice blend resulted with 4 log reduction of total aerobic bacteria, yeast and moulds (Xu et al., 2015), whereas sonication treatment on blueberry-orange-pomegranate juice blend was less effective in yeast inactivation (Bevilacqua et al., 2014). Pulsed light treatment on apple-cranberry juice blend shows 3 and 4 log reduction of *E. coli* (K 12 DSM 1607) and *P. fermentans* (DSM 70090) respectively. Based on the prior research, study on microbial inactivation of juice blend using ultraviolet irradiation (UV-C) treatment is still limited. Thus, the present study is intended to study the effectiveness of

UV-C treatment on pineapple-mango juice blend. Through numerous prior research, UV-C shows minimal degradation effect on single fruit juice quality attributes (Shah et al. 2016), which promising as an alternative to thermal pasteurization. Besides, compared to other non-thermal technology of PEF, HPP the treatment and equipment cost of UV-C treatment is minimal which can be done in ambient temperature (Rosnah et al., 2013).

UV-C treatment denotes as non-ionizing radiation, which is chemical free and ecologically friendly (Gómez-López et al., 2012) done at germicidal wavelength ranges from 200 to 280nm (Teja et al., 2017) with 254nm is the best wavelength in killing the microorganism (Santhirasegaram et al., 2015). However, penetration of UV-C light on the liquid foods especially opaque liquid is low due to the high UV light absorption and scattering (Koutchma, 2009), especially in turbid juice. Thus, application of Dean-vortex technology extensively explored to overcome the limitation. Dean-vortex technology in UV-C introduced mixing inside the coiled tube through secondary flow (centrifugal force) that perpendicular towards axial fluid direction as an effect of channel curvature (Chandratilleke et al., 2012;

Fsadni *et al.*, 2016). The effect of UV-C treatment on the microbe inactivation of pineapple-mango juice blend is yet to be discussed elsewhere. Single mango and pineapple juice both different in quality in which the blend of pineapple and mango together will result with juice quality different from their single juice counterpart. The effectiveness of UV-C treatment on microorganism inactivation depends greatly on juice turbidity in which, study by Kamarul Zaman *et al.* (2016) on pineapple-mango juice blend at blending ratio of 70% pineapple and 30% mango showed that of pineapple-mango juice blend ( $438 \pm 1.00$  NTU) less turbid than single mango juice ( $798 \pm 1.00$  NTU). Thus, this intended study was done to investigate the inactivation of *E. coli* O157: H7 (as selected pathogenic bacteria) by using UV-C of Dean-vortex technology in the pineapple-mango juice blend. Besides, the blend of pineapple-mango juice can be marketed as super juice as mango is regarded as super fruit. Lopez (2014) supported that, the blending of traditional fruit juice with exotic fruit promotes the development of juice with super fruit label. Therefore, the use of ultraviolet irradiation treatment on pineapple-mango juice blend may preserve the quality and nutritional content of juice as well as enhance the commercial value of the tropical fruit of Malaysia. Hashem *et al.* (2014) and Huang *et al.* (2009) added that consumer demands for functional foods with an excellent source of antioxidants and good organoleptic properties increase the interest of fruit juice blend in the market.

## 2. Materials and methods

### 2.1 Pineapple-mango juice blend preparation

*Josapine* pineapple and *Chok Anan* mango were obtained from the local retailer in Selangor. Both fruits were purchased at their commercial maturity. After cleaning, peeling and cutting pineapple and mango juice were extracted separately using juice extractor (Power Juice Smartshop, TM US) without the addition of water. In order to minimize the cloudiness and turbidity of fruit juice both pineapple and mango juice was centrifuge to separate the sediment from the juice. Besides, the centrifugation process was added due to the thick creamy-like of the extracted mango which made it unsuitable to be mixed together with pineapple. Both pineapple and mango juice were centrifuged separately at 8000 rpm for 15 mins (Benchtop Centrifuge, Universal 320/320 R, Hettich Zentrifugen, Germany) (Santhirasegaram *et al.*, 2015) and filtered with muslin cloth afterward. The juice then mixed together at blending ratio of 70% pineapple and 30% mango as it gives the best quality of juice after blending, as stated by Kamarul Zaman *et al.* (2016).

### 2.2 *E. coli* O157: H7 inoculation

*E. coli* O157: H7 was obtained in Tryptic Soy Agar (TSA) from Bacteriological Food Safety Laboratory, Food Science and Technology Faculty, Universiti Putra Malaysia. The colonies of *E. coli* O157: H7 was then cultured in Tryptic Soy Broth by taking a loop of the colony. The remaining colonies in the TSA kept refrigerated at 4°C for further use. Figure 1 shows the inoculation step of *E. coli* O157: H7. The cultured colonies were incubated at 37°C for 24 hrs (Gayán *et al.*, 2011) to give time for bacteria to replicates and re-growth. Next, 10 mL of the stock culture was taken and centrifuged at 500 rpm Benchtop Centrifuge, Universal 320/320 R. Hettich Zentrifugen, Germany) to obtain the cell pellet. Cell pellet then washed with 0.85% sodium chloride (NaCl) (Tosun and Gönül, 2006). To ensure the presence of *E. coli* O157: H7 serial dilution was done using 0.1% peptone water (range of  $10^{-1}$  to  $10^{-5}$ ). TSA and sorbitol McConkey agar (SMAC) (DifcoTM, Dickinson and Company, USA) were used for the detection of *E. coli* O157: H7. Both plates incubated at 37°C for 24 hrs. *E. coli* O157: H7 colonies observed will be pink in colour on the SMAC agar and colourless on TSA plate. After ensuring the presence of *E. coli* O157: H7 inside the stock culture, the bacteria inoculated into pineapple-mango juice blend. The inoculated juice sample then, refrigerated for an hour to before preservation treatment was done. The initial counts of the microorganism inside the pineapple-mango juice blend were analysed in serial dilution methods in triplicate.

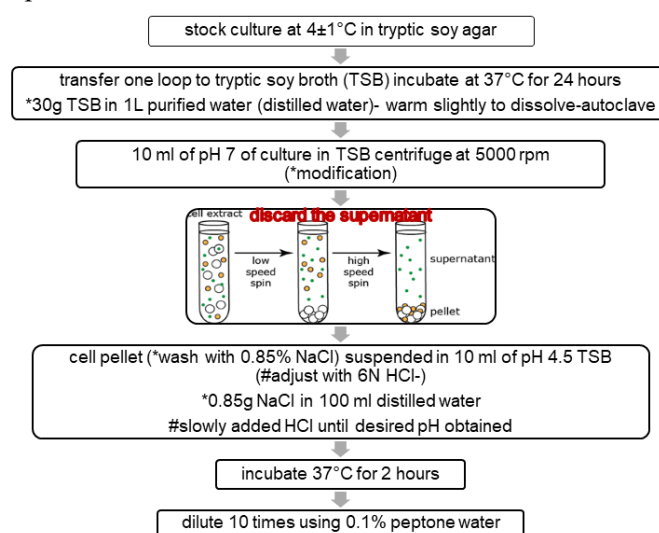


Figure 1. *E. coli* O157:H7 stock preparation

### 2.3 Microbiological analysis

Total plate counts (TPC) and Yeast and Mould counts (YMC) were also evaluated in this study. Plate count agar (Merk, Germany) was used for TPC plating and the plate was incubated at  $25 \pm 2^\circ\text{C}$  for 2 days. YMC

was done through plating on Dichloron rose Bengal Chloramphenicol (DRBC) agar and incubated for 5 days at 37°C. All experiments were done in triplicate.

The log reduction of microbial counts in pineapple-mango juice blend was calculated as follows:

Log reduction CFU/ml = Initial log counts before treatment – Final log counts after treatment

#### 2.4 Sample calculation for log reduction CFU/ml after UV-C treatment

The Initial log counts of microorganism in pineapple-mango juice blend was calculated as:

Log (total number of colonies × dilution factor)/volume culture plate.

Taking the Total plate counts (TPC) as example, the initial total number of colonies of aerobic microorganism were 446 with a dilution factor of 10<sup>5</sup> and volume of culture plate of 0.1. The final total number of colonies after UV-C treatment was 0 colony with dilution factor of 10<sup>1</sup> and 0.1 volume culture plate. The log reduction CFU/ml then determine as follows:

$$\begin{aligned} \text{Log reduction CFU/mL} &= 7.65 \text{ Log CFU/mL} - 0 \text{ Log CFU/mL} \\ &= 7.65 \text{ Log reduction CFU/mL} \end{aligned}$$

#### 2.5 Ultraviolet Irradiation (UV-C) treatment

Malaysia patent (PI201203186) ultraviolet reactor was used to treat pineapple-mango juice blend. A similar reactor was used to treat single pineapple (Mansor *et al.*, 2014; Mansor, *et al.*, 2017), tamarind (Mohd-Hanif *et al.*, 2016) and lime (Mohd-Hanif *et al.*, 2016) juice. The reactor consists of 6 quartz sleeve low mercury lamps (Philips, Malaysia) with 5 of the lamp was occupied with polyfluoroalcoxy (PFA) coiled onto the lamp. UV radiometer was installed in each lamp to measure the irradiance intensity of the lamp that will later use to calculate the UV-C dosage. The schematic diagram of the ultraviolet reactor as illustrated in Figure 2. In the present study, only one coiled lamp and the middle lamp was used in order to test the efficiency of the ultraviolet reactor following the previous study by Mansor *et al.* (2014) and Mansor *et al.* (2017). A total of 5 L of pineapple-mango juice blend inside the feed tank flowed into the rotary lobe pump into PFA tube that helically arranged around UV lamp. The time taken for the juice to flow out from the reactor to the collecting tank was taken manually using stop watch. The UV-C dosage was determined using equation as indicate by Mansor *et al.* (2017). The irradiance intensity was obtained directly from the UV radiometer, while the residence time distribution obtained by dividing the volume of PFA tube (0.1 m<sup>3</sup>) with juice flow rate.

$$\text{Dose (mJ/cm}^2\text{)} = \text{Irradiance intensity (mW/(cm}^2\text{))} \times \text{Residence time distribution (RTD) (s)}$$

Other parameter that important for ultraviolet irradiation treatment with dean-vortex technology is Dean number (*De*) (Moulin *et al.*, 1996):

$$De = Re \sqrt{\frac{Di}{Dz}}$$

Where *Di* and *Dz* are internal diameter of tube (0.00165 m) and coiled diameter (0.0032 m) respectively.

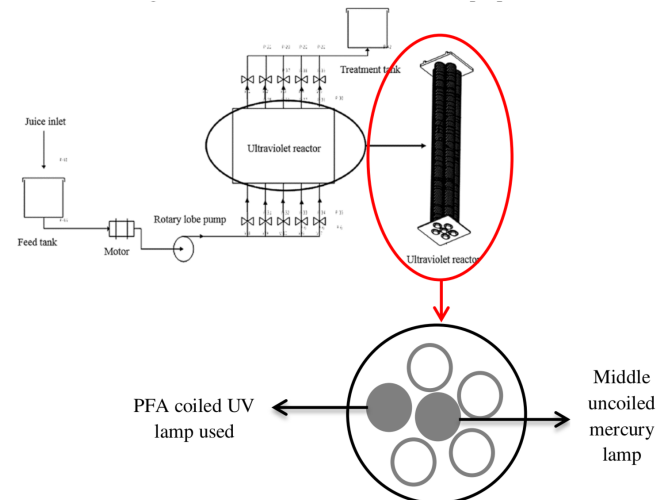


Figure 2. Schematic diagram of the ultraviolet reactor (Adapted from (Mohd-Hanif, Shamsudin, and Adzahan (2016))

#### 2.6 Thermal pasteurisation

Thermal pasteurisation was done as a comparison to the non-thermal treatment of UV-C done on pineapple-mango juice blend. Treatment was done at 90°C for 5 mins using batch pasteuriser (P9000, Elecrem, France). Pineapple-mango juice blend was tightly capped in the sterilised glass bottle before submerged into the pasteuriser using water bath system to minimize the effect heat on juice quality (Hounhouigan *et al.*, 2014).

All the experimental work was done in triplicate.

### 3. Results and Discussion

#### 3.1 UV-C dosage for inactivation of *E. coli* O157: H7 in pineapple-mango juice blend

Pineapple-mango juice blend of pH 4.32±0.02 with turbidity value of 438 NTU was treated with the ultraviolet reactor at 2 different pump frequency (40 and 45 Hz). The selected pump frequency will later affect the flow rate of the juice flowing inside the UV-C reactor. Table 2 shows the parameters obtained at the two different pump frequency selected.

Juice pumped at lower pump frequency resulted in lower flow rate. Based on Table 1, juice pump at 40 Hz

Table 2. UV-C parameters at a different pump flow

Pump frequency (Hz)	Flow rate (L/s)	RTD(s)	UV-C dose (mJ/cm <sup>2</sup> )	Reynolds no (Re)	Dean number (De)
40	0.012±0.001 <sup>a</sup>	8.65±0.003 <sup>a</sup>	8.38±0.079 <sup>a</sup>	5093±1.357 <sup>a</sup>	995.73±0.668 <sup>a</sup>
45	0.014±0.001 <sup>a</sup>	7.28±0.003 <sup>b</sup>	6.47±0.059 <sup>b</sup>	6053±2.969 <sup>b</sup>	1183.37±0.971 <sup>b</sup>

RTD=residence time distribution. A value followed by the same letter within the same column not significantly different from each other ( $p>0.05$ ).

having juice flow rate of 0.012 L/s while at 45 Hz the flow rate of juice was slightly higher at 0.014 L/s. Flow rate affects the RTD and UV-C dosage induced as lower flow rate resulted with longer residence time distribution (RTD) and higher UV-C dosage. The present study shows consistency with the prior studies by Mansor *et al.* (2014), and Mohd-Hanif *et al.* (2016) on single pineapple and lime juice respectively, in which at lower pump frequency selected the UV-C dosage was higher. Such phenomenon happened due to the longer time of interaction for the juice flowing with the light source. Mansor *et al.* (2014) added that high frequency resulted with lower RTD and relatively caused the juice flow rate to be higher, hence lowering the UV-C dose.

The parameter of flow rate later affects the flow pattern inside the PFA coiled tubing of the UV-C reactor. Higher flow rate (0.014 L/s) resulted with more turbulence flow (6053±2.969) of pineapple-mango juice blend inside the PFA coiled tubing as tabulated in Table 2. The Reynolds number (Re) denoted as turbulence at value >4000 and recognized as laminar at value <2000. The present study shows deviation from Mansor *et al.* (2014) as UV-C treatment on single pineapple juice using the same UV-C reactor having laminar flow pattern (ranging from 396±10.4 to 610±15.4) at the UV-C dose ranging from 10.10±0.7 to 13.75±1.5 mJ/cm<sup>2</sup>. Laminar flow pattern may cause inconsistency of UV-C dose distribution along the ultraviolet reactor (Koutchma *et al.*, 2004). Pineapple-mango juice blend exhibit turbulent flow pattern for both designated pump frequency which may be contributed by the juice properties of turbidity. Pineapple-mango juice blend was less turbid (438 NTU) compared to single pineapple juice which having turbidity value of 1441.25±43.45 NTU (Shamsudin *et al.*, 2014). The turbidity of pineapple-mango juice blend was reduced during processing by centrifugation method. Juice turbidity affects the UV-C treatment efficiency due to the scattering of light and shadowing effect on microbes (Mohd Adzahan *et al.*, 2011). Turbulence flow more effective in microorganism disinfection as the targeted microorganism brought closer to the ultraviolet light source (Koutchma *et al.*, 2007). Apple juice and apple cider recorded a higher log reduction of *E. coli* O157: H7 in turbulent treatment compared to laminar flow treatment (Sauer and Moraru, 2009).

In the Dean-vortex technology of UV-C reactor, an

internal mixing promotes better microorganism inactivation. The dean effect during the UV-C treatment was represented by the Dean number (De). At higher Re, the dean effect was more prominent. Based on data obtained in Table 2, at Re value of 5093±1.357 and 6053±2.969, the De values were 995.73±0.668 and 1183.37±0.971 respectively. A similar trend of De increase with the increment of Re value observed in the study by Mansor *et al.* (2014) and Müller *et al.* (2011) on single pineapple and apple juice. De value >100 indicate the greater effect of mixing (Johnson and Kamm, 1986) which increased the momentum, mass transfer, heat transfer and Reynolds number which contribute to decrement in axial dispersion (Irudayaraj, 2002). Despite the greater mixing effect obtained at higher Re value in the present study, the treatment at UV-C dosage of 8.38mJ/cm<sup>2</sup> (obtained at lower Re value of 5093±1.357) was selected as the best dosage due to its greater microbial inactivation. Too turbulent flow pattern may cause instability of fluid flow thus, mixing of fluid unable to be done perfectly (Mansor *et al.*, 2014; Mohd-Hanif *et al.*, 2016). Nikolof *et al.* (2013) added that uniform mixing inside the ultraviolet reactor is crucial for effective irradiation effect on the fluid treated.

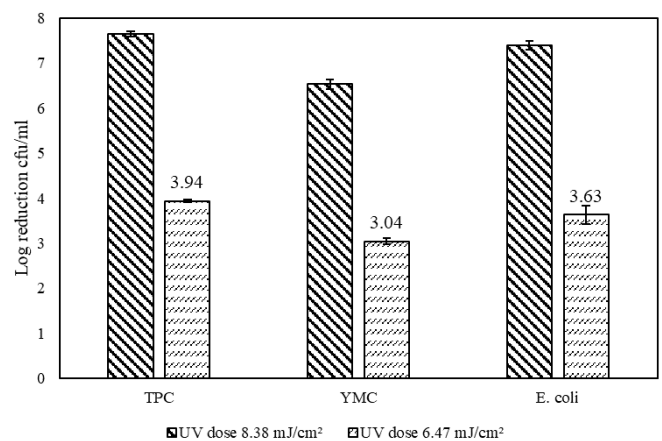


Figure 3. Microorganism inactivation at the different UV-C dosage (TPC, YMC and *E. coli* are total plate count, yeast and mould count, and *E. coli* O157: H7 respectively)

Referring to Figure 3 on inactivation of microorganism at UV-C dosage of 8.38 mJ/cm<sup>2</sup> and 6.47 mJ/cm<sup>2</sup> was greater. The unstable turbulence flow at higher pump frequency caused the microorganism unable to be fully exposed to the UV-C light source thus, reduced the killing rate of the microorganism (Mohd-Hanif *et al.*, 2016). *E. coli* O157: H7 initial counts of 7.4 log CFU/mL was completely inactive resulted with 7.4



log reduction after treatment at UV-C dose of 8.38 mJ/cm<sup>2</sup>. Previous study by Keyser *et al.* (2008) on inactivation of *E. coli* O157: H7 in apple juice at UV-C dosage of 14 mJ/cm<sup>2</sup> resulted with 6.65 log reduction which meets the FDA regulation of 5 log reduction of a pertinent pathogen in fruit juice (FDA, 2004) showing the effectiveness of ultraviolet irradiation treatment in pathogenic bacteria inactivation. The present study resulted with lower UV-C dosage needed by pineapple-mango juice blend to achieve more than 5 log reduction of microorganism compared to the study by Keyser *et al.* (2008) due to the centrifugation process done during juice preparation to reduce the limitation of ultraviolet treatment on turbid and high opacity fluid. Opaque juice having absorption coefficient ranging 40 to 100 cm<sup>-1</sup>, will be unable to meet the requirement of 5 log reduction of the pertinent microorganism (Koutchma, 2009). In the present study, however, the opacity of the pineapple-mango juice blend was not measured. Higher turbidity juice resulted with high opacity in which in the present study the juice turbidity value categorized as less turbid as the value is less than 600 NTU (Benitez *et al.*, 2007a; Benitez *et al.*, 2007b). Caminiti *et al.* (2012) supported that apple juice only requires a low dosage of ultraviolet treatment compare to orange juice to effectively inactive *E. coli* K12 as apple juice was less turbid than orange juice.

The present study resulted with YMC log reduction at UV-C dosage of 8.38 mJ/cm<sup>2</sup> was the lowest compared to TPC and *E. coli* O157: H7, but still more than 5 log reduction. While, at 6.47mJ/cm<sup>2</sup> UV-C dose, YMC (3.04 log reduction), TPC (3.94 log reduction) and *E. coli* O157: H7 (3.63 log reduction) log reduction was under the permissible limit indicate inadequate dosage induce for the treatment. Franz *et al.* (2009) study on cloudy apple juice applying the dean vortex technology of ultraviolet irradiation treatment also obtained similar observation of lower log reduction of yeast and lactic acid (3 log reduction) as compared to *E. coli* (5 log reduction). According to Bhat, Kamaruddin *et al.* (2011) due to the bigger DNA structure of yeast it exhibits greater resistant towards chemical changes which require a higher dosage to be inactivated. However, UV-C treatment at 0.032W/cm<sup>2</sup> resulted with no detection of a microorganism of yeast and mould, and mesophilic bacteria in apple juice (Juarez-Enriquez *et al.*, 2016) indicate the dosage induce was enough to inactive the microorganism below the detection limit.

### 3.2 Comparison with thermal pasteurization

Thermal pasteurization was known to be widely used in juice processing industry as it proven to be effective to kill microorganism in fruit juice. Table 3 shows the initial microbial counts in pineapple-mango juice blends before and after treatment with thermal and UV-C. From the data obtained, UV-C treatment with dean vortex technology was effective in inactivation of *E. coli* O157: H7 in pineapple-mango juice blend comparable to thermal pasteurization. As far as the author's concern, there was no reported study on inactivation of *E. coli* O157: H7 on juice blend (pineapple-mango juice blend specifically) applying the dean vortex technology, however, several studies on single fruit juices were available. *E. coli* O157:H7 effectively inactive up to 5 log reduction in apple cider (Basaran *et al.*, 2004), orange (Oteiza *et al.*, 2010), clear apple juice (Gabriel, 2012; Usaga *et al.*, 2017) and tamarind juice (Mohd-Hanif *et al.*, 2016) after treatment with UV-C irradiation with dean vortex technology.

Based on the results obtained in Table 3, the yeast and mould after UV-C treatment was not fully inactive due to the higher resistant of yeast and mould towards UV-C light. However, the yeast and mould count (YMC) was still lower than 5 log CFU/mL. The effectiveness of UV-C on cell destruction of microorganism depends on the sensitivity of microorganism towards the UV-C light as different microorganism reacts differently (Tran and Farid, 2004). As mention earlier, yeast and mould having DNA size bigger than another microorganism of *E. coli* O157: H7 and aerobic microorganism which scatter and block the UV-C penetration.

### 4. Conclusion

UV-C treatment at UV-C dosage of 8.38±0.079 mJ/cm<sup>2</sup> able to fully inactive the *E. coli* O157:H7 in pineapple-mango juice blend. The dean vortex technology helps to promote mixing in the PFA coiled tube which relatively improves the efficiency of microbial inactivation. The present study can be improved in the future by varying the selection of pump frequency to increase the inactivation rate of yeast and mould that shows greater defends towards UV-C light. Besides, the effect of juice optical density and viscosity may be studied as the information can be used to increase the effectiveness of UV-C treatment. Comparison with thermal pasteurization shows that UV-

Table 3. Microbial counts at difference pasteurisation treatment

Treatment	TPC (log CFU/mL)	YMC (log CFU/mL)	<i>E. coli</i> O157: H7 (log CFU/mL)
Fresh juice	7.65±0.052	7.79±0.102	7.40±0.096
UV-C (8.38mJ/cm <sup>2</sup> )	0	1.26±0.107	0
Thermal pasteurization (90°C, 5 min)	0	0	0

(TPC and YMC are total plate count, yeast and mould count respectively)

C irradiation treatment with dean vortex technology can be considered to be implemented in juice processing industry in Malaysia as it shows a promising effect on juice safety.

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