UNIVERSITI PUTRA MALAYSIA

TEXTURAL, IMAGING AND HEAT TRANSFER STUDIES OF OIL PALM FRUITLETS IN CONTINUOUS STERILSER

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FK 2008 48

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By

SAAD ABDULAMIR ABBAS

Thesis Submitted in Fulfillment of the Requirement for the Degree of Doctor Philosophy in the Faculty of Engineering Universiti Putra Malaysia

January 2008

Dedication

To him who give me the patient, wisdom, power and guidance, I thank him, the most merciful, ALLAH (s. w. t.)

I sincerely dedicate the fruits of my effort to my dearest parents who really plant in me the principal of love, care, and respect. I hope ALLAH will give me the health and welfare to do my duty towards them.

I dedicate also this work to my continuity, lovely children Saif and Farah, who are worth a lot to me…..

ABSTRACT

Abstract of theses presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy.

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Chairman: Associate Professor Dr. Thomas S. Y. Choong, PhD

Faculty: Engineering

Commercial palm oil mills in Malaysia are using batch sterilisation process, which had considerable disadvantages and negative impact on palm oil mill industry. The aim of the study is to investigate some aspects of continuous steriliser, which may help in reducing the high operational cost of palm oil mills and provide a possibility of minimizing the oil lost that escape with effluent in which rendering the yield of oil and impacting environment. Sterilisation has a direct effect on textural properties of palm oil fruitlets. The level of sterilisation effect is proportional to the amount of heat applied on the process. A significant changes of certain parameter was observed and documented during this work.. Sterilisation causes softening of fruitlets texture and the degree of softening is proportional to the level of thermal treatment. Intensive work was carried out to determine textural analysis of the fruits and comparing the result with the sterilised

samples that were collected from commercial mill. Different residence times were applied to investigate the changes in textural properties. Average values of fracturability, hardness and adhesiveness of abscission layer of sterilised fruitlets were measured using laboratory fabricated steriliser. Reading of these parameters are; 9 (gram force), 304 (gram force) and -8 (gram force. second), respectively. Standard values of fracturability, hardness and adhesiveness of mesocarp of sterilised fruitlets were 11.3 (force gram), 192 (force gram) and -5.7 (gram force. second), respectively. Comparing with fracturability, hardness and adhesiveness of abscission layer of fresh fruitlets of 23 (gram force), 1113 (gram force) and -15 (gram force. second), respectively. Standard values of hardness and cohesiveness of palm kernel nut of sterilized fruitlets were found to be 5293 (gram force) and 0.66 respectively. Compare with hardness and cohesiveness of palm kernel nut of fresh fruitlets of 15700 (gram force) and 0.94, respectively. It was observed from monitoring behavior of fruits texture during sterilisation that optimization process of residence time is fully complies with the objectives of sterilisation. Values of fracturability of abscission layer obtained from applying residence times of 30, 40, 45, 50 and 55 minutes were 10.7, 10.2, 9.9, 8.1 and 7.6 (gram force), respectively. Hardness values of abscission layer of 371, 265, 221 and 197 (gram force) were recorded when applying residence time of 40, 45, 50, and 55 minutes respectively. Values of adhesiveness of abscission layer of (-16.1), (-16), (-13), (-10.7) and (-8.4) (gram force. second) of residence times of 30, 40, 45, 50 and 55 minutes respectively were recorded. Hardness values of mesocarp of 302, 266, 205, and175 (gram force) were recorded with residence time of 40, 45, 50 and 55 minute respectively. Adhesiveness values of mesocarp of (-1.6), (-1.1), (-1.1), (-1.1) and (-0.97) (gram force. second) are obtained from applying residence time of 30, 40, 45, 50 and 55 minutes, respectively. Values of fracturability for the mesocarp are 11.6, 11, 10.2, 9.4 and 9 (gram force) were obtained from applying residence times of 30, 40, 45, 50 and 55 minutes respectively. Hardness and cohesiveness of fresh and sterilised palm kernel nut were investigated also. Hardness values of palm kernel nut of sterilised fruitlets are 11800, 8330, 7231, 5651, and 4516 (gram force) were obtained when applied the same residence times. Cohesiveness values of palm kernel nut of sterilised fruitlets are 0.82, 0.73, 0.71, 0.66 and 0.56 were obtained when applying same residence time also. A correlation between residence time and textural properties helps in the prediction of process optimization. The fruits normally reached the mills in different ripeness categories. Oil content and color of fruits are also not of same categories. Fruit color was observed in this study to be an excellent indicator on the oil content. Color criteria produced very good correlation on ripeness level. Intensive experiments were carried throughout in this study to establish a correlation between oil content and color of fruit. An emphasis was paid on red color band and oil content exhibits a regression value (R^2) of 0.86. Color of fruits was measured in terms of digital number configuration. To verify the results obtained experimentally, a numerical and analytical simulation was developed. Models are proposed to solve heat transfer problems in sterilisation tunnel. Heat transfer model was developed under transient condition with constant fruit properties and no heat generation and the fruit was considered of spherical geometry. The model predicts temperature distribution at the center of fruit and its variation with time. Experimentally it was found that fruit needs to reside 47 minutes inside the sterilisation tunnel to reach 106 ºC which is the desired temperature to reach at the surface of palm kernel nut. Whereas residence time of 45 and

49 minutes were found to complete the required thermal treatment cycle using analytical and numerical simulation, respectively.

ABTRAK

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KAJIAN TEXTUR, PENGIMEJAN DAN PEMINDAHAN HABA BUAH KELAPA SAWIT DALAM PENSTERIL BERTERUSAN

Oleh

SAAD ABDULAMIR ABBAS

Januari 2008

Pengerusi : Profesor Madya Dr. Thomas S. Y. Choong, PhD

Fakulti : Kejuruteraan

Kilang minyak sawit komercel di Malaysia menggunakan proses pensteril berkelangat, dimana melibatkan kekurangan dan impak negative dalam industri minyak sawit. Matlamat penyelidikan ini adalah untuk meskaji dan mengetahui beberapa aspek dalam perstil berturskan, dimana ia membantu dalam mengurangkan kos perseluaran minyak sawit dan kemungkinan mengurangkan kehilangan minyak yang dibuang dengan bahan yang boleh menghasilkan minyak dan kesan terhadap alam sekitar. Eksperimen ini dibuat menggunakan persteril bertaretan, dengan menjangkakan penambahan mutu minyak kelapa sawit. Pensteril mempunyai kesan ke atas tekstur buah sawit. Darjah akibat kesan itu adalah berkadaran dengan jumlah kepanasan yang diberi. Semasa proses steril,

sesetengah tekstur jelas menunjukkan perubahan, steril menyebabkan tekstur buah menjadi lembut, dimana memerlukan darjah yang berlainan. Darjah untuk melembutkan adalah berkadaran kepada tahap rawatan terma. Eksperimen yang intensif telah dibuat untuk menentukan analisis fizikal buah dengan membandingkan keputusan dengan contoh steril yang diambil dari kilang. Cara yang mengikut garis panduan telah digunakan untuk menentukan nilai kesegaran dan buah yang di steril sebagai panduan untuk menjayakan kesinambungan proses steril. Ia dibuat di tempat yang berlainan untuk memperolehi perubahan dalam tekstur. Nilai yang digariskan dalam kekerasan fraktur dan adhesiveness of abscission lapisan buah yang disteril adalah 9 gram, 304 gram dan -8 gram. Berbanding dengan nilai pecahan, kasar dan lekatan buah segar dari 11 gram, 2034 gram dan -88 gram saat. Nilai standar pecahan, kasar dan lekatan mesocarp dari buah yang di steril adalah 11.3 gram, 192 gram dan -5.7 gram saat. Berbanding dengan pecahan, kasar dan lekatan lapisan buah segar dari 23 gram, 1113 gram dan -15 gram saat. Nilai standard kasar dan kehalusan isi buah kepala sawit di mana di jumpai menjadi 5293 gram and 0.66 gram. Berbanding dengan kekasaran dan cohesiveness buah kelapa sawit segar dari 15700 gram dan 0.94. Ini di lihat daripada pemantauan kelakuan tekstur buah semasa proses steril yang optimakan proses masa ialah sama dengan objektif steril. Nilai dari proses pecahan lapisan di dapati dari masa yang di ambil iaitu dari 30, 40, 45, 50 dan 55 minit iaitu 10.7,10.2, 9.9, 8.1 dan 7.6 gram. Nilai kasar dari lapisan abscission dari 371, 265, 221 dan 197 gram di mana di ambil dari masa 40, 45, 50, 55 minit. Nilai lapisan abscission dari (-16.1), (-16), (-13), (-10.7) dan (-8.4) gram saat dalam masa dari 30, 40, 45, 50, dan 55 minit yang direkodkan. Nilai kasar mesocarp dari 302, 266, 205, dan 175 gram di rekodkan semasa kutipan masa pada 40, 45, 50 dan 55 minit. Nilai adhesiveness mesocarp dari (-1.6), (-1.1), (-1.1), (-1.1) dan (-0.97) gram saat diperolehi daripada masa 30, 40, 45, 50 and 55 minit setiap satunya. Nilai pecahan mesocarp dari 11.6, 11, 10.2, 9.4 dan 9 didapati dari masa 30,40, 45, 50 dan 55 minit. Kasar dan cohesiveness isi buah kelapa sawit segar dan steril di buat siasatan juga. Nilai kasar isi buah kelapa sawit steril dari 11800, 8330, 7231, 5651 dan 4516 gram didapati apabila masa yang di ambil pada 30, 40 ,45, 50 dan 55 minit. Nilai cohesiveness isi buah kelapa sawit dari 0.82, 0.73, 0.71, 0.66 dan 0.56 didapati apabila masa yang diambil pada 30, 40, 45, 50 dan 55 minit. Korelasi antara masa tinggal dan maklumat tekstur membantu dalam proses mengoptimumkan hasil. Selalunya buah-buahan akan masak di dalam kategori kematangan yang tertentu. Kandungan minyak dan warna buah tersebut juga tidak sana kategori. Kepelbagaian dalam kandungan minyak dan warna buah adalah berkaitan dengan tahap kematangan buah tersebut. Eksperimen dijalankan di dalam kajian ini untuk mendapatkan korelasi antara kandungan minyak dan warna sesuatu buah. Hubungan di antara band warna merah dan kandungan minyak mempunyai nilai pengunduran (R^2) dari 0.86. Warna buah diukur dalam bentuk nombor digital. Untuk mengesahkan keputusan yang didapati dari eksperimen ini, penjelmaan numeric dan analitikal telah di bina. Model yang di cadangkan untuk menyelesaikan masalah permindahan haba dalam terowong steril. Model permindahan haba dibina di bawah keadaan sementara dengan buah yang tetap dan tiada haba yang terhasil dan mengambil kira geometri buah yang berbentuk sfera. Model taburan haba mentafsirkan pada tengah buah dan variasi mengikut masa. Ekperiment ini menjumpai buah perlu di biarkan selama 47 minit dalam terowong steril sehingga mencecah 106 ºC di mana ia merupakan suhu untuk sampai ke isi buah sawit. Di mana masa di antara 45 dan 49 minit merupakan masa jangkaan yang diperlukan untuk menyiapkan pusingan rawatan haba menggunakan simulasi numeric masing-masing.

ACKNOWLEDGMENTS

I would like to take this opportunity to express my sincere thanks to the chairman of my supervision committee, Associate Prof. Dr Thomas S. Y. Choong for his continuous help and support during the period of this study. Sincere thanks are extended to past committee members: Associate Prof. Dr Fakhrul'-Razi Ahmadun and Mr. Mohd halim Shah Ismail and to present committee members: Associate Prof. Dr Robiah Yunus and Dr Salimaton Ali for their support, cooperation and guidance. A sincere thanks also goes to Associate Prof. Dr Abdul Rashid Mohamed Shariff for his support and useful contributions.

Special thanks to all staff of texture laboratory in Faculty of Food Science and technology for their assistance during the construction of texture experimental setup. I wish to express great thanks to Mrs. Rohaya Halim from Malaysian Palm Oil Board (MPOB) and to all the staff of Chemical Analysis Laboratory/Department of Engineering and Technology for their assistance during the construction of images and oil content experiments, who has been kind enough to provide help and support, all the encouragement and help thankfully acknowledged.

Great thanks to my dearest friend Prof. Dr Amir Hassan Khadum who really assist me in accomplishing my work, and who never reserved any effort to support and encourage me from the beginning until the very last of this work. I ask ALLAH (s.w.t.) to bless him and his family.

I also wish to acknowledge the experimental and computational faculties provided by the Faculty of Engineering during the course of work.

I also wish to express my deepest gratitude to the staff of the Graduate School for all kinds of assistance provided to us, international students that make our life easier.

The present work is funded by MOSTI, Intensified Research Priorities Area (IRPA) (09-02-04-032-EA001), which is thankfully acknowledge.

DECLRATION

I declare that the thesis is my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously and is not currently, submitted for any other degree at UPM or any other institution.

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SAAD ABDULAMIR ABBAS

Date: April 11th, 2008

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

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Date: 8/5/2008

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BBREVIATIONS

Symbol	meaning	Unites
A	Area	m^2
Ad	Adhesiveness	gram seconds
Av	Average	Unit less
Co	Cohesiveness	Unit less
C_p	Thermal heat capacity	kJ/kg. K
CPO	Crud palm oil	-
DN	Digital number	Unit less
EFB	Empty fruit bunch	-
EWL	Equivalent Water Loss	%
FFB	Fresh Fruit bunch	-
FFA	Free fatty acid	%
FAC	Fatty acid compositions	-
Fr	Fracturability	gram
FS	Fresh fruitlets sample	-
H	Hardness	gram
M_C	Relative oil content	%
K	Thermal conductivity	W/m. K
PKO	Palm kernel oil	%
r	radius	m
SS	Standard sterilized fruitlets	-
SD	Standard deviation	unit less
T	Temperature	°K

t	Time	Minutes
ρ	Density	kg/m^3
α	Heat transfer coefficient	W/m2 .k

CHAPTER 1

INTRODUCTION

1.1 Palm Oil Milling Technology

The spectacular growth of the palm oil industry in Malaysia since the 1960s has led to refinement in palm oil milling technology that have facilitated simplified operation and easy maintenance, larger-scale operation, lower operating and maintenance costs and lower product losses (Sivasothy *et al.,* 1997).

Currently there are about 330 palm oil mills operating in Malaysia. Even though the milling technology can be somewhat different but they are similar in nature. Figure 1.1 shows the typical process flow diagram in a mill (Sivasothy *et al.,* 1992b). There has been no fundamental change in the milling process itself since the Mongana research in 1955. About 10% of the palm oil and palm kernels are currently lost during processing. Fine-tuning the conventional processes, using techniques such as two-stage stripping and pressing, can reduce the losses. Most of the losses, however, cannot be avoided using conventional mechanical extraction techniques, thereby making it necessary to investigate the use of new extraction processes. In the past, there has been a general lack of interest in completely different processing techniques. The design of mills was also largely based on rule-of-thumb (Sivasothy *et al.,* 1993).

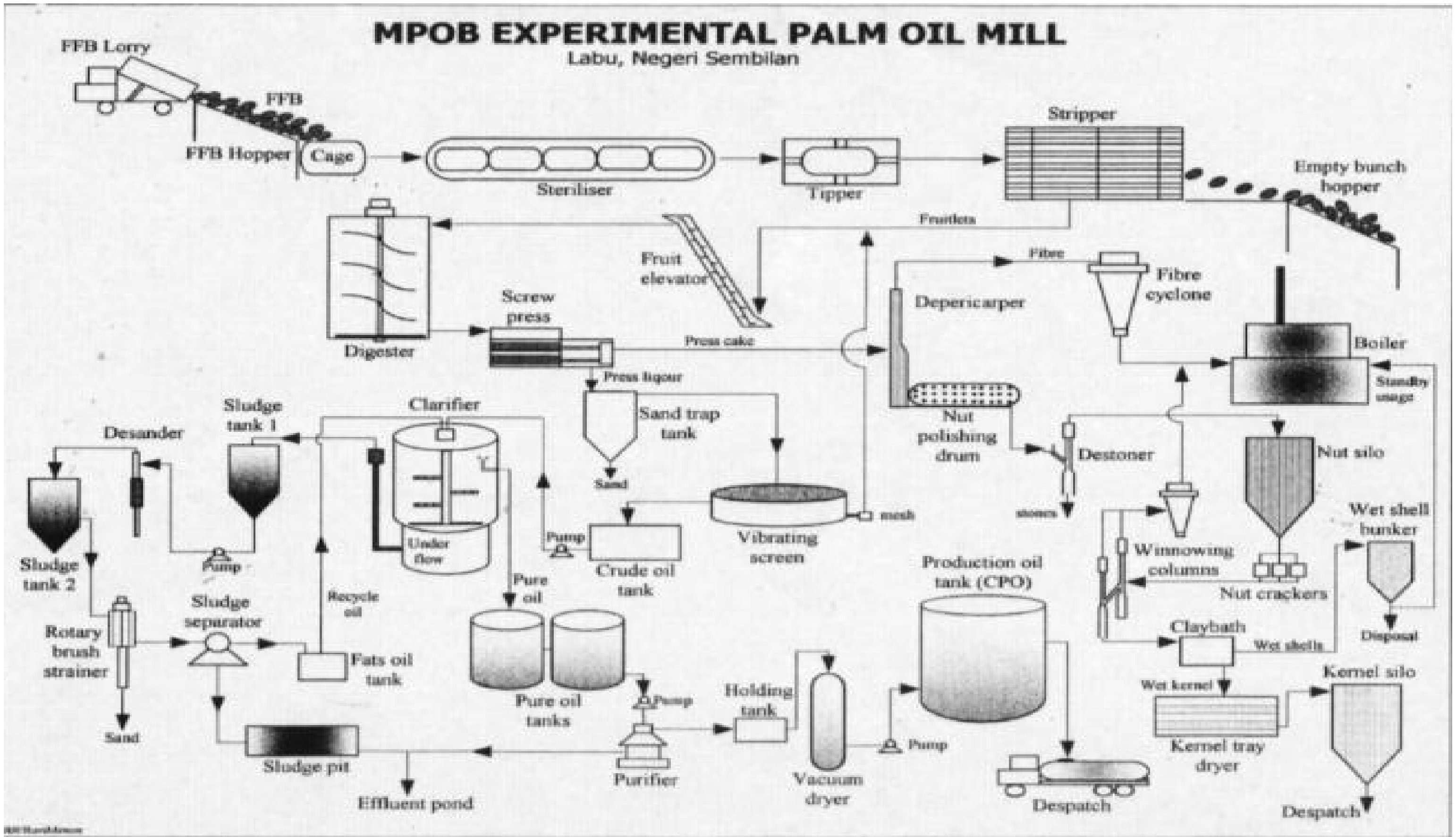

Figure 1.1: Typical Palm oil mill (Adopted from PORIM, 1989)