UNIVERSITI PUTRA MALAYSIA

***IMPROVEMENT OF ULTRAVIOLET PASTEURISER FOR PRODUCTION OF PINEAPPLE FRUIT JUICE***

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# IMPROVEMENT OF ULTRAVIOLET PASTEURISER FOR PRODUCTION OF PINEAPPLE FRUIT JUICE

By

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Currently, the existing ultraviolet (UV) pasteuriser cannot achieve the FDA standard which is 5 $log_{10}$ reductions of microorganisms in tropical fruit juice because of the high soluble content in the tropical fruit juice. Therefore, a new ultraviolet pasteuriser was designed which it was able to inactivate microorganisms in tropical fruit juice up to 5 $log_{10}$ reduction. This study aims to develop an ultraviolet pasteuriser which able to inactivate microorganisms with at least 5 $log_{10}$ reductions in pineapple fruit juice and maintain the quality attributes of juice for SME industry. A new designed UV pasteuriser was developed based on Dean Vortex technology with an additional UV light to give extra UV radiation to the juice. The experiment was conducted using the UV pasteuriser which the UV lamp was not enclosed with quartz glass (UV pasteuriser (without quartz)) and UV pasteuriser that UV lamp was enclosed with quartz glass (UV pasteuriser (with quartz)). For both pasteurisers, two difference frequencies was tested which are at 30 Hz and 40 Hz to investigate the effect of difference flow rate on quality of pineapple juice based on the physico-chemical and the microbial analyses. The result showed the UV pasteuriser (with quartz) at frequency of 30 Hz (flow rate of 0.00153 L/s) and UV-C dosage of 64.11 mJ/cm$^2$ was showed better quality based on physico-chemical results and able to inactivate Salmonella *typhimurium* up to 5.91 log CFU/ml. The UV pasteuriser (without quartz) was slightly affected the quality of juice because none installation of quartz glass at the UV-C lamp was affected the quality attributes of juice. The lightness (L-value) and total soluble solid (TSS) of juice after treated with UV pasteuriser (with quartz) at 30 Hz was not significantly changes comparing to untreated juice. Meanwhile, the Chroma, hue angle and ascorbic acid content were significantly changes compare to the untreated juice. However the range of ascorbic acid was fall in slightly noticeable range thus, it can be negligible. The turbidity of juice treated with UV pasteuriser (with quartz) was significantly difference than untreated juice. During 9 weeks of storage, the TSS, L-value, hue angle, Chroma, ascorbic acid content and turbidity of untreated and UV pasteurised (with quartz) juice were give a significant decreased whereas their titratable acidy (TA) were not significantly decreased during storage. There is no significant increase of pH of untreated and UV pasteurised (with quartz) juices during storage. Regarding the microbiological analysis, count of Salmonella *typhimurium* was significantly increased after nine weeks of storage at 4±1°C. Other than that, the pineapple juice that was treated by ultraviolet pasteuriser (with quartz) was able to extend the shelf life of pineapple juice from 2 weeks to 5 weeks longer. Therefore, these results on physico-chemical and microbiological analysis was demonstrate the effectiveness of UV pasteuriser (with quartz) in preserving the

nutritional attributes and inactivate microorganisms in pineapple fruit juice which achieved the FDA standard.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai Memenuhi Keperluan untuk Ijazah Sarjana Sains

**PENAMBAHBAIKAN PEMPASTEUR ULTRAUNGU BAGI PENGELUARAN JUS BUAH NANAS**

Oleh

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Kini, pempasteur ultraungu (UV) yang sedia ada tidak boleh mencapai standard FDA yang merupakan pengurangan sebanyak 5 $log_{10}$ mikroorganisma di dalam jus buahan tropika disebabkan oleh kandungan larut yang tinggi di dalam jus buah-buahan tropika. Oleh itu, satu alat pempasteur ultraungu telah direkacipta yang mana ia mampu untuk menyahaktifkan mikroorganisma di dalam jus buah tropika sehingga pengurangan sebanyak 5 $log_{10}$ CFU/ml. Tujuan kajian ini adalah untuk membangunkan satu pempasteur ultraungu di mana ia mampu untuk menyahaktifkan mikroorganisma sekurang-kurangnya 5 $log_{10}$ di dalam jus buah nanas dan sekaligus dapat mengekalkan kualiti jus untuk kilang SME. Pempasteur UV adalah direkacipta berdasarkan Dean Vortex teknologi dan mempunyai satu lampu UV tambahan dimana ia bertindak untuk memberi tambahan sinaran UV kepada jus. Eksperimen ini telah dijalankan dengan menggunakan pempasteur UV dimana bahagian lampu UV tidak ditutupi dengan kaca kuarza (Pempasteur UV (tanpa kuarza)) dan pempasteur UV yang mana bahagian lampu UV ditutupi dengan kaca kuarza (Pempasteur UV (dengan kuarza)). Untuk kedua-dua pempasteur, dua frekuensi yang berbeza telah diuji iaitu pada frekuensi 30 Hz dan 40 Hz untuk menyiasat kesan kadar aliran jus yang berbeza terhadap kualiti jus nanas berdasarkan analisis fizikal-kimia dan mikrobiologi. Keputusan menunjukkan pempasteur UV (dengan kuarza) pada frekuensi 30 Hz (kadar aliran 0.00153 L/s) dan dos UV-C pada 64.11 mJ/cm$^2$ telah menunjukkan kualiti lebih baik berdasarkan hasil keputusan dari ujian fizikal-kimia dan berjaya menyahaktifkan Salmonella *typhimurium* di dalam jus sehingga penurunan sebanyak 5.91 log CFU/ml. Pempasteur UV (tanpa kuarza) telah menjejaskan sedikit kualiti jus kerana tiada pemasangan kaca kuarza di lampu UV-C. Perubahan kecerahan (L*) dan jumlah pepejal larut (TSS) jus selepas dirawat dengan pempasteur UV (dengan kuarza) pada 30 Hz adalah tidak signifikan berbanding dengan jus yang tidak dirawat. Sementara itu, perubahan Chroma, sudut rona dan kandungan asid askorbik adalah signifikan berbanding dengan jus yang tidak dirawat. Walaubagaimanapun, julat asid askorbik adalah jatuh di dalam katogeri perubahan yang kurang ketara di mana perubahan ini boleh diabaikan. Kekeruhan jus yang dirawat dengan UV sinaran (dengan kuarza) telah menunjukkan perubahan yang signifikan berbanding dengan jus yang tidak dirawat. Semasa penyimpanan jus selama 9 minggu, TSS, nilai L*, sudut rona, Chroma, kandungan asid askorbik dan kekeruhan jus yang tidak dirawat dan jus terpasteur dengan UV sinaran (dengan kuarza) menunjukkan penurunan secara signifikan manakala keasidan tertitrat (TA) menunjukkan penurunan secara tidak signifikan semasa penyimpanan. pH jus yang tidak dirawat dan jus UV sinaran (dengan kuarza) menunjukkan tiada peningkatan yang signifikan semasa

penyimpanan. Berhubung analisis mikrobiologi pula, bilangan Salmonella *typhimurium* adalah bertambah secara signifikan selepas sembilan minggu penyimpanan pada suhu 4±1°C. Selain daripada itu, jus nanas yang telah dirawat oleh pempasteur ultraungu (dengan kuarza) dapat melanjutkan jangka hayat penyimpanan jus nanas daripada 2 minggu kepada 5 minggu. Oleh itu, keputusan hasil analisis mikrobiologi dan fizikal-kimia adalah menunjukkan keberkesanan pempasteur UV (dengan kuarza) untuk mengekalkan sifat-sifat nutrisi jus buah nanas dan menyahaktifkan mikroorganisma di dalam jus buah nanas di mana ia adalah mencapai standard FDA.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| UV | Ultraviolet |
| DNA | Deoxyribonucleic acid |
| FDA | Food Drugs Administration |
| MOA | Malaysian of Agriculture |
| USDA | US Department of Agriculture |
| SME | Small and medium enterprise |
| PFA | Polyfluoroalkoxy |
| MPIB | Malaysian Pineapple Industry Board |
| PEF | Pulsed electric field |
| RNA | Ribonucleic |
| FEP | Fluorinated ethylene propylene |
| TSS | Total soluble solids |
| HTST | High-temperature short-time |
| TISTR | Thailand Institute of Scientific and Technological Research |
| TSA | Tryptic Soy Agar |
| TSB | Triptic Soy Broth |
| XLD | Xylose lysine desoxycholate |
| CFU | Colony form units |
| ANOVA | Analysis of variance |
| DMRT | Duncan's Multiple Range Test |
| SAS | Statistical Analysis System |

## LIST OF NOMENCLATURES

| | |
|---|---|
| t | times |
| s | seconds |
| min | minutes |
| Hz | hertz |
| $mJ/cm^2$ | milligram per centimetre square |
| $mW/cm^2$ | miliwatt per centimetre square |
| kWh | kilowatt hour |
| USD | US Dollar |
| NTU | nephelometric turbidity units |
| % | percent |
| L | litre |
| L/h | litre per hour |
| nm | nanometer |
| $m^2$ | meter square |
| RM | ringgit malaysia |
| mm | milimeter |
| ml | milileter |
| rpm | round per minutes |
| °C | degree celcius |
| L* | Lightness |
| i.e | That is |

# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

Recently, the trend in consuming fruit juice has increased. Therefore, the global market for juice products was estimated to increase about 50 billion litres in the early 1990s due to its diverse health effects (Bates et al., 2001). Fruit juices are much easier to consume and have become an alternative to eat fruit. Furthermore, processing liquid food is much easier as compared to the solid products. Hence, the quality and safety requirements of processing liquid food such as fruit juice should be completely fulfilled (Bates et al., 2001). The highest quality of fruit had to choose to make sure a good quality of fruit juice product. Meanwhile, food industries must completely fulfilled the HACCP and FDA requirement for safety requirement. Food safety had become one of the important issues that have to face in food industry due to the growing demand for a variety of prepared foods which makes the risk of contamination an issue of concern (Falguera et al., 2011).

Unpasteurised or fresh juice can commonly be spoiled by the outgrowth of pathogenic microorganisms and bacteria. For instance, food spoiling microorganisms such as yeast and moulds, *Lactobacillus*, *Leuconostoc* and thermophilic *Bacillus* can be found in orange juice (Tran and Farid, 2004). The presence of these microorganisms is due to the presence of osmophilic microflora which can cause fermentation and produce mould in the juice (Tahiri et al. 2006, Tournas et al., 2006).

According to the FDA (1998), pasteurisation is an effective and well-known technology used to satisfy safety requirements. In citrus juice production, pasteurisation is important to stabilise the fruit juice during transportation and marketing (Lee and Coates, 2003). Further, thermal pasteurisation is an effective technology to extend product shelf life by inactivating the microorganisms and enzymes (Noci et al., 2008). However, thermal pasteurisation may cause changes in the carotenoid pigment content and juice colour (Lee and Coates, 2003). This will affect the consumer satisfaction and the quality of the juice.

Ultraviolet (UV) treatment is a non-thermal method that can be used to inactivate harmful microbes that are contained in food products (Tran and Farid, 2004). The DNA (deoxyribonucleic acid) level will be affected when the microorganisms are exposed to UV light and this injures the reproductive system of the cells. Thus, this will lead to their death (Guerrero-Beltran and Barbosa-Canovas, 2004). This technology can produce food products without hazardous microorganisms and without any changes of sensory characteristics. Moreover, UV treatment was found to be effective in extending the shelf life fruit juice (Chia et al, 2012; Shamsudin et al., 2014; Sew et al., 2014).

Pineapple (*Ananas comosus*) or locally known as *nanas* is grown in tropical countries such as Hawaii, Malaysia, India and the Philippines. It is the most popular non-citrus tropical fruit in the world and its juice is very well known for its flavour and nutrition (Montero et al., 2008). The total pineapple production worldwide is based on 12 countries who together account for about 80 % of the market. The most common pineapples grown in Malaysia are Cayenne, Queen and Spanish group; while Josapine and Moris pineapples are preferred for their juice (Rosnah et al., 2009). However, a new variety of pineapple called MD2 has been highly recommended to juice manufacturers because of its characteristics of being much sweeter and juicier. The MD2 pineapple variety has a sweeter taste and has a longer shelf life compared to the other varieties (MOA & Fisheries and RADA Newsletter, 2010).

Pineapple juice is commonly consumed around the world, mostly as a by-product of the canning industry in the form of blended composition or in concentrated juice in order to attain new flavours in beverages and other products (Carvalho et al., 2008). The pineapple juice has a sweet and sour flavour that enjoyed by most of fruit juice consumer and also have beneficial health compound, such as bromelain and phenols (Sew et al. 2014). Nevertheless, the flavour of pineapple juice can undergo extreme changes after the heat treatment (Barros et al., 2003). According to Mohd Adzahan and Benchamaporn (2007), the high content of ascorbic acid and nutritional quality of guava, papaya and pineapple juices may be lost when exposed to the heat treatment. Further, the processing of fruit juice is a complex operation with many variables that may influence the final product quality (Rosnah et al., 2009). Therefore, ultraviolet irradiation may be an appropriate technology for processing pineapple juice.

## 1.2 Problem Statement

Commonly, in order to prolong the shelf life of pineapple juice, a thermal pasteurisation treatment is applied. However, thermal treatment may cause a change in flavour, colour and also the nutritional qualities of the fruit juice (Lee and Coates, 2003). Thus, the alternative of a non-thermal preservation technology has been investigated due to the increasing demand for fresher, more natural and nutritionally healthier food (Caminiti et al. 2012). Many researchers have stated the effect of thermal treatment in destructing the freshness and quality attributes of fruit juice (Aguilar-Rosas et al., 2007; Igual et al., 2010; Chia et al., 2012; Lee and Coates, 2003).

Ultraviolet (UV) pasteurisation as one of the non-thermal methods has been chosen to apply in food processing, especially in juice processing. Ultraviolet irradiation has a positive consumer image due to the ability of this treatment to maintain nutritional characteristics and minimal loss of quality in terms of flavour and colour (Falguera et al., 2011). The UV radiation is not only low cost but also required simple process treated juice and needs low maintenance, no formation of chemical residue and by-product in the finished product (Tan et al., 2014).

Presently, ultraviolet technology is not yet applied in juice processing in Malaysia. Thus, little research has been reported on the use of UV irradiation technology for processing of fruit juice, especially for the local tropical fruit juices. Therefore, ultraviolet radiation technology can create business opportunities for small and medium enterprise (SME) companies to produce fresh pasteurised fruit juice, especially for tropical fruit juice which is safe to consume, high nutritional content and has a longer shelf life compare to thermal treatment.

Currently, an Ultraviolet machine, CiderSure 3500-B (Macedon, New York) that is currently available in the market is not too suitable for tropical fruit juice. According to Halim et al. (2012), the pitaya juice was not able to achieve a 5 $\log_{10}$ microbial reduction after treated with the UV machine, CiderSure 3500-B. The design of CiderSure 3500-B was not suitable for tropical juice because the juice have to flow simultaneously from the inlet tube to the outer tube of concentric tube and only some the mixing effect of juice with the ultraviolet radiation happened during the process (Koutchma et al., 2004). This will reduce the reduction of microorganisms in juice during process. Without proper mixing factor in the design, the tropical fruit juice which high soluble solid content cannot pasteurized properly and achieved 5 $\log_{10}$ CFU/ml reduction of pertinent microorganisms (Koutchma et al., 2004). Other than that, pineapple juice only could achieve around a 3 log CFU/ml reduction of total plate count after UV treatment at a dosage of 53.42 mJ.cm$^2$ (Chia et al., 2012). This occurs mostly because the tropical fruit juices have high soluble solids content which makes ultraviolet radiation difficult to consistently penetrate by the juice.

Therefore, a newly invented machine has been introduced to overcome this problem as well as to maintain the quality of the juice. The newly invented UV pasteuriser machine (Malaysian Patent number: PI201203186) was created based on Dean Vortex (secondary eddy flow) technology (Kok Yong, 2012). This Dean Vortex provides the opportunity for the fruit juice to be mixed intensively in order to target as many microorganisms as possible for inactivation.

Unfortunately, this machine operated at a very low velocity, thus affecting the value of the final product which is only 8 L/hr. The design of the machine was such a polyfluoroalcoxy (PFA) tube was coiled around five individual UV lamps which were connected to each other. The fruit juice was pumped into the PFA tube and had to flow around all five UV lamps before being discharged out to the storage container (Figure 1.1). Thus, it will take longer time to collect the treated juice.

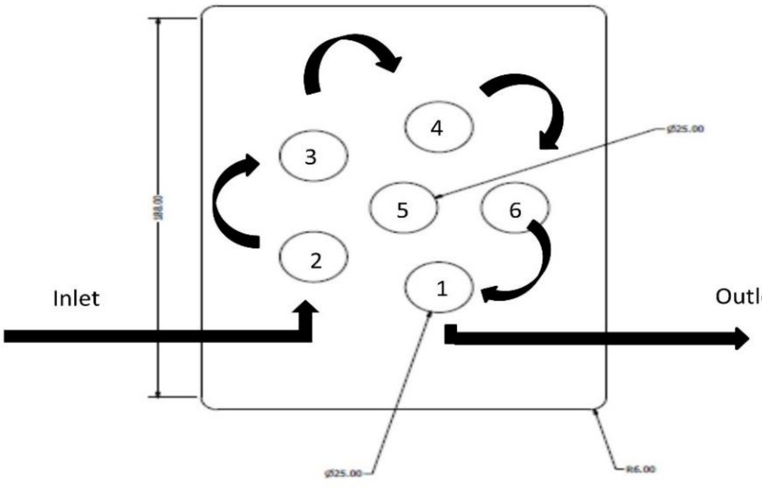


**Figure 1.1: Flow of juice through the five UV lamps before redesign (Kok Yong, 2012)**

Moreover, this UV pasteuriser machine was not provided with a tank to collect the treated juice. This tank is important to avoid the juice becoming contaminated with bacteria and microorganisms after the pasteurisation process. Therefore, an improvement in the design of the UV pasteuriser machine was made to make sure a greater amount of final product could be produced and it was able to inactivate microorganisms up to 5 $\log_{10}$ reduction to fulfil the FDA requirements and maintain the quality of the juice.

## 1.3 Objectives

The general objective of this study is to develop an ultraviolet pasteuriser for fresh pineapple fruit juice and to investigate effect of ultraviolet irradiation on the pineapple fruit juice. In more detail:

1) Improvement of ultraviolet pasteurizer based on Dean vortex technology for the small and medium enterprise (SME) which is able to inactivate at least a 5 $\log_{10}$ of microorganisms in pineapple fruit juice.
2) Determine the effect of quartz glass sleeve and UV-C dosage using two UV lamps (coiled and uncoiled lamp) on the physico-chemical and microbiological properties of pineapple fruit juice during storage at temperature of 4±1°C for 9 week.

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