



UNIVERSITI PUTRA MALAYSIA

***DEVELOPMENT AND PERFORMANCE EVALUATION OF A
MECHANICAL
POMELO FRUIT JUICE EXTRACTOR***

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**DEVELOPMENT AND PERFORMANCE EVALUATION OF A MECHANICAL
POMELO FRUIT JUICE EXTRACTOR**

By

NUR SALIHAH BINTI BUANG

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

June 2016

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

DEVELOPMENT AND PERFORMANCE EVALUATION OF A MECHANICAL POMELO FRUIT JUICE EXTRACTOR

By

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June 2016

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The aim of the beverage industries in the juice extraction process is to produce juice with high yield while preserving its nutritive values and quality. The pomelo (*Citrus grandis* (L.) Osbeck) fruit flesh compounded with numerous sacs containing juice, which the texture cell wall of juice sacs much more firm compared to other citrus' fruit sacs. Extraction is one of the most important processes in the fruit juice processing to extract almost all juice from the fruits. Generally, fruit juices are extracted using conventional juice extractor, but there might be some cases where the juice is not optimally extracted, thus yielding a portion of the remaining juice in the pulp. This study aims to develop a juice extractor which able to produce a high juice yield, high extraction efficiency with low extraction loss while preserving the juice quality attributes. Some properties of pomelo fruits were evaluated; namely the physical, chemical and mechanical properties. The development of juice extractor started with the design considerations, and then the several conceptual designs were generated. The details of design process in terms of calculations, selection of suitable materials and the assembly parts for fabrication were discussed in this study. A juice extractor was designed and constructed as an improvement of conventional juice extractor to extract almost juice-free fruit flesh of pomelo sacs. It consists of hopper to feed the fruit flesh, and two main process chamber which crushes and filters chamber. A crushing chamber was provided with a pair of two-level roller-cog to crush the fruit flesh. Then, the filtering chamber provides centrifugal force to spin the crushed fruits from crushing chamber in order to separate juice from pulp and expel more juice to flow out. The results showed that the roller speed of crushing chamber at 1125 rpm and spinning time of 420 s gave the high juice yield (80.07%) and extraction efficiency (81.35%) with lower moisture of pulp waste at 52.31%. The quality attributes based on ascorbic acid, lightness and total soluble solids were not significantly different between the tested roller speed and spinning time. The optimum condition from the developed juice extractor was then been used for the comparison to the other juice extraction method. The developed juice extractor was compared with the performance of centrifugal juice extractor, screw press type extractor, blending type extractor and hand press. The data obtained indicated that the developed juice extractor yielding high juice yield, high

extraction efficiency, low extraction loss and high extraction capacity. Significant differences at $p < 0.05$ were detected in total soluble solids (TSS), titratable acidity, lightness and ascorbic acid but no significant difference between the pH values. Therefore this project is expected to introduce a new knowledge of extraction method to small scale juice processors and may be useful for postharvest technologist, food technologist and food manufacturers.



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PEMBANGUNAN DAN PENILAIAN PRESTASI PENGEKSTRAK MEKANIKAL BUAH LIMAU BALI

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Tujuan industri minuman dalam proses pengekstrakan jus adalah menghasilkan jus yang tinggi sambil mengekalkan nilai-nilai pemakanan dan kualitinya. Isi buah limau bali (*Citrus grandis* (L). Osbeck) terdiri daripada kantung jus, di mana tekstur dinding sel kantung jus limau bali lebih kukuh berbanding buah sitrus lain. Pengekstrakan ialah salah satu proses penting dalam memproses jus buah untuk mengekstrak hampir semua jus dari buah. Pada umumnya, jus dihasilkan menggunakan pengekstrak jus konvensional, tetapi ada kemungkinan pengeluaran jus tidak optimum, maka terdapat sebahagian jus masih kekal dipulpa buah. Kajian ini bertujuan untuk membangunkan pengekstrak jus yang mampu menghasilkan jumlah jus yang tinggi, pengekstrakan yang efisien dengan kehilangan pengekstrakan yang rendah sambil mengekalkan kualiti jus. Beberapa sifat buah limau bali telah dinilai; iaitu sifat mekanik, fizikal dan kimia. Pembangunan pengekstrak jus telah dimulakan dengan pertimbangan reka bentuk dan beberapa reka bentuk konsep telah dihasilkan. Butiran proses rekaan dalam soal pengiraan, pemilihan bahan yang sesuai dan bahagian pemasangan untuk rekaan telah dibincangkan. Pengekstrak jus direka bentuk dan dibina sebagai peningkatan kepada pengekstrak jus konvensional untuk mengekstrak hampir ketiadaan jus di pulpa kantung buah. Ia terdiri daripada corong untuk memasukkan isi buah limau bali dan dua bahagian proses utama iaitu proses penghancuran dan penapisan. Bahagian penghancuran terdiri daripada sepasang pengelek bergigi pada dua tahap untuk menghancurkan isi buah. Kemudian, bahagian penapisan menggunakan daya emparan kepada bekas penapis yang berputar untuk memisahkan jus dari pulpa dan mengeluarkan lebih banyak jus. Hasilnya menunjukkan bahawa kelajuan 1125 rpm pengelek menghancurkan buah dan masa penapisan 420saat memberi hasil (80.07%) jus yang tinggi dan kecekapan pengekstrakan (81.35%) dengan lembapan sisa pulpa lebih rendah pada 52.31%. Sifat-sifat kualiti berasaskan asid askorbik, kecerahan dan jumlah pepejal larut tidak jauh berbeza. Keadaan optimum pengekstrak jus yang dibangunkan kemudiannya dibandingkan dengan kaedah pengekstrakan jus lain seperti jus pemerah empar, jenis pengekstrak skru, jenis pengekstrak campur dan pemerah

menggunakan tangan. Data yang diperolehi melaporkan bahawa pengestrak jus yang dibangunkan menghasilkan jus yang tinggi, kecekapan pengestrakan yang tinggi, kehilangan pengeluaran yang rendah dan kapasiti pengeluaran yang tinggi. Perbezaan yang signifikan pada $p < 0.05$ dikesan dalam jumlah pepejal larut (TSS), keasidan tertitrat, kecerahan dan asid askorbik tetapi tiada perbezaan signifikan di antara nilai pH. Oleh itu projek ini dijangka memperkenalkan pengetahuan baru tentang kaedah pengestrakan kepada pemproses jus skala kecil dan mungkin berguna untuk ahli teknologi lepas tuai, teknologi makanan dan pengeluaran makanan.



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I certify that a Thesis Examination Committee has met on 2 June 2016 to conduct the final examination of Nur Salihah binti Buang on her thesis entitled "Development and Performance Evaluation of a Mechanical Pomelo Fruit Juice Extractor" 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

FDA	Food Drugs Administration
DOA	Department of Agriculture
TSS	Total soluble solids
ANOVA	Analysis of variance
FAO	Food and Agriculture Organization
ASME	American Society of Mechanical Engineering
TA	Titrateable acidity

LIST OF NOMENCLATURES

L*	Lightness value
a*	Greenness
b*	Yellowness
cv	Cultivar
Max	Maximum
Min	Minimum
RH	Relative humidity
Stdev.	Standard deviation
PO55	Ledang variety
PO52	Tambun variety
g	grams
mL	milimeter
mm	milimeter
cm	sentimeter
rpm	Rotation per minute
R ²	Regression coefficient
t	times
s	seconds
min	minutes
kw	kilo watt
%	percent
L	litre
m ²	meter square
rpm	round per minutes
°C	degree celcius



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CHAPTER 1

INTRODUCTION

1.1 General Overview

The demand for maintaining a healthy and nutritious diet is well entrenched in the minds of Malaysians as they are becoming more conscious on healthy lifestyle (Jagtiani et al., 1988; Stanton et al., 2011). The consumption of fresh fruit juices has always been synonymous as a staple in a healthy lifestyle for generations. Fruit juices are caffeine-free, so there are healthier than any other caffeine-containing beverages.

Juices can be defined as the extractable fluid contents of cells or tissues (Meriam-Webster, 2007) which is obtained by extracting the cellular juice from a single fruit where all seeds, skin, stones, and other than flesh fruits are removed (FAO, 2009). Codex Alimentarius has defined juice as unfermented but fermentable juice, intended for direct consumption, obtained by the mechanical process of ripe fruits, preserved exclusively by physical means, and the produced juice may be clear, turbid or pulpy. On other words, juice is the fluid obtained from plant material by crushing, comminuting or pressing (FAO, 1992).

Fresh fruit juices are normally packed with nutrients which are naturally found when a whole fruit is consumed. The demand for fruit juice is largely based on their nutritive value, flavor, aroma, and color. Furthermore, juices can be consumed more conveniently than consuming the whole fruits (Bates and Moris, 2001). These quality factors are directly dependent on the structure and chemical composition of the fresh fruit juices after going through several processes from fresh fruit to fruit juices (Mc-Lellan et al., 2004).

The quality of fruit juices depends on the quality of the juice processing from the start until the end of processing. There are a number of unit operations involved in processing of fresh fruits to obtain the desired juices or any other products. Generally, the major operations in fruit juice processing are washing, sorting, peeling, extraction, separation, enzymation, centrifugation, filtration, pasteurization, hot filling and cooling, and packaging where each step has its own importance.

Fruit extraction is one of the most important unit operations. It has its own impact towards the efficiency of the whole system (FAO, 1992). However, the operations depend on the process design, volume, the end use, and the raw material of specific type of fruit juices to be processed. Juice extraction opens up new market opportunities for tailoring fruit products to modern consumer demands. The goal in juice manufacturing is to remove as much as possible the juice from the fruits without extracting the undesired component (Quek et al., 2012). Juice manufacturers have been focusing on maximizing the juice yield through physical treatments designed to weaken the plant cell walls and loosen its membranes (Hancock and Stewart 2010).

There are many fruit-specific ways to extract juice. Hand labor is the past alternative with many minor fruits, although there is an economic incentive to mechanize if possible. Extraction equipment should therefore be designed to handle a high level of solid content during separation process. By removing the solid matter and pulp, then the juice can give a good appearance and quality of fruit juice produced in terms of color, appearance, and end product. Table 1.1 lists some fruit characteristics affecting the juice or the operation in juice extractions.

Table 1.1: Fruit characteristics affecting juicing (FAO, 1992)

Type	Procedure	Example
Soft, all edible	Comminute, grind, and press	Berry
Soft, seed inedible	Crush and press	Grape
Firm, seed inedible	Grind coarse and press	Apple
Firm, inedible skin ± seeds	Ream and press flesh	Citrus
Soft inedible skin ± seeds	Pre-peel and gently press flesh	Mango
Brittle inedible skin ± seeds	Slice and gently press flesh	Passion fruit and lychee
Tough adhering skin ± seeds	Hand or contour peeling	Guanabana and pineapple
Soft, inedible skin	Roller or squeeze peel	Banana

Note: ± indicates that either an existence or non-existence of seeds

Recently, the research on pomelo fruit in Malaysia has been expanded. Muhammad (1999) studied the aroma compounds from the essential oil of Malaysian fresh pomelo peel while Cheong et al. (2011) have identified aroma-active compounds by gas chromatography-olfactometry in Malaysian fresh pomelo peel. The study on the antioxidant properties has been conducted by Toh et al. (2013) to compare the antioxidant content and the antioxidant capacity of the pulp and peel of two types of Malaysian pomelo fruit (Tambun White and Tambun Pink). Shah et al. (2012) have identified the phenolic contents of pomelo fruit juice using high-performance liquid chromatography-diode array detection (HPLC-DAD).

An interview with farmers as well as survey studies on pomelo fruit production, it shows that the pomelo juice production in Malaysia is still low to meet the national consumptions (DOA, 2013). Currently, there is no commercial fresh pomelo juice in Malaysia. Pomelo juices and pomelo-flavored juice drink mixes are common in Philippines (DOA, 2013) but in Malaysia pomelo fruits are normally eaten raw rather than being processed into juice (Anem, 2010). Yeo's manufacturing has been producing canned drink of pomelo with the brand of Fizzi pomelo but it is not the fresh pomelo juice. Another company, One Foods & Beverages Sdn. Bhd. produces pomelo juice cordial while Pitaberry Sdn. Bhd. produces a vitamin C drink with pomelo flavor under the brand named VitaminPlus. In Thailand, the fruits are processed into can beverages while in China it is processed into wine. During the Chinese New Year, this is a sought after fruit as some Chinese believe that taking the fruit is a sign of prosperity and good

fortune. It is also used for the preparation of “Yee Sang”, which is a Chinese dish eaten during the Chinese New Year.

1.2 Problem Statement

According to Kader (1992), pomelo has unique characteristics worth exploring. The numerous juice sacs of pomelo fruit flesh may adhere to each other or be loosely joined where it is normally firm and compact in any types of pomelo. The walls of exposed juice sacs are strong enough to keep the juice from leaking out (Warren, 1987). Several studies have been focused on physico-chemical or mechanical properties of the whole pomelo fruits or pomelo juice (Shah et al., 2012; Sirisoomboon, 2012). Recently, there is no study related to physico-chemical and mechanical properties which focusing on flesh of pomelo fruits. According to Robert (1964), usually a mature pomelo fruit has less spongy peel, the flesh that contains juice sacs is firm and crisp, while the lamella and the walls of juice sacs are quite tough.

The types of fruit dictate the mechanics and ease the juice extraction (Arthey and Ashurst, 1996). The mechanical citrus juice extractor for producing the pomelo juice and other citrus juices (Figure 1.1) has been introduced in the market. The concept was used a screw press type which generally consists of a pair of squeezing rollers in the form of spiral screws. Squeezing process of fruit is carried out simultaneously with slicing and conveying to the end plate in order to extract the juice, but there might be some cases whereby the juice is not compressed well, yielding a portion of the remaining juice in the pulp due to the compression occurs only at the end of extracted juice chamber.



Figure 1.1: Citrus Juice Extractor (Sunrise, Henan, China)

Excluding pomelo fruit, the method of juice extraction in terms of mechanical extraction for some citrus fruits have been developed (Marin et al., 2002; Yoichi et al., 2003; Kazembe-Phiri, 2005; Abulude et al., 2007; and Olaniyan, 2010). However, to date, only one study by Nair et al. (2007) conducted the research of different mechanical extraction methods of pomelo juice. The methods of pomelo juice extraction were developed by using several methods which were osmoextraction, screw pressing, crushing and mixing, and hand press method. The efficiency of each method

of extraction was evaluated based on the yield of extraction, pomace content, total soluble solid, acidity, and ascorbic acid content of the juice and its sensory attributes. But all these methods still did not show the best in terms of efficiency and economic extraction method of pomelo juice. Based on that study, further research is needed to increase the efficiency of pomelo juice extraction method by considering the economic impact.

1.3 Objectives

The aim of this study is to determine the extraction yield of pomelo juice from the developed juice extractor and existing extraction methods of fleshy juice sacs that could be applied to the industries. To achieve the goal, the objectives can be specified as:

1. To determine the physico-chemical and mechanical properties of two Malaysian grown variety of pomelo fruits.
2. To design and develop a mechanical juice extractor for the extraction of pomelo juice.
3. To evaluate the performance of a developed juice extractor in terms of quantity and quality of pomelo fruit juice and compare with the conventional juice extractor.

1.4 Scope of Work

The scope of works focused on the determinations of fruit properties, where the physico-chemical and mechanical properties of the whole pomelo fruit and the pomelo flesh were determined. Two Malaysian varieties of pomelo fruits (Ledang and Tambun) were used in this part of research. The physical properties of whole pomelo fruits were determined in terms of weight, volume and dimensions. The chemical properties of pomelo fruit juice was studied while the mechanical properties (puncture test) on pomelo fruit flesh with different probe size and positions were studied for the first time. The properties could be used as a preliminary study for the development and fabrication of juice extractor.

The work was focused on the development of a juice extractor to extract the pomelo fruit flesh in order to achieve the high juice yield and extraction efficiency with lower extraction loss, and then can preserve the quality attributes of fresh pomelo juices. The performance of fabricated juice extractor was evaluated in terms of quality and quantity of extracted juice. The performance is then was compared with the extracted juice from the conventional juice extraction method such as screw-press, centrifugal extractor, blending and hand press method.

However, this machine was designed mainly for the extraction of juice from fleshy fruits like citrus fruits. It might not be suitable used for extracting oil from oil bearing fruits or mushy fruits like banana, etc. The machine was constructed for crushing the fruits flesh where normally the seeds and peels were discarded manually. This project is actually proposed to add to the existing research on pomelo fruits while increasing the

pomelo products since the pomelo fruit is normally eaten raw in Malaysia. More recently, it has become clear that fruit pretreatments and extraction methods can give significant impacts on the nutritional quality of the product. Thus, while proposing the methods of juice extraction, the nutritional quality of the extracted juice must be considered well.

1.5 Thesis Outline

In this thesis, work conducted was mainly on the studies of the properties and extraction method of pomelo fruit juice. Chapter 2 introduces the pomelo fruit, benefits in medication and also the physico-chemical and mechanical properties of Malaysian variety pomelo fruits. The mechanisms of several conventional fruit juice extractor are studied. The measurement analyses used by previous studies were included. The prior art and past studies of several fruit juice extractor was also reviewed to generate the idea to develop the new concept of juice extractor.

Chapter 3 describes the materials, methods, procedures, equipment, experimental designs and statistical analysis used for the entire experimental works. The research work was performed in three parts. In the first part, a brief introduction about the content of this chapter and the physico-chemical and mechanical properties of Malaysian variety pomelo fruit were evaluated. Then, the next part of this research work was to design and develop a juice extractor for pomelo fruit juice. Then, the extracted pomelo juice from developed pomelo juice extractor was evaluated by comparing the extracted juice from the conventional fruit juice extractor. The methods to determine the quality and quantity of extracted pomelo juice from different extraction methods were obtained from this research work.

Chapter 4 discusses the results of analysis and discussions of the experimental works. The physico-chemical and mechanical properties of pomelo fruit were evaluated as the preliminary study and basis information for extended research. A few concepts in designing a juice extractor were generated and the best concept was selected based on some consideration. A selected concept was then proceeds for fabrication process. The performance of developed juice extractor was tested based on the pomelo juice yield, extraction efficiency, extraction loss and quality attributes of juices. Different extraction techniques from conventional fruit juice extractor, namely, hand press, centrifugation, screw press, and blending were evaluated based on the juice yield, moisture content of pulp, color of juice, total soluble solids, titratable acidity, pH and ascorbic acid. The performance from pomelo fruit juice extractor was then compared with the conventional fruit juice extractor based on the quality and quantity of extracted pomelo juice.

Lastly, chapter 5 summarizes the main findings obtained in this research. The recommendation works are also suggested for future research.

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