UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF OIL PALM FRUIT BUNCH CHOPPING MACHINE FOR IMPROVING CONTINUOUS STERILIZATION PROCESS

FATIN SYAKIRAH BT ALI

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By

FATIN SYAKIRAH BT ALI

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FATIN SYAKIRAH BT ALI

March 2016

Chairman : Rosnah Bt Shamsudin, PhD
Faculty : Engineering

At present, a bunch crusher is used to split the fresh fruit bunches (FFB) into small pieces prior to the continuous sterilization process. However, the bunch crusher causes a great force during the crushing process and results in severe damage to the FFB. Consequently, a lot of oil loss occurs in the oil condensate. Therefore, this study depicts the development of an FFB chopping machine to improve the continuous sterilization process. A preliminary study was conducted to determine the effects of different chopping methods of oil palm fruits on the FFA formation to predict the ample time required before the sterilization process. Besides, all the categories of the chopped fruits, which are minor damage, major damage, and chopped fruits (using knife blade), must be immediately transferred into the sterilization process less than 120 min to halt the development of FFA content. The mechanical properties of chopping the fruit bunch were obtained by using a fabricated chopping blade, which was fixed on the universal testing machine. The results were used to develop an FFB chopping machine. The FFB chopping machine was comprised of a conveyor unit; a chopping unit to chop the FFB; and a dropping unit to push the chopped fruit bunches out into a sterilizer. The chopping unit was comprised of a cross-shaped chopping blade and a v-shaped platform to hold the FFB during operation. On top of that, the performance of the machine was evaluated and upgraded to be more productive, as well as to meet the demand of the industry. Furthermore, the hydraulic and the pneumatic systems that were applied to replace the electric motor system had successfully increased the machine capacity from 0.38 ton/h to 2 ton/h, whereas the machine operating time was reduced from 106 s to 20 s. Other than that, the percentage of damaged fruits produced by the FFB chopping machine was reduced to 6.64% in comparison to that caused by the continuous sterilizer, which was 30.74%. On the other hand, the oil quality was measured by varying the holding time (0-120 min) of the chopped fruit bunches. The FFA content and the moisture content were found to increase gradually from 0.97-2.21±0.29 % and 0.15-0.40±0.02 % respectively within the holding time. On the contrary, the contents of DOBI and carotene decreased from 3.43-0.85±0.09 and 430.40-326.08±0.77 ppm respectively due to oil oxidation and denature of carotenoids during heating. Apart from that, it was revealed that the chopped

FFB could produce the highest percentage of detached fruits, which was 93.51±0.80%, at the pressure of 43.40 psi and 40 min of sterilization time. Nevertheless, the percentage of oil loss in condensate for the chopped FFB was found to be slightly increased as the pressure and the sterilization time were increased. In addition, this study was expanded to determine the effects of sterilization conditions in terms of storage time, pressure, and sterilization time of the chopped FFB on the oil quality, which focused on FFA, DOBI, and percentage of oil yield. As a result, the best condition was achieved at 0.75 min of holding time, 43.40 psi of pressure, and 40 min of sterilization time, which satisfied all the palm oil qualities. As a conclusion, throughout this study, the development of the FFB chopping machine had been proven to be a success as it was able to chop the FFB, and subsequently, enhanced the oil quality and the bunch strippability, besides reducing the percentage of oil loss in condensate.

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

PEMBANGUNAN MESIN BELAH BUAH KELAPA SAWIT UNTUK MENINGKATKAN PROSES PENSTRILAN

Oleh

FATIN SYAKIRAH BT ALI

Mac 2016

Pengerusi : Rosnah Binti Shamsudin, PhD
Fakulti : Kejuruteraan

Pada masa kini, sebuah mesin menghancurkan buah kelapa sawit telah digunakan di kilang pensterilan. Tetapi, mesin itu menyebabkan kerosakkan yang teruk kepada buah kepala sawit. Kesannya, terdapat banyak kehilangan minyak di dalam tangka kondensat. Oleh itu, kajian ini cuba untuk membangunkan satu mesin membelah kelapa sawit untuk meningkatkan prestasi proses pensterilan itu. Satu kajian awal telah dijalankan untuk menentukan kesan kaedah membelah buah kelapa sawit yang berbeza pada kadar pembentukkan asid lemak bebas untuk meramalkan masa yang mencukupi diperlukan sebelum proses pensterilan. Semua kategori buah yang di belah, yang kerosakan kecil, kerosakan besar, dan buah yang dibelah (menggunakan pisau bilah), perlu segera dipindahkan ke dalam proses pensterilan kurang daripada 120min untuk menghentikan pembangunan kandungan asid lemak bebas. Ciri-ciri mekanikal untuk membelah buah kelapa sawit telah dijalankan menggunakan satu bilah yang direka yang dipasang pada mesin universal testing. Keputusan itu digunakan untuk membangunkan mesin membelah kelapa sawit. Ia terdiri daripada: satu unit penghantar; unit membelah untuk membelah buah; dan unit pemacu penolak untuk menolak buah yang telah dibelah ke dalam alat penstrilan. Mesin membelah itu terdiri daripada bilah yang bersilang dan tempat pemegang buah berbentuk v untuk memegang buah ketika membelah. Selain itu, prestasi mesin dinilai dan dipertingkatkan untuk memenuhi permintaan industri. Sistem hidraulik dan pneumatik digunakan untuk menggantikan sistem motor elektrik telah dapat meningkatkan keupayaan mesin dari 0.38 ton/jam kepada 2 ton/jam, manakala masa mesin operasi telah dikurangkan daripada 106 saat kepada 20 saat. Peratusan buah yang rosak ialah 6.64% jika dibandingkan dengan alat penstrilan di kilang iaitu 30.74%. Selain itu, kualiti minyak terhadap kepelbagaian masa simpanan (0-120) telah dikaji. Kandungan asid lemak bebas dan kandungan lembapan telah meningkat sara beransur-ansur 0.97-2.21±0.29 % dan 0.15-0.40±0.02 % dalam masa penyimpanan. Sebaliknya, kandungan DOBI dan karoten menurun 3.43-0.85±0.09 dan 430.40-326.08±0.77 ppm kerana pengoksidaan minyak dan menghapuskan keaslian karotenoid semasa pemanasan. Selain itu, ia telah mendedahkan bahawa buah yang dibelah boleh menghasilkan peratusan peleraian buah tertinggi iaitu 93.51±0.80 %, pada tekanan 43.40

psi dan 40 min masa pensterilan.Walau bagaimanapun, peratusan kehilangan minyak di kondensat untuk buah yang dibelah telah didapati meningkat sedikit mengikut peningkatan tekanan dan masa pensterilan. Tambahan lagi, kajian ini telah diperluaskan untuk memastikan keadaan pensterilan terbaik dari segi masa penyimpanan, tekanan, dan masa pensterilan buah yang dibelah kepada kualiti minyak, yang memberi tumpuan kepada kandungan asid lemak bebas, DOBI dan peratusan hasil minyak. Keadaan optimum telah dicapai pada 0.75 min masa penyimpanan, 43.40 psi tekanan, dan 40 min masa pensterilan, yang memuaskan semua kualiti minyak sawit. Sepanjang kajian ini, pembangunan mesin membelah buah kelapa sawit telah terbukti berjaya kerana ia mampu membelah buah kelapa sawit, dan seterusnya, meningkatkan kualiti minyak dan peratusan peleraian buah, selain mengurangkan peratusan kehilangan minyak di kondensat.

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I certify that a Thesis Examination Committee has met on 1 March 2016 to conduct the final examination of Fatin Syakirah binti Ali on her thesis entitled "Development of Oil Palm Fruit Bunch Chopping Machine for Improving Continuous Sterilization Process" 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.

Members of the Thesis Examination Committee were as follows:

Mohd Shamsul bin Anuar, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Mohd Noriznan bin Mokhtar, PhD, Ing.
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Alawi bin Haji Sulaiman, PhD
Senior Lecturer
Universiti Teknologi MARA
Malaysia
(External Examiner)

ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 21 April 2016

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:

Rosnah binti Shamsudin, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Robiah binti Yunus, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

____
BUJANG KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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Signature: ______________________________

Name of Chairman of Supervisory Committee: Assoc. Prof. Dr. Rosnah Shamsudin

Signature: ______________________________

Name of Member of Supervisory Committee: Prof. Dr. Robiah Yunus

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LIST OF ABBREVIATIONS

AC	Alternate Current
ANOVA	Analysis of Variance
CPO	Crude Palm Oil
DOBI	Deterioration of the Bleachability Index
EFB	Empty Fruit Bunch
FFA	Free Fatty Acids
FFB	Fresh Fruit Bunch
MPOB	Malaysia Palm Oil Board
MPOC	Malaysian Palm Oil Council
OER	Oil Extraction Rate
PKO	Palm Kernel Oil
PORIM	Palm Oil Research Institute of Malaysia
PLC	Programmable Logic Controllers
RPM	Revolutions Per Minute
SPSS	Statistical Program Social Science
USB	Un-Stripped Fruit Bunches

LIST OF SYMBOLS

°C	degree celcius
g	Gram
h	Hours
J	Joule
kW	Kilowatt
kWh	Kilowatt hour
μ	Coefficient friction
m	Meter
ms^{-1}	meter/second
m^2	meter square
min	Minutes
mm	millimeter
ml	milliliter
N	normality
Nm	Newton meter
N/mm	Newton/milimeter
ppm	Part per million
RM	Ringgit Malaysia
s	seconds
V	volume
%	percent

CHAPTER 1

INTRODUCTION

1.1 Overview of oil palm plantations in Malaysia

The oil palm tree or *ElaeisguineensisJacq* is a very famous plant, which is also known as the *tree of life*, since it has many benefits. It is believed that the origin of the oil palm is from the West and Central Africa. After that, it spread to 43 countries, such as Africa, Indonesia, Malaysia, India, Colombia, Thailand, and others. In Malaysia, the first oil palm seeds were planted in RantauPanjang Estate in Selangor,while the first commercial planting was developed in 1917 at the Tennamaran Estate in Kuala Selangor (Sheil et al., 2009). At that time, the Malaysian Government recognised the potential of oil palm plantations to replace rubber plantations. This became one of the government alternatives to reduce the dependence on natural rubber, which had to compete with synthetic rubber. After several years, the oil palm plantations rapidly expanded throughout Peninsular Malaysia, Sabah, and Sarawak (Sheil et al., 2009). Hence, palm oil has become one of the most important commodity crops in Malaysia. It also enhances the Malaysian socioeconomic development and agricultural-based industry.

Generally, Malaysia had 54000 hectares of land area for cultivation of oil palm in 1960 and this increased to 4.5 million hectares in 2008. This shows that the performance of the palm oil industry has rapidly increased year by year. In 1966, Malaysia and Indonesia dominated the trade of palm oil and took over from Nigeria and Zaire. In recent years, Malaysia and Indonesia have been together producing 85 % of the total world production of palm oil (Sheil et al., 2009). At present, Indonesia is the largest producer because of the wide land areas and the availability of cheap labour. The oil palm plantation land areas are in Kalimantan, Sumatera, Sulawesi, Java, and also Papua. Over the last decade, the Malaysian palm oil industry has developed to become the world's largest exporter of palm oil products even though Indonesia overtook Malaysia in terms of volume of crude palm oil (CPO) production in 2006 (Abdullah and Wahid, 2009). As a leading palm oil exporter, Malaysia had supplied about 18.8 million tons of palm oil products in 2011 to China, Pakistan, the European Union, United States, and India (MPOB, 2012). Furthermore, it is indeed fortune for Malaysia to have a humid tropical climate that encourages the growth of the oil palm trees.

Globally, there is a great demand for palm oil as it is very versatile, nutritious, and healthier than the alternatives. In addition, the oil palm is very productive and it is the most efficient oil seed crop compared to soybean, sunflower or rapeseed crops. The oil palm fruits are able to produce approximately ten times more oil per hectare of land than other seed crops (Abdullah and Wahid, 2009). According to the Malaysian Palm Oil Council (MPOC) 2006, palm oil and palm kernel oil (PKO) demonstrate an efficiency of 27.5 %, which is the highest percentage of the world production of oils and fats compared to soybean oil, coconut oil, corn oil, rapeseed oil, sunflower oil, butter, lard, and others.

Currently, about 80 % of the palm oil is applied as edible food, while the remainder is used for non-edible products. Research has also found that palm oil has the potential to be a biofuel resource because of its high yield of production per hectare and the lowest cost compared to rapeseed oil (Tan et al., 2009). Since oil palm plantations have such a high impact in terms of production and profitability, the government does not hesitate in investing in the palm oil mill industry.

1.2 Palm Oil Milling

Palm oil milling is the process of extracting the CPO from the fleshy mesocarp after which the kernels are sent to a palm kernel mill to extract the PKO. The milling process involves many stages, which include FFB grading, sterilization, threshing, digestion, clarification, and drying. All the processing steps are crucial to obtain a high percentage of oil extraction rate (OER) with superior oil quality. In fact, a total of 428 oil mills cover all states, including Sabah and Sarawak, which process the fresh fruit bunch (FFB) into CPO and PKO (MPOB, 2012).

The main aspect of palm oil milling is the sterilization process. It cooks the FFB using highly pressurised steam to halt the development of free fatty acids (FFA) due to enzymatic activity. The process also softens the fruit cells, and subsequently, facilitates the detachment of the fruits from the bulk of the FFB (Wan Ismail et al., 2011). In Malaysia, the predominant sterilization system used is the conventional sterilization method. Approximately 2.5 ton of the FFB are dumped into each cages and sterilized under high pressure steam ranging from 15-45 psi for 90 min (Umudee et al., 2013).

In addition, the palm oil mill industry has also implemented an automatic system, which is the continuous sterilizer (CS) system, to enhance the sterilization process in the mill. The CS system uses a bunch splitter to split the FFB into small pieces. A bunch splitter consists of double rollers, which are operated to crush the FFB prior to the sterilization process. After that, the crushed FFB is conveyed into an enclosed CS system and steam is blown at a low pressure of 14.34psi to heat the fruits.

1.3 Problem Statement

The main step of the CS system is the crushing process. The purpose of the crushing process is to disrupt the bulkiness of the fruit bunch, hence encouraging heat penetration into the inner layers of the fruits. Therefore, a double roll crusher is designed and installed in the inlet flap valve with a fixed gap of 15 mm between the rollers (Figure 1.1) (Sivasothy et al., 2005). However, the gap causes severe damage to the larger FFB and fails to effectively open up the very small bunches. Thus, the oil quality will be affected if no heat treatment is applied immediately for the damaged FFB. In addition to that, the damaged fruits also cause oil to exude from the mesocarp of the fruit during the steam injection (sterilization process) and consequently, the oil is washed out and collected in the condensate. Other than that, the oil is also absorbed by the empty fruit bunch(EFB).

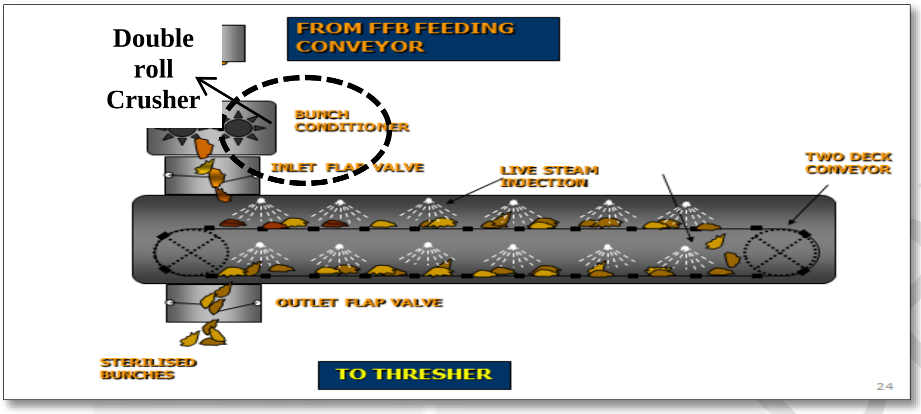

Figure 1.1: The continuous sterilization system applies low pressure steam to heat the crushed FFB (Sivasothy et al., 2006)

The CS system loads a lot of fruit bunches into the double-roll crusher within 30 to 60 s of intervals (Sivasothy et al., 2005). Some of the FFB, especially the small-sized FFB, are not crushed or opened up effectively, as shown in Figure 1.2. The uncrushed FFB tends to contribute to the undetached fruits during the stripping process since it is sterilized under low steam pressure. The low steam pressure is inadequate to detach many layers of the fruitlets from the bunch and this problem also contributes to the poor oil yield extracted at the end of the process.

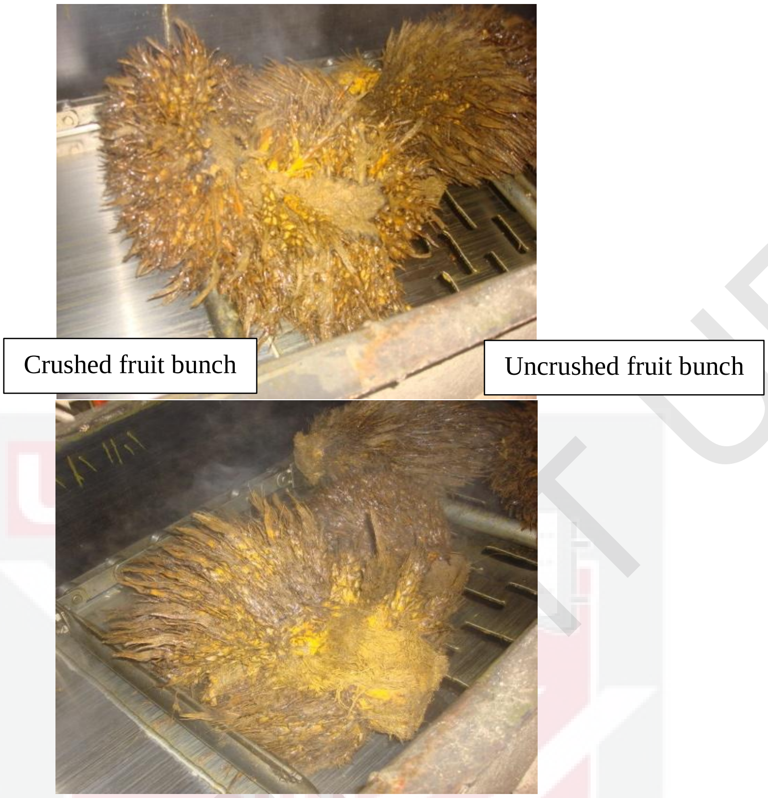

Figure 1.2: The crushed and the uncrushed fruit bunchesafter the bunch splitter

The inefficient crushing process that severely damages the surface of the fruit and causes oil loss,as well as unstripped hard bunches, are the major problems that need to be handled by the CS mills. Basically, a mill that applies the CS system handles these problems by utilising the oil loss. The utilisation of oil loss is important to maintain the OER at the end of the milling process. At present, the CS mills still maintain their percentage of OER at about 21 % and often above 22 %, but no any significant increase in the OER (Sivasothy et al., 2006).

With regard to these problems and the very limited amount of studies pertaining to the crushing process of FFB, a need was identified and this study was conducted to propose an alternative to break up the fruit bunch by using a chopping mechanism. The chopping mechanism was generated by an FFB chopping machine. The mechanism was able to reduce the percentage of damaged fruits and oil loss in the condensate.

1.4 Scope of study

The scope of study was focused on the development of an oil palm FFB chopping machine to improve the current bunch crusher in the continuous sterilization system. The chopping method was carried out in order to chop the FFB by using the FFB chopping machine. The FFB chopping machine was equipped with a specialized cross-shaped chopping blade to chop the FFB into small parts and a v-shaped platform to hold the FFB during the chopping operation. On top of that, the study was extended to determine the effect of the chopping process, as well as the sterilization process on the oil quality.

1.5 Objectives

Therefore, this research was carried out based on the following specific objectives:

1. To elucidate the mechanical properties of chopped fruit spikelets and their effect on the formation of free fatty acids(FFA) content.
2. To develop a design concept and to evaluate the performance of the developed FFB chopping machine.
3. To determine the effect of different holding time, sterilization pressures, and sterilization time of the chopped FFB on the oil quality.

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