UNIVERSITI PUTRA MALAYSIA

PERFORMANCE OF UVC IRRADIATION WITH DEAN VORTEX TECHNOLOGY ON CLEAR AND TURBID TAMARIND (TAMARINDUS INDICA L.) JUICE

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By

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PERFORMANCE OF UVC WITH DEAN VORTEX TECHNOLOGY ON CLEAR AND TURBID TAMARIND (*Tamarindus Indica* L.) JUICE

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Tamarind juice is commonly treated by thermal treatment to inactivate microorganisms. However, thermal treatment causes changes in appearance and taste of tamarind juice. Ultraviolet (UV) irradiation has emerged as an alternative to thermal processing. Nonetheless, the application of UV irradiation on tamarind juice is not sited in the literature. In addition, the implementation of UV system with Dean Vortex technology are still limited. Therefore, the present study was aimed to investigate the performance of UVC irradiation on the quality and microbial reduction of clear and turbid tamarind juice. Results of microbiological analyses showed that UVC dosage of 35 mJ/cm^2 was found effective in reducing microbial load to a 5-log reduction. The survival curves of viable bacteria (*Escherichia coli* and native microflora) were best-fitted with the log linear with tailing model (R^2 =0.999). UVC treatment significantly reduced the total soluble solids of tamarind juice by 18-21% ($p<0.05$) but successfully retains the pH, titratable acidity and colour of tamarind juices ($p>0.05$). Differences in turbidity were significant in UVC-treated clear tamarind juice as UVC dosage increases. Dean Vortex technology was able to reduce the influence of turbidity in UV treatment. In comparison to thermal treatment, the inactivation of microbes by UVC treatment were not as efficient. Thermally treated juice exerted a good resemblance to UVC-irradiated juice in terms of pH, titratable acidity and colour. It also retained the total soluble solids of tamarind juice better than UVC-irradiated juice. Nonetheless, the differences in turbidity were significant ($p<0.05$) after thermal treatment especially in clear tamarind juice. During seven weeks of storage, the pH of tamarind juices had changed significantly ($p<0.05$). Total soluble solids had increased ($p<0.05$) in clear tamarind juice after storage period. The titratable acidity of thermally-treated clear tamarind juice had increased from 0.43% to 0.48% ($p<0.05$) whereas the titratable acidity of UVC-irradiated turbid tamarind juice decreased from 0.40% to 0.30% ($p<0.05$). In terms of turbidity, UVC-treated juices showed the lowest turbidity values compared to fresh and thermally-pasteurised juice after seven weeks. On the other hand, there were no effects of different treatments on the lightness, hue angles and chroma after seven weeks of storage. UVC-treated juice exerted the lowest overall changed in colour throughout seven weeks of storage. From microbial analysis, UVC-treated juice showed good stability of viable bacteria during storage. Nonetheless, tamarind juice was spoiled due to outgrowth of yeast and mould after two weeks. Contradictory, thermal treatments successfully retained microbial loads to below detection level during refrigerated storage. In conclusion, the existing UVC treatment may not be a suitable alternative in replacing thermal pasteurisation especially for long-term storage.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Sarjana Sains

PRESTASI PENYINARAN UV DENGAN TEKNOLOGI DEAN VORTEX KE ATAS AIR ASAM JAWA (*Tamarindus Indica* L.) JERNIH DAN KERUH

Oleh

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Jus asam jawa biasanya dirawat dengan rawatan haba untuk membunuh mikroorganisma. Walaubagaimanapun, rawatan terma menyebabkan perubahan dalam penampilan dan rasa jus asam jawa. Penyinaran ultraviolet (UV) telah muncul sebagai alternatif kepada pemprosesan terma. Namun begitu, penggunaan penyinaran UV untuk jus asam jawa tidak ditemui dalam kajian literatur. Di samping itu, pelaksanaan sistem UV dengan teknologi Dean Vortex masih terhad. Oleh itu, kajian ini bertujuan untuk menyiasat prestasi penyinaran UVC pada pengurangan mikrob dan kualiti jus asam jawa jernih dan keruh. Keputusan analisis mikrobiologi menunjukkan bahawa dos UVC pada 35 mJ/cm^2 didapati berkesan dalam mengurangkan mikrob sebanyak 5-log. “Linear log with tailing” adalah model terbaik bagi menggambarkan penyahaktifan bakteria (*Escherichia coli* dan mikroflora asli) (R^2=0.999). Rawatan UVC mengurangkan jumlah pepejal larut air jus asam jawa dengan ketara iaitu sebanyak 18-21% ($p<0.05$) tetapi berjaya mengekalkan pH, keasidan dan warna jus asam jawa ($p>0.05$). Terdapat perbezaan yang ketara dalam kekeruhan jus asam jawa jernih apabila dos UVC bertambah. Teknologi Dean Vortex dapat mengurangkan pengaruh kekeruhan dalam rawatan UV. Berbanding dengan rawatan haba, penyahaktifan mikrob oleh rawatan UVC tidak begitu efisyen. Jus yang dirawat dengan rawatan terma mempunyai persamaan dari segi pH, keasidan dan warna dengan jus yang dirawat dengan UV. Ia juga mengekalkan jumlah pepejal larut air asam jawa lebih baik daripada jus yang dirawat oleh UV. Namun begitu, perbezaan dalam kekeruhan adalah ketara ($p<0.05$) selepas rawatan haba khususnya dalam air asam jawa jernih. Sepanjang tujuh minggu penyimpanan, pH jus asam jawa telah berubah dengan ketara ($p<0.05$). Jumlah pepejal larut telah meningkat ($p<0.05$) dalam jus asam jawa jernih selepas tempoh penyimpanan. Keasidan tertitrat jus asam jawa jernih yang dirawat oleh haba telah meningkat daripada 0.43% kepada 0.48% ($p <0.05$) manakala keasidan jus asam jawa keruh dirawat oleh UVC-radiasi berkurangan daripada 0.40% kepada 0.30% ($p<0.05$). Dari segi kekeruhan, jus dirawat UVC menunjukkan nilai kekeruhan rendah berbanding dengan jus segar dan terma-pasteur selepas tujuh minggu.

Sebaliknya, tidak ada kesan rawatan yang berbeza pada keterangan, sudut warna dan kroma selepas tujuh minggu penyimpanan. Jus dirawat UVC menunjukkan perubahan keseluruhan warna terendah sepanjang tujuh minggu penyimpanan. Daripada analisis mikrob, jus dirawat UVC menunjukkan kestabilan bilangan bakteria yang baik semasa penyimpanan. Walaubagaimanapun, air asam jawa telah rosak hasil daripada pertumbuhan yis dan kulat selepas dua minggu. Sebaliknya, rawatan haba berjaya mengekalkan bilangan mikrob dibawah tahap pengesanan semasa penyimpanan sejuk. Kesimpulannya, rawatan UVC yang sedia ada mungkin tidak boleh menjadi alternatif yang sesuai untuk menggantikan pempasteuran haba terutama untuk simpanan jangka panjang.

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I certify that a Thesis Examination Committee has met on 28 October 2016 to conduct the final examination of Hani Afiffa Mohd Hanif on her thesis entitled "Performance of UVC Irradiation with Dean Vortex Technology on Clear and Turbid Tamarind (*Tamarindus indica* L.) Juice" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CFU	Colony forming units
DRBC	Dichloro Rose Bengal
FDA	Food and Drug Administration
HACCP	Hazard Analysis and Critical Control Point
HPP	High Pressure Processing
HTST	High Temperature Short Time
MAC	MacConkey Agar
PEF	Pulsed Electric Field
PFA	Polyfluoroalcoxy
TA	Titratable acidity
TSA	Trypticase Soy Agar
TSB	Trypticase Soy Broth
TSS	Total soluble solids
UV	Ultraviolet
UVC	Ultraviolet-C

CHAPTER 1

INTRODUCTION

1.1 Overview

World fruit juice consumption is predicted to increase each year with continuous development of processes in producing a high quality juice product. In the recent years, there is a growing demand by consumer for a safe, minimally processed food that resembles the quality attributes of a fresh product with extendable shelf life. The convincing epidemiological evidence that consumption of fresh fruit juice is beneficial to health has contributed to the growth of such demand. Unfortunately, fresh fruit juice can spoil easily by the outgrowth of yeast and bacteria. This has become one of the main obstacles faced by fruit juice manufacturers in producing safe, consumerable juice products. Furthermore, the implementation of several safety procedures and regulations such as the hazard analysis critical control point (HACCP) were found to be insufficient in reducing the number of outbreaks related to foods (Bintsis *et al*., 2000).

The most common and conventional way in killing pathogens in food is by thermal processing. However, Lado and Yousef (2002) stated that the application of heat treatment destroys the flavour, nutritional content and colour of the food while successfully kills bacteria. Even with the modern thermal technologies such as high temperature short time pasteurisation, the final products are not closely resembled the actual or fresh products. Other alternative available is to add chemical preservatives for commercial use (Koutchma, 2009). However, this spurs a negative public reaction, as they prefer safe, healthier and natural foods.

In order to retain the quality of fresh juice as per consumers demand, studies have been done intensively on non-thermal processing (Guerrero-Beltrán *et al*., 2009). Ultraviolet (UV) irradiation is a non-thermal process that is considered to be one of the effective means to inactivate bacteria in liquid foods. As it excludes heat treatment, it minimises changes in sensory qualities, nutritional values and appearances of the final product. In addition, UV systems do not produce chemical residues, by-products or radiation (Guerrero-Beltran & Barbosa-Canovas, 2004) and are low in cost, as they require low initial investment and lower operational cost (Choudhary & Bandla, 2012).

1.2 Research background

The application of UV light in treating fruit juices is still limited due to low transmittance of UV (Guerrero-Beltran & Barbosa-Canovas, 2004). UV transmittance is highly reduced in the presence of particles and soluble solutes. Therefore, liquid with high total soluble solid or turbidity is not effectively treated (Koutchma, 2009). To overcome this limitation, the liquid can be presented in a thin film to increase the transmittance of UV light (Koutchma *et al*., 2004). A commercial UV reactor called CiderSure (FPE, Macedon, New York, USA) used this kind of approach in its design. However, the process results in incomplete mixing of juice in the reactor which will reduce the microbial reduction by UVC light (Koutchma *et al*., 2004). It was reported by Chia *et al.* (2012) that the CiderSure unit was able to reduce up to 3-log reductions of total plate count in pineapple juice after UV treatment at 53.42 mJ/cm^2. This shows that the microbial reduction does not meet the minimum of 5-log reduction of pertinent pathogens as required by the Food and Drug Administration (FDA) which could be due to high soluble solids content in the juice. Therefore, UV reactors designed based on Dean Vortex technology was introduced. In this system, liquid food will flow in a coiled tube that surrounds the UV lamp to create secondary eddy flow effects called Dean Vortices (Müller *et al*., 2011). This technique enhances mixing of the liquid thus, results in higher microbial inactivation (Müller *et al*., 2011). A study by Franz *et al.* (2009) showed that the system was capable to reduce *Escherichia coli* (*E.coli*) and *Lactobacillus brevis* from initial concentration of 10^6 CFU/mL or 10^4 CFU/mL to below detection limit in a naturally cloudy apple juice after irradiated with UVC light (254 nm) at 60 W/m^2 with a flow rate of 2 L/h. The use of Dean Vortex technology in UVC system has shown promising results in inactivating target pathogens (Franz *et al*., 2009; Lu, Li, & Liu, 2011; Mansor *et al*., 2014; Müller *et al*., 2011; Pala & Toklucu, 2013).

In Malaysia and other Southeast Asian and African countries, tamarind has been used for many purposes such as in culinary, as medicine or drinks due to its unique taste and high nutritional contents. Furthermore, they are inexpensive and readily available in most households. Nevertheless, the current practice of extracting the juice, which is by soaking the pulp in water and manual squeezing by hand is inconvenient and unhygienic (Lee *et al*., 2009). They spoil easily upon storage and need to be freshly prepared. As thermal pasteurisation has been known to alter the quality attributes of juice, UV irradiation rises as a promising alternative to conventional thermal treatment in tamarind juice processing.

1.3 Problem statement

Despite of its wide range of domestic and industrial uses, tamarind has been underutilised due to lack of awareness on its economic potential, limited processing technology and poor marketing (Gajanana *et al*., 2007; Singh *et al*., 2007). Gajanana *et al*. (2010) stated that underutilised fruit such as tamarind has been one of the main sources of livelihood for the poor and can help in overcoming malnutrition due to its therapeutic and nutritive values. According to Singh *et al.* (2007), the traditional processing for food preparation is widespread however, commercial products of tamarind such as pasteurised juices and tamarind paste are still undeveloped.

Tamarind juice is usually prepared fresh in common household. Nonetheless, the method of preparation is unhygienic and inconvenient (Lee *et al.*, 2009). In addition, fresh unpasteurised juice has long history of numerous outbreaks due to contamination of pathogenic microorganisms such as *E. coli* and *Salmonella typhimurium (S. typhimurium).*Therefore, commercial pasteurised tamarind juice was developed for the convenience and safety of consumers. Furthermore, there has been an increasing demand on tamarind juice due to its health benefits and uses in culinary which contribute to the production of commercial tamarind juice. However, to date, the production of tamarind beverage is labour intensive, has low aesthetic value, poor hygiene practice, short product shelf life and no standardisation of ingredients (Adeola & Aworh, 2014). This could be attributed to the lack of development and effort in tamarind juice processing. Previous finding by Chavasit *et al.* (2006) claimed that the commercial tamarind beverages tested had no presence of coliform, *E.coli* and mould but they were 100% contaminated by yeast. Thermal treatment is the conventional and widely used method in pasteurising tamarind beverages. However, thermal treatment resulted in change in flavour, appearance and especially nutritional content such as antioxidants of juice (Choi & Nielsen, 2005; Gabriel, 2015a; Gayán *et al*., 2015). This defeats the purpose of drinking tamarind juice, which is known to cure sore throat, fever and many other diseases.

Therefore, there is a need to find alternatives i.e. non-thermal treatments to process tamarind juice. So far, there is only one research that studied on non-thermal processing of tamarind juice, which is by using gamma irradiation (Lee *et al*., 2009). Gamma irradiation was found to be a promising alternative in tamarind beverage processing. However, gamma irradiation system is not feasible for small and medium enterprise as the system is very costly. Ultraviolet-C (UVC) irradiation is a hopeful solution in treating tamarind juice. However, poor light penetration is the main hindrance of UVC application in fruit juice. At the present time, there is no reported data on the performance of UVC light on tamarind juice. Since tamarind juice is usually murky and cloudy, depending on its concentration, the efficiency of UVC inactivation may or may not be affected.

It is a well-known fact that turbidity of juice will impact the killing efficiency of UVC treatment. Nonetheless, it was discovered by a few researches that this assumption might not be true, depending on the absorption coefficient of the juice, dosage used and the design of UVC reactor. Orlowska *et al.* (2014) discovered that UV treatment (UV fluence of 50 mJ/cm^2, 500-1500 mL/min, 200 rpm) on apple cider (537 NTU) resulted in 2.85 to 4.76 log reduction of surrogate strain of *E.coli* O157:H7. In contrast, earlier research by Donahue *et al.* (2004) successfully reduced *E.coli* O157:H7 to more than 5-log reductions in apple cider (92.02 NTU) after UV treatment at 8.77 to 35.11 mJ/cm^2. The discrepancies between these results could be attributed to the different turbidity of juice, dosage used and type on inactivation equipment where Donahue *et al.* (2004) used a thin film reactor whereas Orlowska *et al.* (2014) used a Taylor-Couvette unit. Therefore, Muller *et al.* (2011) recommends that comparison on UVC inactivation efficiency of a product should be done with similar or identical equipment and dosage measurement for a fair comparison.

1.4 Objectives of the study

This study aims to investigate the performance of UVC irradiation with Dean Vortex technology on the quality attributes and microbial inactivation of clear (~150 NTU) and cloudy (~900 NTU) tamarind juice. The objectives of this study can be divided into 3 parts:

1. To study the effects of UVC dosage (27.40 -67.56 mJ/cm^2) and the influence of turbidity on the physicochemical properties such as pH, total soluble solids, titratable acidity, turbidity and colour and microbial reduction of native microflora and *E. coli* O157:H7 in clear (~150 NTU) and turbid (~900 NTU) tamarind juice.

2. To compare the performance of UVC irradiation with Dean Vortex technology at optimised dosage (From Part 1) against thermal pasteurisation at 80 ^{o}C for 5 minutes on the physicochemical properties such as pH, total soluble solids, titratable acidity, turbidity and colour and microbial reduction of native microflora and *E. coli* O157:H7 in clear (~150 NTU) and turbid (~900 NTU) tamarind juice.

3. To evaluate the stability of UVC-irradiated clear and turbid tamarind juice against thermally pasteurised juice under refrigerated storage (4 – 8 ^{o}C) at 0, 2, 4 and 7 weeks (49 days) in terms of the physicochemical properties such as pH, total soluble solids, titratable acidity, turbidity and colour and microbial population of native microflora in clear (~150 NTU) and turbid (~900 NTU) tamarind juice.

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