



UNIVERSITI PUTRA MALAYSIA

***EFFECT OF ULTRAVIOLET IRRADIATION WITH DEAN VORTEX
TECHNOLOGY ON QUALITY OF PINEAPPLE-MANGO JUICE BLEND***

AMANINA AMANI BINTI KAMARUL ZAMAN

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By

AMANINA AMANI BINTI KAMARUL ZAMAN

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in
Fulfilment of the Requirements for the Degree of Master of Science**

July 2018

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of
the requirement for the degree of Master of Science

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Conventional thermal pasteurisation is more preferable by juice processor in microorganism inactivation due to its effectiveness but results in nutritional and quality degradation. Due to that, the alternative non-thermal technology of ultraviolet-irradiation (UV-C) gaining interest to minimise the stated effects. Application of UV-C in single fruit juice already well explored compared to a juice blend. Thus, this present research aimed to investigate the effect of UV-C on the quality attributes of pineapple-mango juice blend. Pineapple-mango juice blend at blending ratio of (pineapple to mango) 70:30 (v/v), exhibit best results of ascorbic acid, total phenolic with lowest turbidity value compared to blending ratios of 50:50 and 30:70. Colour appearance of pineapple-mango juice blend at all different blending ratios was not significantly different. Pineapple-mango juice blend at blending ratio of 70:30 were selected for further preservation treatment. UV-C dosage of 8.38mJ/cm² able to reduce the microbial load (*Escherichia coli* O157: H7, total plate count, yeast and mould count) to safety limit of 5-log reduction. Storage of 9 weeks at 4°C of pineapple-mango juice blends resulted in significant changes in pH, total soluble solids, turbidity and DPPH assay ($p<0.05$) of untreated, thermal and UV-C treated juice. Although, the ascorbic acid and total phenolic content of UV-C treated pineapple-mango juice blend was decreasing ($p<0.05$) the values were higher compared to thermally treated juice. Colour degradation (lightness, hue, chroma, browning index, colour difference (ΔE) and non-enzymatic browning) of thermally treated pineapple-mango juice blend was also prominent in thermally treated juice compared to UV-C treated juice. During storage, reoccurrence of microbiological activities of UV-C and thermally treated pineapple-mango juice blend observed starting at week 3 and 5 respectively. Kinetic model of ΔE during storage of the untreated and thermally pineapple-mango juice blend fitted to zero order model, while UV-C treated fitted to first order. Ascorbic acid degradation of untreated, UV-C and thermally treated pineapple-mango juice blend best fitted to modified first order model indicate storage time together with other parameter such as pH, temperature and oxygen contribute to the degradation rate. The present study showing promising effect of UV-C treatment in preserving the quality of pineapple-mango juice blend.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

**KESAN SINARAN ULTRA-UNGU DENGAN TEKNOLOGI DEAN VORTEX
TERHADAP KUALITI JUS CAMPURAN NANAS-MANGGA**

Oleh

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Pempasteuran termal secara konvensional lebih disukai oleh pengusaha jus untuk menyahaktif mikroorganisma kerana keberkesananya tetapi mengakibatkan degradasi nutrisi dan kualiti. Justeru, teknologi alternatif bukan termal, sinaran ultra-ungu (UV-C) semakin menarik perhatian bagi mengatasi kesan pempasteuran termal. Penggunaan UV-C dalam pemprosesan jus buah tunggal telah diterokai secara meluas berbanding jus campuran. Oleh itu, penyelidikan ini dijalankan untuk mengkaji kesan UV-C terhadap kualiti jus campuran nanas-mangga. Jus nanas-mangga dengan nisbah campuran (nanas kepada manga) 70:30 (v/v), mempamerkan hasil terbaik bagi kandungan asid askorbik, fenolik dan nilai kekeruhan paling rendah berbanding nisbah campuran 50:50 dan 30:70. Warna jus campuran nanas-mangga tidak menunjukkan perubahan yang begitu ketara. Jus campuran nanas-mangga dengan nisbah campuran 70:30 telah dipilih untuk rawatan lanjut. Dos UV-C sebanyak 8.38mJ/cm² dapat mengurangkan beban mikrob (*Escherichia coli* O157: H7, jumlah bakteria, yis dan kulapuk) kepada had keselamatan 5-log pengurangan. Penyimpanan jus campuran nanas-mangga selama 9 minggu pada suhu 4°C menunjukkan perubahan ketara dari segi pH, pepejal larut, kekeruhan dan antioksidan DPPH ($P<0.05$) bagi jus yang tidak dirawat, pempasteuran haba dan UV-C. Walau bagaimanapun, asid askorbik dan jumlah kandungan fenolik jus campuran nanas-mangga yang dirawat dengan UV-C menurun semasa penyimpanan tetapi nilainya lebih tinggi berbanding yang dipasteur. Degradasi warna (kecerahan, kepekatan, saturasi, indeks keperangan, perbezaan warna (ΔE) dan keperangan-bukan-enzymatik) jus campuran nanas-mangga menunjukkan perubahan yang lebih ketara berbanding jus yang dirawat dengan UV-C. Semasa penyimpanan, kemunculan aktiviti mikrobiologi bakteria bagi jus yang dirawat dengan UV-C dan pempasteuran termal dilihat pada minggu ke 3 dan 5 penyimpanan masing-masing. Model kinetik ΔE bagi jus campuran nanas-mangga semasa penyimpanan bagi jus yang tidak dirawat dan jus dipasteur sesuai dengan model kinetik sifar manakala jus yang dirawat dengan UV-C sesuai dengan model kinetic pertama. Asid askorbik model untuk jus campuran nanas-mangga yang tidak dirawat, dipasteur dan dirawat dengan UV-C menunjukkan kesesuaian dengan model kinetic pertama ubahsuai menunjukkan kesan masa penyimpanan mempengaruhi degradasi asid askorbik bersama dengan parameter lain seperti, pH, suhu dan oksigen yang menyumbang kepada kadar degradasi. Kajian ini memperlihatkan kesan rawatan UV-C dalam mengekalkan kualiti jus campuran nanas-mangga.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
CFU	Colony forming units
DRBC	Dichloro Rose Bengal
FDA	Food Drug Administration
MAC	MacConkey Agar
TA	Titratable acidity
TSA	Tryptic Soy Agar
TSB	Tryptic Soy Broth
TPC	Total phenolic content, Total plate count
TSS	Total soluble solids
UV	Ultraviolet irradiation
UV-C	Ultraviolet irradiation-C

CHAPTER 1

INTRODUCTION

1.1 Overview

Trends of consuming juice had been rising each year due to the diverse health benefits of fruit juice (Pina-Pérez, Rodrigo, & Martinez, 2014) with increment of 40% and 33% of new juice product in Europe and Asia-Pacific region respectively (Štbac, M., Savić, 2010). Consumer demands for fresh like and natural fruit juice products for consumption to gain maximum nutritional benefit of fruit juice. Unfortunately, fresh juice easily spoiled with food borne microorganism which relatively affect the quality attributes and shorten juice shelf life. Several outbreaks related to spoiled fresh juice were reported (Aneja et al., 2014) in which 16 cases of *Escherichia coli* O157: H7 outbreak was reported beginning in the year of 1980 in Canada involving apple cider as transmitting agent followed by outbreak in Massachusetts due to consumption of unpasteurised apple cider. Outbreak of *Salmonellosis* with 62,298 and 400 no of cases was reported in 1995 and 1999 respectively in United States, Canada and Australia due to consumption of unpasteurised orange juice (Wareing & Davenport, 2007). The scenario has been one of the challenges faced by the juice manufacturing industry in producing microbiologically safe and consumable fruit juice.

Thermal pasteurization is the most common practice in juice processing industries as it effective in destroying common spoilage microorganism in fruit juice. However, thermal pasteurisation unable to meet consumer preference as it results with non-enzymatic browning, loss of nutrients and massive degradation of heat sensitive antioxidant (Remini et al., 2015). This promotes a potential market for minimally processed fruit juice, which opened new possibilities of fruit juice utilization using novel technologies for preservation.

In order to meet the consumer needs, non-thermal technologies as alternative methods explored in providing milder processing condition (Caminiti et al., 2012). Ultraviolet irradiation using UV light spectrum C (UV-C) is a non-thermal technology inducing chemical modification on the DNA of microorganism cell by blocking DNA transcription and replication, consequently causing cell damage (Guerrero-Beltran and Barbosa-Canovas, 2004). UV-C having wavelength ranging from 200 to 280 nm known to have germicidal effect on microorganism (Gautam et al., 2017; Mansor, Shamsudin, Mohd Adzahan, & Hamidon, 2017). The use of UV-C proved to be environmentally safe without any by-product produced after treatment (Koutchma et al., 2016). Quality of fruit juice ultraviolet irradiated also showed better retention in heat sensitive nutrients compared to thermally treated juice (Goh et al., 2012; Santhirasegaram et al., 2015; Tikekar et al., 2011; Tran & Farid, 2004).

1.2 Research background

Fruit juice blend or commercially known as mixed fruit juice gain attention due to its improved taste and nutritional content from the effect of combining two or more different types of fruit juices. Pineapple and mango are among two important commodities of Malaysia plantation sector (Hossain, 2016; Jahurul et al., 2015). The mixed pineapple and mango fruit as juice blend promotes new flavour which distinct in taste from their respective single fruit juice. Conventional thermal pasteurisation widely implemented in juice processing manufacturing in Malaysia and up to date, none has ever practiced alternative technology of non-thermal ultraviolet irradiation treatment commercially.

Application of UV-C on commercialise fruit juice have been implemented in small and medium scale industry in another country such as United States. UV-C is a safe alternative to conventional thermal pasteurization as it do not results with toxic product or by-product with added advantages of no off-flavour and off-odour after treatment (Koutchma, 2009). However, low penetration depth and homogenization of juice during processing become main limitation leads to further improvement with application of dean vortex technology. Dean vortex define as secondary flow developed from the different in pressure between the internal and external wall of a helically arranged tube or channel (Moulin, Rouch, Serra, Clifton, & Aptel, 1996). Ultraviolet irradiation with dean vortex technology promotes radial mixing of the fluid inside the coiled tube promote more reduction of viable microorganism (Franz et al., 2009).

1.3 Problem statement

Juice blending is a method of utilizing fruits to overcome the supply shortage (Azlina, Abdul, & Abdul, 2014) and enhance the fruit quality and marketability. Pineapple and mango among are 15 tropical fruits in Malaysia that is expected to generate national gross income in 2020 (Ding & Mijin, 2013). However, pineapple fruit easily affected by blackheart disorder (also known as “endogenous brown spots” and “internal browning”) which is temperature related physiological disorder that inhibit development of dark spots in flesh areas near to the core (Hassan et al., 2010) causing off-flavour and off-colour (Latifah et al., 2016). Pineapple of *Josapine* variety able to survive up to a week at 10°C (Hassan et al., 2010). Similarly, mango fruit easily deteriorate due to tropical weather of Malaysia which accelerate fruit ripening, as high temperature and relative humidity with intense sunlight fasten the metabolic process (Khaliq et al., 2016; Léchaudel and Joas, 2007; Raymundo et al., 2009). Besides, under commercial practice, mangoes arrived the market almost ready for consumption, having only a few days (2-3days) left for marketing and causing high losses and problem to the seller (Pauziah et al., 2014). *Chok Anan* mango has a large stock annually, but easily deteriorate at ambient temperature. Thus, pineapple and mango utilized into juice to extend their shelf life. Pineapple juice without any added additives or sugar often not really suitable to be consumed alone due to its strong taste (Jan & Masih, 2012; Kortbech-Olesen, 1997; Shamsudin et al., 2014). Blending together pineapple and mango could result in a juice blend or mixed fruit juice product with enhancement of nutritional quality and better sensory acceptability when compared to

the raw materials (pineapple and mango). The quality characteristic will depend on the ratio of juice blended together. A study on best blending ratio of pineapple-mango juice blend with excellent nutritional quality was not yet reported elsewhere.

Thermal pasteurisation widely implement in Malaysia juice manufacturing to effectively kill microorganism. The FDA recommended 5-log reduction of infectious pathogen in a fruit juice, which can be achieved by pasteurisation at 90-95°C which effective against *E. coli* (Strawn, Schneider, & Danyluk, 2011). *E. coli* O157: H7 is associated with massive number of outbreaks due to consumption of unpasteurized fruit juice (Aneja et al., 2014). Although, both pineapple and mango have acidic pH, acid adapted *E. coli* O157H7 have been able to survive in pineapple juice for 3 days at 4°C and 25°C (Strawn et al., 2011), and detected in commercial mango juice (Hsin-Yi & Chou, 2001). The pineapple was planted on ground, which susceptible for contamination from pathogenic microorganism. In the meanwhile, improper handling and harvesting of mango fruits may cause the fruit to fall on the ground and get contaminated. Tribst et al. (2009) stated that faeces that contaminate the fruit surface can contaminate the washing water and permit internalization of food borne pathogens in fruit juice. Thermal pasteurization excellent in microbial inactivation but, result in nutritional loss, off-flavour and browning of juice. UV-C is a promising non-thermal technology to be applied as alternative in fruit juice processing. Despite the advantages of minimal nutritional loss after UV-C treatment, the inactivation rate of microbial inactivation is lower due to the low penetration of UV light towards the DNA of microorganism in fruit juice as effect of juice opacity. Thus, implementation of UV-C treatment with added dean vortex technology believed to be able to overcome such issue. Dean vortex promotes mixing of liquid flow inside the UV-C reactor, bringing the fluid to be closer towards the UV-light source, hence improves the inactivation rate. Presently, the use of UV-C treatment with dean vortex technology on pineapple-mango juice blend was not yet explored. Fresh mango juice without added water more viscous compared to pineapple juice thus, the blend of the two will have different quality properties compared to their single juice counterpart, which will require different UV-C treatment condition or parameter (flow rate) in determination of suitable UV-C dosage for microbial inactivation.

1.4 Objectives

This study aims to investigate UV-C performance on pineapple-mango juice blends for inactivation of pathogenic microorganism. The objectives for this study divided as follows:

1. To determine the best blending ratio of pineapple-mango juice blends.
2. To determine the best UV-C dosage for *Escherichia coli* O157: H7 inactivation of pineapple-mango juice blend.
3. To compare the effects of UV-C irradiation on the physicochemical and microbiological properties of pineapple-mango juice blend during storage (4°C, 9 weeks) with thermal pasteurization.
4. To fit the kinetic model of the selected quality attributes of pineapple-mango juice blend during storage.

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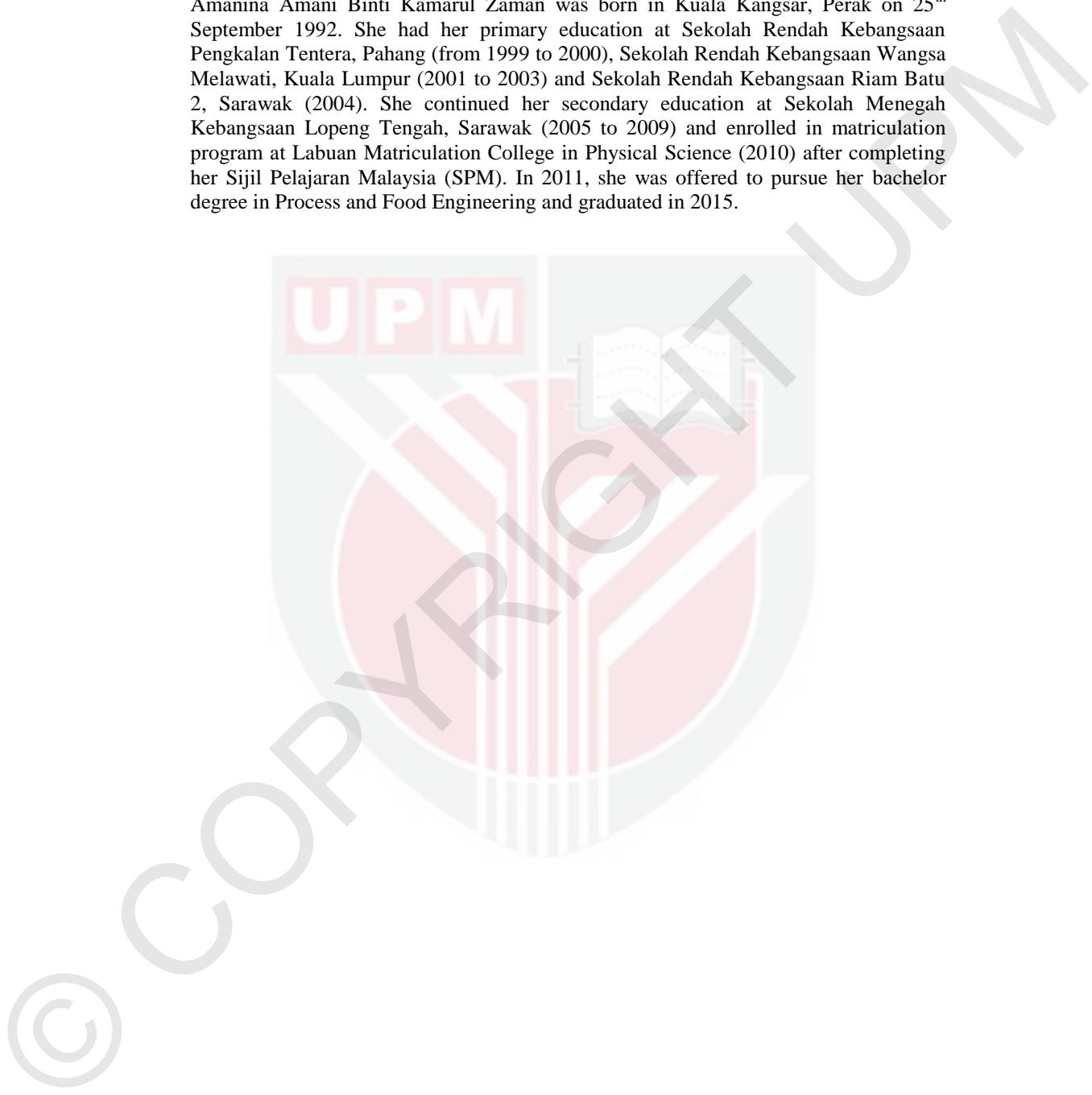
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LIST OF PUBLICATIONS

Articles – Publish

Kamarul Zaman, A. A., Shamsudin, R. and Mohd Adzahan, N. (2016). Effect of blending ratio on quality of fresh pineapple (*Ananas comosus* L.) and mango (*Mangifera indica* L.) juice blends. International Food Research Journal, 23 (Suppl): S101-S106.

Amanina Amani KAMARUL ZAMAN, Rosnah SHAMSUDIN, Noranizan MOHD ADZAHAN, and Alifdalino SULAIMAN, (2017). Effect of Ultraviolet Irradiation (UV-C) on quality attributes of pineapple-mango juice blend compare with thermal pasteurization. Pertanika Journal of Scholarly Research Reviews, 3(2): 33-44.

Articles – Accepted

Amanina Amani Kamarul Zaman, Rosnah Shamsudin, Noranizan Mohd Adzahan, and Alifdalino Sulaiman. UV-C effect on microbial disinfection of pineapple-mango juice blend using Dean-vortex technology. FR-2018-113. Food Research Journal

Articles – Submitted

Amanina Amani Kamarul Zaman, Rosnah Shamsudin, Noranizan Mohd Adzahan, and Alifdalino Sulaiman. Shelf-stable changes of pineapple-mango juice blend UV-C treated.IFSET_2018_713. International Journal of Food Science and Technology

Amanina Amani Kamarul Zaman, Rosnah Shamsudin, Noranizan Mohd Adzahan, and Alifdalino Sulaiman. Comparison of UV-C and thermal pasteurisation for the quality preservation of pineapple-mango juice blend. Food Research Journal.

Proceedings

Kamarul Zaman, Amanina Amani and Shamsudin, Rosnah and Mohd Adzahan, Noranizan and Sulaiman, Alifdalino (2017). Shiga toxin Escherichia coli survival in different blending ratio of fresh pineapple-mango juice blends. In: International Food Research Conference (IFRC 2017), 25-27 July 2017, Complex of the Deputy Vice Chancellor (Research and Innovation), Universiti Putra Malaysia. (pp. 17-20)

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Amanina Amani Kamarul Zaman, Rosnah Shamsudin, Noranizan Mohd Adzahan, Alifdalino Sulaiman (2018) Efficacy of Ultraviolet Irradiation on Shiga toxin Escherichia coli Inactivation of Pineapple-Mango Juice Blend. In: MSAE Conference 2018, 7-8 February 2018, Faculty of Engineering Universiti Putra Malaysia, Universiti Putra Malaysia



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