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

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

By

ZAIBUNNISA ABDUL HAIYEE

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, In Fulfiment 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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March 2002

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 different ($p>0.05$) 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

ZAIBUNNISA ABDUL HAIYEE

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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 cetek (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 laktic secara bererti ($p<0.05$) lebih rendah dibiji 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 defermentasi 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 $65^{\circ}C$ sehingga kandungan air mencecah 20-25%, diikuti dengan pengeringan akhir suhu $65^{\circ}C$ sehingga kandungan air mencecah 7.5%. Pengeringan diberhentikan pada malam hari (phäsa rehat). Kelajuan angin panas 5.2 m/s dan kelajuan putaran 0.5 rpm dikekalkan sepanjang pengeringan. Secara umumnya, mutu biji koko fermentasi-penggeringan 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 $55/65^{\circ}$C dan $45/65^{\circ}$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, dikuti 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' $55/65^{\circ}$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 $55/65^{\circ}$C adalah disarankan.

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I certify that an Examination Committee met on 19th March 2002 to conduct the final examination of Zaibunnisa Abdul Haiyee on her Master of Science thesis entitled "Development of Fermentation and Drying of Cocoa Beans Using a Rotary Fermentor-Drier" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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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	milliequalent
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 whether 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 Steward (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; Liau, 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-galactosidly and 3-β-L-arabinosidylcyanidin is responsible for the purple colour of fresh Forestero cocoa beans (Forsyth and Quesnel, 1957). Anthocyanin does not directly contribute to flavour. However, reports indicated that there is an inverse relationship between