UNIVERSITI PUTRA MALAYSIA

FUNDAMENTAL STUDIES ON THE FIELD STRIPPING SYSTEM OF OIL PALM FRUITLETS

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DOCTOR OF PHILOSOPHY
UNIVERSITI PERTANIAN MALAYSIA
1994

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BY

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Dissertation Submitted in Fulfilment of the Requirements for the Degree of Doctor of Philosophy in the Faculty of Engineering Universiti Pertanian Malaysia

April 1994

ACKNOWLEDGEMENTS

I wish to express my profound gratitude to Prof. Dr. Mohd. Zohadie Bardaie, chairman of my supervisory committee, who has guided me in conducting the research work and in writing up this dissertation. Prof. Dr. Zohadie also arranged for additional financial support to carry out this study.

I also wish to thank Assoc. Prof. Ir. Dr. Desa Ahmad and Dr. Azmi Yahya, members of my supervisory committee, for their valuable advice and guidance in supervising this dissertation.

I expresses sincere gratitude to Prof. W.J. Chancellor and Prof. Makoto Hoki, my external examiners, who have given useful guidance concerning the final construction of the thesis.

Mr. Mesran R. and Mr. Mohd. Kamal H. have been very helpful especially in allowing the use of workshop facilities and developing the test rigs. Miss Fadzlon Mohd. Yusof, Mrs. Fauziah Hassan and Miss Chang Poo Yin have read this dissertation and made helpful suggestions. Mr. A. Shafi A. and Mrs. Rufina R. have provided the computer facilities. I really appreciate their contributions.

SEARCA and DAAD (Deutscher Akademischer Austauschdienst) provided the financial assistance throughout my Ph.D study. To these institutions, thank you very much.

Last but not least, I am particularly grateful to my beloved family: Lies, Pritha, and Heru; and my dearest friends: Ron Loewen and Brenda Wiebe.

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LIST OF ABBREVATIONS

Symbols

ANE	edge angle of the knife
ANO	oblique angle
Anova	analysis of variance
BI	bruise index
D	diameter, m
DA	drum angle angle between drum axis and horizontal line
DW	weight density of water, gram/cm^3
DF	density of fruitlet, gram/cm^3
DP	density of packing, gram/cm^3
DF	degrees of freedom
DSPEED	rotational speed of the threshing drum, rpm
E	Modulus elasticity, N/m^2
FFB	fresh fruit bunch
EFB	empty fruit bunch
ENCSA	specific cutting energy per cut solid area, N/cm^2
F	component of the cutting force acting opposite to the feeding direction, N
FFA	free fatty acid
FOE	edge force, N
FOX	cutting force component in direction of the travel of knife, N
FOCSA	specific cutting force per cut solid area, N/cm^2
FOW1N	normal component of wedge force on the slanted blade side of knife, N
FOW2N	normal component of wedge force on the plain side of knife, N
JR	just ripe bunch
LF	number of loose fruits/kg bunch
LP	main cutting power, watt
m'	feeding rate, kg/s
MAD	major diameter of fruitlet, cm
MID	minor diameter of fruitlet, cm
MOD	moderate diameter of fruitlet, cm
MS	mean square
N	normality of alkali solution
NLP	no-load power of rotational speed of saw, watt
OILDK	percentage of oil in dry kernel
OILWP	percentage of oil in wet pericarp.
P	total power utilized to strip fruitlets, watt
PF	porosity of fruitlets, %
PORIM	Palm Oil Research Institute of Malaysia
r	coefficient of correlation
R	ripe bunch

Rd	radius of the inner drum, m
R^2	coefficient of determination
RCB	randomized complete block
Sg	gage factor
SA	shear angle
SAF	surface area of fruitlet, cm^2
SSPEED	rotational speed of saw, rpm
SS	sum of squares
T	torque, Nm
TA	threshability
	percentage weight of threshed to the total fruitlets
TCP	total cutting power, watt
UR	under ripe bunch
v	Poisson's ratio
V	speed of feeding, m/s
VF	volume of fruit, cm^3
Vs	source voltage, volt
Vo	output voltage, volt
w	angular speed of the inner drum, radian/s
W	weight of oil, gram
WF	weight of fruitlet, gram
WWCF	weight of water, container and submerged fruitlet,gram
WWC	weight of water and ontainer, gram
α	angular acceleration, radian/s^2

Units

cm	centimetre
g	gramme
ha	hectare
hr	hour
hp	horsepower
kg	kilogram
km	kilometre
kw	kilowatt
m	metre
mg	milligramme
min	minute
ml	millilitre
N	newton
rpm	revolutions per minute
RM	Malaysian Ringgit
s	second

Abstract of dissertation submitted to the Senate of Universiti Pertanian Malaysia in fulfillment of the requirements for the degree of Doctor of Philosophy.

FUNDAMENTAL STUDIES ON THE FIELD STRIPPING SYSTEM OF OIL PALM FRUITLETS

By

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April 1994

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Faculty : Engineering

In the present harvesting system, fresh fruit bunch (FFB) is transported and sterilized in the mill as a whole material instead of only fruitlets. This procedure causes some problems such as extra costs to transport and to sterilize the stalk, difficulty to heat the heavy bunch, and oil loss absorbed by the empty bunch.

To overcome this problem, an attempt was made to separate the fresh fruitlets from the cut spikelets in the field, so that only the fruitlets will be transported to the mill, while their stalks will be left in the field as mulch. The required steps of the proposed in-field stripping system are to reduce the removal force of fruitlet, to prepare the cut spikelets as threshed material, and to detach loose fruitlets from the cut spikelets using a drum thresher.

In order to accomplish the in-field stripping process, attempts were made: 1) to identify effective treatments which may accelerate the loosening process of fruitlets such that it can be stripped easily without deteriorating the oil quality, 2) to establish design parameters for cutting the spikelets from the treated bunch by means of a knife blade or a circular saw, 3) to develop an experimental drum thresher and to study the effects of various design constrains on the threshing performance. Bruise index, an indicator of the quality of stripped fruitlets due to the introduction of the thresher, was developed. Some physical properties of the oil palm fruitlets pertaining to the design of the thresher were also identified.

The fruitlets abscission could be hastened by spraying ethephon on cut spikelets or the brushing this chemical on the cut stalk of FFB. Its effect on the percentage of detached fruitlets and the removal force of the fruitlet were significant. This application did not affect the development of free fatty acid content.

Low speed cutting tests using a knife blade showed that the specific cutting force and energy for the stalk and spikelet were significantly influenced by the knife edge angle, oblique angle, shear angle, but not by the cutting speed. Experiments using a circular saw showed that the total cutting power requirement for the bunch was directly proportional to the thickness of material, feeding rate, and the rotational speed of saw.

Tests on the performance of the experimental drum thresher showed that threshability increased by increasing the inner drum speed and the number of rubber teeth of the outer drum. The threshing power requirement was influenced by the rotational speed and the diameter of the inner drum, and the feeding rate. The threshing operation slightly increased free fatty acid (FFA) content of the threshed fruitlets. However, it was still less than 5% i.e. the maximum FFA allowed in the traded oil. This study showed that FFA content was closely related to the bruise index of the fruitlets.

It was suggested that the threshing machine should use an inner drum with a diameter of 16 cm at the speed of about 300 rpm and drum angle of about 2.5°. The rubber teeth arranged at 5cm x 10cm would be suitable for various length of spikelets. The results of this study showed that the stripping of the spikelets under these conditions produced more than 95% threshability, provided that the spikelets were taken from FFB treated with 4 gram of ethephon with 30% concentration and stored for 24 hours.

Abstrak disertasi yang dikemukakan kepada Senat Universiti Pertanian Malaysia bagi memenuhi syarat untuk Ijazah Doktor Falsafah.

KAJIAN ASAS TENTANG SISTEM PELERAIAN BUAH KELAPA SAWIT DI LADANG

Oleh

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April 1994

Pengerusi : Prof. Dr. Mohd. Zohadie Bardaie

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Dalam sistem penuaian kelapa sawit dimasa ini, bahan tandan akan diangkut dan disterilisasi di kilang secara keseluruhan. Kaedah ini menimbulkan beberapa masalah seperti peningkatan dalam kos pengangkutan dan pensterilan tangkai tandan, kesukaran dalam pemanasan tandan yang besar, dan kehilangan minyak yang diserap oleh tandan kosong.

Untuk mengatasi masalah ini, usaha perlu dilakukan untuk memisahkan buah-buah segar daripada potongan spikelet di ladang, sehingga hanya buah-buah ini saja yang diangkut ke kilang sementara tandan-tandan kosong ditinggalkan sebagai kompos di ladang. Beberapa langkah yang diperlukan oleh sistem peleraian yang dicadangkan ini adalah terdiri daripada rawatan untuk mengurangkan daya pemisahan buah, penyediaan spikelet, dan pemisahan buah-buah daripada spikelet dengan menggunakan mesin pelerai.

Untuk mencapai dengan sempurna proses peleraian di ladang, usaha dilakukan untuk: 1) mengenal pasti rawatan yang dapat digunakan untuk mempercepatkan proses pelonggaran buah tanpa menurunkan mutu minyak, 2) menentukan parameter rekabentuk untuk pemotongan spikelet dari tandan dengan menggunakan pisau dan gergaji bulat, 3) membangunkan drum pelerai dan mengkaji kesan-kesan berbagai ketetapan rekabentuk pada prestasi peleraian. Indeks lebam sebagai penunjuk mutu minyak yang mungkin dipengaruhi oleh mesin pelerai telah diperkenalkan. Sifat-sifat fizik buah kelapa sawit yang berkaitan dengan rekabentuk mesin pelerai juga dikenal pasti.

Peleraian dapat dipercepatkan dengan menyemburkan ethephon pada potongan spikelet atau dengan menyapukan bahan kimia tersebut pada tangkai tandan. Pengaruh rawatan ini terhadap peratus buah terlerai dan daya pemisahannya adalah sangat berkesan. Walau bagaimanapun, rawatan ini tidak memberi kesan kepada kandungan FFA (Asid Lemak Bebas) dalam minyak tersari.

Ujian pemotongan dengan menggunakan pisau pada kecepatan yang rendah menunjukkan bahawa daya dan tenaga pemotongan tentu untuk tangkai tandan dan spikelet dipengaruhi oleh sudut mata pisau, sudut serong, dan sudut ricih; tapi bukan oleh kecepatan pemotongan. Ujikaji dengan gergaji bulat menunjukkan bahwa jumlah kuasa untuk pemotongan tandan berkadar terus dengan tebal tandan, kadar suapan, dan halaju pusingan gergaji.

Ujian untuk prestasi pelerai menunjukkan bahwa kecekapan peleraian akan bertambah dengan pertambahan dalam halaju pusingan dram dalaman serta jumlah bilangan batang-batang getah pada selinder luar. Kuasa peleraian dipengaruhi oleh halaju pusingan, garis pusat dram dalaman, dan kadar suapan. Operasi peleraian sedikit menaikkan asam lemak bebas (FFA) daripada buah terlerai. Bagaimanapun kandungan tersebut lebih kecil daripada 5% iaitu FFA maksimum yang dibenarkan dalam minyak dagangan. Kajian ini juga menunjukkan bahawa kandungan FFA berkaitan erat dengan indeks lebam daripada buah.

Adalah dicadangkan, untuk penggunaan mesin pelerai dengan dram dalaman yang bergaris pusat pendek disekitar 16 sm, halaju pusingan disekitar 300 ppm, dan sudut condong daripada dram pelerai disekitar 2.5°. Batang-batang getah yang dipasang pada 5 sm x 10 sm adalah sesuai untuk spikelet yang mempunyai panjang berbeza-beza. Kajian ini menunjukkan bahawa peleraian dalam keadaan ini memberikan hasil kecekapan pelaraian lebih daripada 95%. Ia dilakukan dengan menggunakan spikelet yang diambil dari tandan yang telah diberi rawatan dengan 4 gram ethephon (kepekatan 30%) dan disimpan selama 24 jam di ladang.

CHAPTER I

INTRODUCTION

In 1990, about 15.7% of the world's edible oil is from oil palm mainly grown in Malaysia and Indonesia with the planting area of 1,984,000 ha and 1,126,000 ha respectively (Adlin, 1992). The extensive cultivation of oil palm is related to the very high oil yield obtained with relatively low input. Mature tenera palms of 10 years old may produce fresh fruit bunches up to 25 tonne/ha for inland area and 27.5 tonne/ha for coastal area annually (Wakefield, 1980). The oil content in mesocarp is about 22.5-27.5% of bunch weight and that in kernel is about 50% of its own weight (Wood, 1981).

In the present harvesting system, the fresh fruit bunch (FFB) is usually transported to the mill as a whole material instead of only fruitlets. In the mill, the bunches are then sterilized and stripped mechanically to remove the fruitlets from the stalks. The fruitlets will be processed in the operations that follow to provide oil and kernel, while the rejected empty fruit bunch will be brought back to the field for mulching.

The implementation of this system created some problems such as the additional costs to transport and to heat the stalk, difficulty in heating the heavy bunch, and oil loss absorbed by the empty bunch.

The first extra cost is required in transporting the stalk comprising 35-45% of bunch weight, from the planting area to the mill. The transportation of the fresh fruit bunch usually make up about 11% of the total field operation cost (Clendon, 1990).

Another additional cost is required to return the empty fruit bunch from the mill to the planting area where it is used as a mulch. Its application of about 37.5 tonne/ha could increase the bunch production by 7% due to the improvement of the uptake of the mineral fertilizer, vegetative growth, retention of water, and additional nutrients supplied by the empty bunch (Chan et al., 1981; Khoo and Chew, 1979). The transportation costs per tonne for the empty fruit bunch was about RM 0.2/km (Abdullah et al., 1990).

Stalks which are processed together with the attached fruitlets cause ineffective sterilization. They do not only absorb a great amount of heat and take a lot of space in the sterilizer but also need a longer sterilization time. Hartley (1967) reported that the sterilization of fresh fruit bunches required 60-75 minutes, while the fruitlets needed only 12 minutes. This was due to the difficulty in heating the fruits located in the centre of a large bunch. Abdul Aziz (1991) described that such a problem become more complicated for the big and compact bunch which are pollinated by weevils. As a result, the sterilization patterns should be modified from a single or double into triple peaks in order to ascertain enough heat reaching the inner fruitlets.

During the sterilization and the stripping of the bunch, a certain amount of oil will be absorbed by the stalk and rejected as waste material. Olie and Tjeng (1974) found that this oil loss ranges between 0.3 and 0.7% of bunch weight depending on the type of sterilizer used.

To overcome these problems, it is worth considering a new harvesting system for separating fresh fruitlets from the stalk in the field, so that only fruitlets will be transported to the mill. Their stalk may be left in the field as mulch.

The main hindrances to this proposal are the high strength of the fruit-stem joint and the structure of the fruitlets densely packed in a bunch. The pull force required to detach a fresh fruitlet from stem could be as high as 300 N. Practically, a direct bunch stripping would result not only in low threshability but also very high bruise level.

The mechanical separation of the fruitlet might be accomplished by stripping the cut spikelets which constitute of fruitlets with a low removal force. There are some procedures to succeed this stripping process. First, the bunch must be treated to reduce the strength of the fruit-stem joint. Once the fruitlets are about to become loose, the spikelets are then cut from the stalks. Without cutting, it will be very difficult to remove the fruitlets located in the inner layer of bunch. Finally, the fruitlets will be stripped from the cut spikelets using a thresher. However, it would be difficult to develop such a threshing system as no basic engineering data is available.

The overall goal of this study was to determine the necessary engineering information for the development of an in-field stripping system of oil palm fresh fruit bunch following the above procedures.

The specific objectives of this study were as follow:

1. To identify the physical characteristics of oil palm fruitletfor the design of an experimental drum thresher. The pertinent characteristics include size, shape, volume, density, porosity, and weight. Surface area of the fruitlet

in relation to the development of a bruise index was examined. Work was also carried out to determine a criteria for the classification on the ripeness of the oil palm bunch. It was one of the factors to be considered in the study on the fruitlet abscission, cutting, and threshing.

2. To identify effective treatments which can be used to accelerate the fruitlets abscission with regards to the concentration of growth regulator (ethephon), storage period, and degree of ripeness. This treatment should reduce the strength of the fruit-stem joint without deteriorating the quality of oil.

3. To establish the design parameters for cutting spikelets from the treated bunch by means of a knife blade and a circular saw. First, low speed cutting tests on the spikelet and stalk using a knife blade were conducted to study the effects of technical conditions and materials on specific cutting force and energy requirement. Secondly, a study on cutting the bunch with a circular saw was carried out to examine the effects of rotational saw speed, feeding rate, and thickness of cut material on cutting power. Therefore, the cutting test rig would be fabricated such that it could be operated at different test conditions. The results are important for the development of the mechanical cutting device required to produce the spikelets. These are the materials that would be threshed in the following procedures.

4. To develop an experimental drum thresher and to investigate effects of the drum speed, drum angle, drum diameter, configuration of beaters, length of the spikelet, and feeding rate on its performances. The stripping of the fruitlet from the cut spikelet was facilitated by its low removal force