



UNIVERSITI PUTRA MALAYSIA

**DEVELOPMENT OF FERMENTATION AND DRYING
OF COCOA BEANS USING A ROTARY FERMENTOR-DRIER**

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By

ZAIBUNNISA ABDUL HAIYEE

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
In Fulfillment of the Requirement for the Degree of Master of Science**

March 2002

To my beloved husband...

Abstract of the thesis presented to the Senate of the Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

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Chairman : Associate Professor Russly Abdul Rahman, Ph.D.

Faculty : Food Science and Biotechnology

Fermentation and drying processes are interrelated, but they are been carried out as separate entities requiring specific equipment at each stage. These processes are very labour intensive and time-consuming. Therefore, this study was designed to mechanically ferment and dry cocoa beans in a single unit using a rotary fermentor-drier as model study. The system would have the advantages of reducing the labour requirement, processing time and produce better or comparable quality to commercial cocoa beans.

This study was carried out using a modified rotary drier with a capacity of 9 metric tonnes wet cocoa beans. Mixed hybrid wet cocoa beans were fermented in the rotary drier (4 days with turning after 48 hours for 5 minutes at 0.5rpm). Samples were taken everyday and were immediately sun dried. Quality characteristics of the fermenting beans were monitored everyday and compared with the existing commercial method of fermentation in Indonesia (4 days with turning every 24 hours) and standard shallow box fermentation in Malaysia (6 days with turning at every 48 hours). The results obtained from cut test, fermentation index

and colour fractionation showed that fermentation occurred significantly ($p < 0.05$) more rapid in the rotary fermentor. Temperature development and bean colour also changed drastically in mechanical fermentation. There was no significant difference ($p > 0.05$) in acidity of the resultant beans from mechanical fermentation (4.45) and beans from commercial fermentation (4.6). However, shallow box (4.3) produced significantly ($p < 0.05$) more acidic beans. Concentration of acetic acid was significantly ($p < 0.05$) low in mechanically fermented beans and that of lactic acid were significantly ($p < 0.05$) low in shallow box fermentation. Percentage of total polyphenol, which contributes to bitterness and astringency in cocoa beans, was also significantly ($p < 0.05$) low in mechanically fermented beans (6.6) compared to other fermentation methods. Sensory evaluation results also showed that cocoa flavour were significantly ($p < 0.05$) better in mechanically fermented beans.

The mechanically fermented beans were then dried in the same rotary drier. The effect of fermentation time and drying temperature on the acidic quality of the resultant beans were investigated. The resultant bean quality was then compared with the control drying methods; sun drying (5 -7 days, 8 hours/day, turning every 12 hours) and commercial bed drier (31 hours, turning every 4 hours). Cocoa beans were fermented in the rotary fermentor-drier for 3 or 4 days. Initial drying temperature was set at 45°C, 55°C and 65°C until the bean moisture content reached 20-25%, followed by final drying at 65°C until bean moisture content reached 7.5%. Drying was stopped at night for 11-14 hours as a resting period. Air speed of the hot air and the rotating speed of the drier were kept constant, 5.2 ms⁻¹ and 0.5 rpm, respectively. Generally, the beans produced from the rotary fermentor-drier were significantly ($p < 0.05$) better quality than the beans produced from commercial bed

drier in term of lower acidity and total polyphenol content and higher fermentation level. However, sun dried beans were significantly ($p<0.05$) better than beans from rotary fermentor-drier. The rate of drying increased with drying temperature; most rapid at 65°C followed by 55/65°C and 45/65°C for both 3 days and 4 days fermented beans. Sun dried beans have significantly ($p<0.05$) the highest level of fermentation, followed by 45/65°C, 55/65°C and 65°C within the same fermentation period. The 4 day fermented beans have significantly ($p<0.05$) lower percentage of total polyphenol compared to 3 day. Drying method and temperature also have a significant effect on the percentage of total polyphenol in the bean. The lowest total polyphenol content were in sun-dried beans, followed with 45/65°C, 55/65°C and 65°C. Sun dried beans have significantly ($p<0.05$) the lowest acidity compared to rotary and commercial bed drying. However, rotary drying temperature of 55/65°C produced the best acidic characteristic beans for both 3 and 4 days fermented beans. The concentration of acetic acid and lactic acid were also low in the beans dried at 55/65°C. Sensory evaluation results showed that cocoa flavour was better in 4 day fermented beans compared to 3 day. Therefore, 4 days rotary fermentation followed with drying temperature of 55/65°C would be recommended.

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

**TEKNIK FERMENTASI DAN PENGGERINGAN BIJI KOKO SECARA
'ROTARY'**

Oleh

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Walaupun proses fermentasi dan pengeringan biji koko saling berkaitan, kedua proses in lazimnya dijalankan secara berasingan dan memerlukan alatan khas yang berbeza. Proses-proses ini memerlukan tenaga buruh yang ramai dan masa pemprosesan yang lama. Pengajian in bertujuan untuk menjalankan fermentasi dan pengeringan biji koko secara mekanikal didalam satu unit. Ini bertujuan untuk mengurangkan keperluan tenaga buruh dan masa pemprosesan yang lama.

Pengajian ini dijalankan menggunakan pengering 'rotary' yang telah diubahsuai yang mempunyai kapasiti pengeringan sebanyak 9 ton biji koko basah. Biji koko difermentasi didalam pengering 'rotary' (4 hari, pembalikkan selepas 48 jam selama 5 minit pada 0.5 rpm). Sampel diambil setiap hari dan dikeringkan dibawah cahaya matahari. Kualiti biji koko diawasi setiap hari dan dibandingkan dengan biji koko difermentasi secara komersial di Indonesia (4 hari, pembalikkan setiap hari) dan fermentasi kotak cetak (6 hari, pembalikkan selepas 48 jam). Hasil yang diperolehi dari kaedah uji belah, indeks fermentasi dan pangasingan warna membuktikan fermentasi mekanikal berlaku secara beerti ($p < 0.05$) lebih cepat

didalam pengering 'rotary'. Perubahan suhu dan warna biji semasa fermentasi juga lebih cepat bagi fermentasi mekanikal. Tahap keasidan biji koko difermentasi secara mekanikal adalah sama dengan fermentasi komersial tetapi fermentasi kotak cetek menghasilkan biji koko secara bererti ($p < 0.05$) lebih berasid. Kepekatan asid acetic secara bererti ($p < 0.05$) lebih rendah di biji koko fermentasi mekanikal tetapi kepekatan asid lactic secara bererti ($p < 0.05$) lebih rendah di biji koko kotak cetek. Ini membuktikan bahawa kepekatan asid acetik amat mempengaruhi keasidan biji koko. Jumlah polifenol yang memberi rasa pahit dan kelat secara bererti ($p < 0.05$) lebih rendah pada biji koko yang difermentasi secara mekanikal. Data yang diperolehi dari penilaian deria menunjukkan perisa biji koko secara bererti ($p < 0.05$) lebih baik jika difermentasi secara mekanikal.

Biji koko yang telah difermentasi secara mekanikal dikeringkan didalam pengering 'rotary' yang sama. Kesan masa fermentasi dan suhu pengeringan terhadap mutu biji koko juga dikaji. Mutu biji koko kering yang diperolehi dibandingkan dengan pengering kawalan; cahaya matahari (5-7 hari, 8 jam/hari, pembalikkan 2 kali/hari) dan pengering 'bed' komersial (31 jam, pembalikkan setiap 4 jam). Biji koko yang difermentasi selama 3 atau 4 hari dikeringkan pada suhu awal 45,55 atau 65°C sehingga kandungan air mencecah 20-25%, diikuti dengan pengeringan akhir suhu 65°C sehingga kandungan air mencecah 7.5%. Pengeringan diberhentikan pada malam hari (phasa rehat). Kelajuan angin panas 5.2 m/s dan kelajuan putaran 0.5 rpm dikekalkan sepanjang pengeringan. Secara umumnya, mutu biji koko fermentasi-pengeringan mekanikal adalah secara bererti ($p < 0.05$) lebih baik dari pengering 'bed' komersial. Tetapi mutu biji koko yang dikeringkan dibawah cahaya matahari adalah secara bererti ($p < 0.05$) lebih baik dari biji koko

fermentasi-pengeringan mekanikal. Kadar pengeringan meningkat dengan suhu pengeringan. Kadar pengeringan paling cepat dengan suhu 65°C, diikuti dengan 55/65°C dan 45/65°C. Jumlah polifenol dalam biji koko yang defermentasi selama 4 hari secara bererti ($p < 0.05$) lebih rendah dari fermentasi 3 hari. Jumlah polifenol juga lebih rendah di biji koko yang dikeringkan dibawah cahaya matahari, diikuti dengan suhu pengeringan 45/65, 55/65 dan 65°C. Kasidan biji koko yang dikeringkan dibawah cahaya matahari adalah secara bererti ($p < 0.05$) lebih rendah dari pengering yang lain. Suhu pengering 'rotary' 55/65°C secara bererti ($p < 0.05$) menghasilkan biji koko berasid rendah bagi kedua-dua 3 dan 4 hari fermentasi. Penilaian deria menunjukkan biji koko yang difermentasi selama 4 hari mempunyai perasa koko yang secara bererti ($p < 0.05$) lebih baik dari 3 hari fermentasi sahaja. Fermentasi selama 4 hari diikuti dengan suhu pengeringan 55/65°C adalah disarankan.

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TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	vi
ACKNOWLEDGEMENTS	ix
APPROVAL SHEETS	xii
DECLARATION FORM	xiv
LIST OF TABLES	xvii
LIST OF FIGURES	xix
LIST OF PLATES	xxi
LIST OF ABBREVIATIONS	xxii
CHAPTER	
1 GENERAL INTRODUCTION.....	1
2 LITERATURE REVIEW.....	6
Changes in Cocoa Beans During Fermentation.....	6
Physical Characteristics.....	6
Temperature.....	7
pH.....	9
Volatile and Non-Volatile Fatty acid.....	11
Factors which Affect Fermentation.....	17
Duration.....	17
Batch Size and Depth of Beans.....	18
Aeration.....	19
Current Methods of Fermentation.....	22
Box Fermentation.....	22
Heap Fermentation.....	22
Basket Fermentation.....	23
Fermentation on Drying Platforms.....	23
Changes in Cocoa Beans during Drying.....	24
Physical Characteristics.....	24
Bean Moisture Content.....	25
Acidic Characteristics.....	27
Polyphenols.....	30
Factors which Affect drying.....	33
Temperature.....	33
Airflow Rate.....	34
Current Methods of Drying.....	36
Sun Drying.....	36
Rotary Drier.....	37
Secador Tubular, Tunnel and Semawar Drier.....	37
Contribution of Organic Acids and Polyphenols to Chocolate Flavour.....	39
3 GENERAL MATERIALS AND METHODS.....	43
Samples for Fermentation.....	43
Fermentation.....	43

Mechanical Fermentation.....	43
Commercial Fermentation.....	45
Shallow Box Fermentation.....	45
Drying.....	46
Rotary Drying.....	46
Sun Drying.....	47
Commercial Drying	48
Physical and Chemical Analysis.....	48
Temperature.....	49
Bean Moisture Content.....	49
pH and Titratable Acidity.....	49
Volatile Fatty Acids.....	50
Non-Volatile Fatty Acids.....	52
Cut Test.....	54
Fermentation Index.....	54
Colour Fractionation.....	55
Total Polyphenol.....	56
Sensory Evaluation.....	57
Statistical Analysis.....	58

4	QUALITY OF MECHANICALLY FERMENTED COCOA BEANS IN COMPARISON WITH OTHER FERMENTATION METHODS.....	59
	Introduction.....	59
	Materials and Methods.....	61
	Samples for Fermentation.....	61
	Fermentation.....	61
	Preparation of Sample for Analysis.....	61
	Physical and Chemical Analysis.....	62
	Sensory Evaluation.....	62
	Statistical Analysis.....	62
	Results and Discussions	63
	Physical Characteristics.....	63
	Temperature.....	63
	Cut Test.....	67
	Fermentation Index.....	69
	Colour Fractionation.....	71
	Total Polyphenol.....	79
	pH.....	82
	Titratable Acidity	85
	Volatile Fatty Acids.....	87
	Non-Volatile Fatty Acids.....	89
	Sensory Evaluation.....	95
	Conclusions.....	98

5	EFFECT OF FERMENTATION TIME AND DRYING TEMPERATURE ON THE QUALITY OF COCOA BEANS.....	99
	Introduction.....	99

Materials and Methods.....	101
Fermentation.....	101
Drying.....	101
Preparation of Sample for Analysis.....	101
Physical and Chemical Analysis.....	101
Sensory Evaluation.....	102
Statistical Analysis.....	102
Results and Discussions	103
Moisture Content.....	103
Cut Test.....	103
Fermentation Index.....	107
Colour Fractionation.....	107
Total Polyphenol.....	109
pH and Titratable Acidity	111
Volatile Fatty Acids.....	114
Non-Volatile Fatty Acids.....	117
Sensory Evaluation.....	119
Conclusions.....	124
6 CONCLUSIONS AND RECOMMENDATIONS.....	125
BIBLIOGRAPHY	127
APPENDICES.....	137
VITA.....	151

LIST OF TABLES

Table		Page
1	Fermentation Index, cut test, pH, titratable acidity, acetic and lactic acid content from different countries of origin	29
2	Some chemical characteristics of the volatile fatty acids in cocoa beans	41
3	Sample drying regimes: resting time, initial and final drying temperature and time.	46
4	Fractions and its corresponding wavelength and solvent used as blank	56
5	Effect of mechanical, commercial and shallow box fermentation on dried cocoa beans surface colour and cut test score.	68
6	Effect of mechanical, commercial and shallow box fermentation on the development of volatile fatty acids.	93
7	Effect of mechanical, commercial and shallow box fermentation on the development of non-volatile fatty acids.	94
8	Effect of fermentation time and drying temperature on bean surface colour and cut test score	106
9	Effect of fermentation time and drying temperature on colour fractions absorbance value, fermentation index and total polyphenol	110
10	Effect of fermentation time and drying temperature on the development of volatile fatty acids	115
11	Effect of fermentation time and drying temperature of fermentor drier on the development of non-volatile fatty acids	120
12	Effect of fermentation methods on colour fractions absorbance value and fermentation index *	150

LIST OF FIGURES

Figure		Page
1	Demonstration of conditions during cocoa fermentation in different layers in deep boxes and shallow boxes. (a) after 3 days of fermentation, (b) after 5-6 days of fermentation.	8
2	Simplified model of pH changes in the seeds during fermentation	10
3	Rate of drying curve for cocoa beans	26
4	Oxidation of polyphenols by polyphenol oxidase	31
5	Condensation and polymerization reaction of o-quinone and amino acids	32
6	Schematic diagram of the rotary fermentor drier	44
7	Flowchart of temperature and duration of commercial bed drying	48
8	Variation in the development of temperature during mechanical, commercial and shallow box fermentation.	66
9	Effect of mechanical, commercial and shallow box fermentation on fermentation index	70
10	Effect of (a) mechanical, (b) commercial and (c) shallow box fermentation on the spectrum of fraction 1 (purple pigment anthocyanin).	74
11	Effect of (a) mechanical, (b) commercial and (c) shallow box fermentation on the spectrum of fraction 2 (red polymers).	75
12	Effect of (a) mechanical, (c) commercial and (c) shallow box fermentation on the spectrum of fraction 3 (brown polymers).	76
13	Effect of fermentation methods on colour fraction absorbance value	77
14	Fraction I / Fraction III ratio of mechanical, commercial and shallow box fermentation	78
15	Changes in the percentage of total polyphenol during mechanical, commercial and shallow box fermentation	81

16	Effect of mechanical, commercial and shallow box fermentation on the development of pH of wet beans (a) and sun dried beans (b).	84
17	Effect of mechanical, commercial and shallow box fermentation on the development of titratable acidity of wet beans (a) and sund dried beans (b).	86
18	Flavour intensity of the cocoa liquor from mechanical, commercial and shallow box fermentation relative to cocoa liquor from Ghana (reference).	97
19	Changes in mechanically fermented beans moisture content during rotary drying	104
20	Effect of fermentation time and drying temperature on pH and titratable acidity	112
21	Effect of fermentation time and drying temperature on flavour intensity of cocoa liquor relative to Ghanian cocoa liquor	123
22	Questionnaire to test panelist interest for sensory evaluation	138
23	Sensory evaluation form used to screen panelist for training.	140
24	Sensory handout used to train panelist	142
25	Sensory evaluation form used by panelist to indicate the difference between the sample and reference.	143
26	Diagram of the rotary drier	145
27	Lateral view of rotary mechanical fermentor drier	146
28	Labourer filling the rotary fermentor drier with wet cocoa beans through the top opening.	147
29	Fermented and dried cocoa beans being collected through the bottom opening of rotary fermentor drier.	148

LIST OF PLATES

Plate		Page
1	Changes in bean colour during (a) mechanical, commercial (b) and (c) shallow box fermentation.	64

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CTS	cut test score
C3	carbon 3
C5	carbon 5
CO ₂	carbon dioxide
cm	centimeter
CF	commercial fermentation
FRI	fraction 1
FRII	fraction 2
FRIII	fraction 3
kg	kilogramme
ms ⁻¹	meter per second
m	meter
ml	milliliter
Meq	milliequivalent
MF	mechanical fermentation
N	normality
NVFA	non-volatile fatty acid
PPO	polyphenol oxidase
rpm	revolution per minute
SAS	Statistical Analysis System
SF	shallow box fermentation
VFA	volatile fatty acid

w/w/w	weight/weight/weight
%	percentage
α	alpha
β	beta
μ	micro

CHAPTER I

GENERAL INTRODUCTION

Proper curing procedures namely fermentation and drying process are essential to ensure the production of good quality cocoa beans. Good fermentation and drying practices will produce cocoa beans, which have low acidity, bitterness and astringency, strong cocoa flavour and a typical brown colour (Lehrian and Patterson, 1983).

Most of the world's cocoa is fermented in boxes, heaps, in baskets and on drying platforms (Lopez and Dimick, 1995; Lehrian and Patterson, 1983). Box fermentation that requires a relatively large fixed volume of cocoa is the method of choice on large estates. The boxes vary considerably in size, the dimensions of the smallest is 0.4 x 0.4 x 0.5 m and the largest is 7 x 5 x 1 m (Lopez and Dimick, 1995). The beans are turned or mixed manually during fermentation from one box to another with varying frequency from every 12 to 48 hr (Hidayatullah *et al.*, 1998). The minimum quantity of cocoa which can be properly fermented under natural conditions vary from 35 kg (Lehrian, 1989) to 450 kg (Shahrir *et al.*, 1978). Traditionally, the Criollo type of cocoa is fermented for 2 to 3 days while Forastero type is generally fermented for 5 to 7 days worldwide (Lehrian and Patterson, 1983; Wood and Lass, 1985; Biehl, 1995). Fermentation process is crucial to remove mucilage of the pulp, to provoke aeration of the seeds and to facilitate drying, to prevent germination of the seeds and to produce flavour precursors (Lopez and Dimick, 1995; Lehrian and Patterson, 1983). Cocoa beans fermentation is

influenced by many factors such as type of cocoa, disease, climatic and seasonal differences (Rohan, 1963), duration, aeration and death of the beans (Lehrian and Patterson, 1983), storage of pods (Lehrian and Patterson, 1983) and also batch size and turning (Lehrian and Patterson, 1983; Mamot and Sammarakhody, 1984).

Following fermentation, the beans are sun or artificially dried until bean moisture content reached about 7.0-7.5% (Lehrian, 1983; McDonald and Freire, 1981). Sun drying is the most preferred drying method for smallholders because it is cheap and simple. This method cannot be practiced by estates and medium scale processors because of the length of time involved, labour requirement and uncertain weather conditions (Jinap *et al.*, 1994). Current available artificial dryers are circular / uni, semawar, samoa, martin, secador tubular, infrared, tunnel, platform, rotary, solar (McDonald *et al.*, 1981) and tray dryer (Lopez and Dimick, 1995). The beans are turned frequently, either mechanically or manually during drying to ensure even drying and to avoid bean clumping. The duration of drying process is from 36 to 96 hours depending on the equipment and drying methods used (Hidayatullah *et al.*, 1998). Sun drying needs longer period, 4 to 7 days in good weather conditions. Quality of dried cocoa beans depends on the temperature, rate of airflow and the depth of the beans (Puziah *et al.*, 1998).

Chocolate manufacturers prefer cocoa beans with a good level of basic cocoa flavour, no excess of acidity and astringency and absence of any off-flavour (Clapperton, 1993; Clapperton *et al.* 1994). Therefore, by determining the acidic characteristics, polyphenol content, fermentation level and also by sensory evaluation, the quality of the resultant beans can be predicted.

pH and titratable acidity of fermented and dried cocoa beans are in the range of 4.70 - 5.74 and 0.109 - 0.198, respectively (Jinap and Dimick, 1990). The volatile acids present in cocoa beans are acetic, propionic, butyric, isobutyric and isovaleric acid (Jinap, 1994). Rohan and Stewart (1964) found that the total volatile acids in cocoa beans from 8 different geographic origins ranged from 0.33 to 1.14 g/100g. However, Jinap and Dimick (1990) reported that the total volatile acids in 39 samples of cocoa beans ranged from 0.43 to 0.82 g/100g. The non-volatile acids include oxalic, citric, tartaric, malic and succinic (Jinap, 1994). Rohan and Stewart (1964) showed that the total non-volatile acids ranged from 1.04 to 5.25 g/100g. However, Jinap and Dimick (1990) found the total non-volatile acids in fermented and dried beans ranged from 1.09-1.83 g/100g. Flavour quality of Malaysian beans was recognized as low, reveals a strong acidic and insipid aroma (Dougan and Carr, 1977). The presence of acetic and lactic acid, either alone or in combination, has been implicated as the most likely cause of the high acidity (Rohan and Stewart, 1964; Biehl, 1965; Lopez, 1983; Chong *et al.*, 1980; Liao, 1980, Jinap and Dimick, 1990).

The decrease in bitterness and astringency during fermentation and drying is probably due to loss of polyphenols through condensation and polymerization reactions (Jinap, 1995). Unfermented cocoa beans contain 12-18% polyphenol (Kim and Keeney, 1984); the value decreases to about 5.27 % after fermentation (Misnawi *et al.*, 2000). Polyphenol, anthocyanin, 3- α -D-galactosidyl and 3- β -L-arabinosidylcyanidin is responsible for the purple colour of fresh Forastero cocoa beans (Forsyth and Quesnel, 1957). Anthocyanin does not directly contribute to flavour. However, reports indicated that there is an inverse relationship between