



**UNIVERSITI PUTRA MALAYSIA**

**ANATOMICAL AND PHYSICO-CHEMICAL CHANGES IN RASTALI  
BANANA (*MUSA AAB RASTALI*) DURING FRUIT GROWTH AND RIPENING**

**TEE YEI KHENG**

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By

**TEE YEI KHENG**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in  
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**ANATOMICAL AND PHYSICO-CHEMICAL CHANGES IN RASTALI BANANA (*MUSA AAB RASTALI*) DURING FRUIT GROWTH AND RIPENING**

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**February 2012**

**Chairman: Phebe Ding, PhD**

**Faculty: Agriculture**

A series of physico-chemical (physical, chemical and physiological qualities) and structural changes of Rastali banana were conducted on weekly intervals from the 1<sup>st</sup> until 12<sup>th</sup> weeks after emergence of the first hand in order to establish growth pattern and physico-chemical changes in Rastali banana during growth and development. Later, experiment was carried out to study the optimum harvest periods of Rastali banana based on the physico-chemical changes during ripening. For these purposes, Rastali bananas were tagged after the emergence of the first hand. Hands were numbered from the top of bunch to the bottom (hand 1: basal fruit at the top; hand 6: distal hand at the bottom) and only six hands of bananas were used in this study. The experiment was conducted using randomized complete block design with three replications and each individual tree of Rastali banana including 6 hands with 3 fingers per hand was considered as a replication. Data from the measurements of physical (fresh weight, length, diameter, peel and pulp colors, pulp firmness, peel and pulp moisture content and stomatal density), chemical (fruit pH, sugars and organic acids content and tannin

concentration), and physiological (respiration rate and ethylene production) quality tests were analyzed using analysis of variance and means separation was carried out using Duncan's multiple range tests. Regression analysis was carried out to describe the relationship of the physico-chemical characteristics during fruit growth and development. Fruit length and diameter followed a similar trend observed in fruit fresh weight throughout banana development and three physiological stages (S1, S2 and S3) of sigmoid growth were identified. Initially, growth was slowed at S1 which occupied the first 4 weeks of growth where the cells were dividing actively. This followed by rapid growth at S2 (5<sup>th</sup> to 10<sup>th</sup> weeks) where cell expansion took place. Growth was constant at S3 (11 and 12 weeks) where the fruits have reached physiological maturity stage. Growth of Rastali banana was further supported by the cellular structure studies using light microscope. Peel cells performed a periclinal growth and was accompanied by an increase in fruit peel and pulp thickness as fruit developed. Peel and pulp colors were expressed in lightness (L\*), chroma (C\*) and hue (h°). Peel turned from matured green to yellow during ripening while pulp color became more vivid and yellow as fruit matured and ripened. Peel moisture content decreased as fruit developed and ripened, in contrast, pulp moisture content increased as fruit developed. During fruit growth and development, pulp firmness increased at initial stages of fruit development and thereafter decreased during maturation and fruits soften during ripening. Fruits became more acidic and taste sweeter as fruit matured and ripened. Sucrose, fructose and glucose were the main sugars found in Rastali banana while malic, citric and succinic acids were the main organic acids found in the fruit. In this study, there was no ethylene production detected throughout 12 weeks of fruit development. Ethylene was detected at

day 1 after ripening was initiated. Rastali banana was characterized as climacteric fruit with the upsurge of CO<sub>2</sub> production coincided with the ethylene production occurred at day 3 after ripening. Peel cells performed a periclinal growth resulted in tangential expansion which led to flattening of the fruit angle when approaching maturation. As fruit developed, parenchymatous cells lose their integrity, lignified fibre degraded at the peel region and starch filled the pulp region. Various shape of starch found at the peel and pulp regions. Starch at the peel was mostly small and granular shape while starch at the pulp was large and flat disc in shape. It is clear that Rastali banana exhibited a sigmoid growth pattern and physico-chemical changes during fruit growth and development. Rastali banana showed physiological maturity at week 11 and 12 after emergence of the first hand with constant fruit growth and fruits are ready to be harvested.

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

**PERUBAHAN ANATOMI DAN FIZIKO-KIMIA PISANG RASTALI (*Musa AAB RASTALI*) SEPANJANG PERTUMBUHAN DAN KEMATANGAN BUAH**

Oleh

**TEE YEI KHENG**

**Februari 2012**

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Satu siri fiziko-kimia (kualiti fizikal, kimia dan fisiologikal) dan perubahan struktur pisang Rastali telah dijalankan pada setiap minggu bermula pada minggu pertama sehingga minggu ke-12 selepas kemunculan tangan pertama demi menentukan corak pertumbuhan dan mengkaji perubahan fiziko-kimia dalam pisang Rastali semasa pertumbuhan dan perkembangan. Kemudian, eksperimen telah dijalankan untuk mengkaji tempoh optima untuk menuai pisang Rastali berdasarkan mutu buah fiziko-kimia pisang Rastali pada tempoh matang. Demi tujuan tersebut, pisang Rastali ditanda selepas kemunculan tangan pertama. Tangan dinomborkan dari atas sehingga dasar tandan (tangan 1: buah asas pada atas; tangan 6: buah hujung pada dasar) dan hanya enam tangan pisang digunakan dalam kajian ini. Eksperimen telah dijalankan menggunakan reka bentuk blok lengkap secara rawak dengan tiga replikasi dan setiap pokok pisang Rastali termasuk enam tangan dengan tiga jari setiap tangan telah

dipertimbangkan sebagai satu replikasi. Data daripada ukuran-ukuran fizikal (berat segar, panjang, diameter, warna kulit dan isi pisang, kekerasan isi, kandungan lembapan isi dan kulit serta ketumpatan stomata), kimia (buah pH, kandungan gula dan asid-asid organik dan kandungan tannin), dan fisiologikal (kadar respirasi dan pengeluaran etilena). Ujian-ujian kualiti telah dianalisis menggunakan analisis varians dan perbezaan min dianalisis dengan menggunakan ujian Duncan's multiple range. Analisis regresi telah dijalankan untuk menggambarkan hubungan ciri-ciri fiziko-kimia semasa pertumbuhan dan perkembangan buah. Panjang buah dan diameter mengikuti satu trend yang sama dengan berat segar buah sepanjang pertumbuhan dan perkembangan pisang dan tiga peringkat pertumbuhan fisiologikal (S1, S2 dan S3) sigmoid telah dikenalpasti. Pada mulanya, pertumbuhan secara perlahan diperhatikan pada S1 selama empat minggu pertama di mana pembahagian sel-sel giat dijalankan. Ini diikuti dengan pertumbuhan pesat pada S2 (minggu kelima sehingga minggu ke-10) di mana pengembangan sel berlaku. Pertumbuhan malar pada S3 (minggu 11 dan 12) di mana buah-buahan telah mencapai peringkat kematangan fisiologi. Pertumbuhan pisang Rastali disokong selanjutnya oleh kajian struktur sel dengan menggunakan mikroskopi cahaya. Sel-sel kulit pisang Rastali mempersembahkan pertumbuhan periklinal selari dengan peningkatan pada ketebalan kulit dan isi pisang. Wana kulit dan isi pisang telah dinyatakan dalam kecerahan ( $L^*$ ), kroma ( $C^*$ ) dan hue ( $h^\circ$ ). Kulit pisang telah bertukar daripada hijau matang ke kuning semasa buah matang manakala isi pisang bertukar menjadi putih kekuningan. Kandungan kelembapan isi berkurangan ketika pertumbuhan dan perkembangan buah manakala kandungan kelembapan isi bertambah semasa buah matang. Semasa pertumbuhan dan perkembangan buah, kekerasan isi bertambah pada peringkat awal perkembangan buah dan selepas itu berkurangan dan buah menjadi semakin lembut

semasa matang. Buah menjadi lebih berasid dan rasa lebih manis ketika buah matang dan masak. Sukrosa, fruktosa dan glukosa merupakan gula utama ditemui dalam pisang Rastali manakala asid seperti malik, sitrik dan suksinik merupakan asid organik utama. Dalam kajian ini, tiada pengeluaran etilena dikesan semasa pertumbuhan dan perkembangan buah sepanjang 12 minggu. Etilena gas dikesan pada hari pertama kemasakan buah bermula. Pisang Rastali dianggap sebagai buah klimakterik dengan kenaikan secara mendadak pengeluaran CO<sub>2</sub> susulan dengan pengeluaran etilena yang berlaku pada hari ketiga buah masak. Sel-sel kulit mempersembahkan satu pertumbuhan periklinal menyebabkan sudut buah menjadi rata disebabkan pertumbuhan melintang pada buah pisang semasa buah matang. Semasa pertumbuhan dan perkembangan buah, sel-sel parenkima hilang integriti, gentian berlignin pecah pada bahagian kulit dan kanji terisi bahagian isi buah. Pelbagai bentuk kanji dijumpai pada kulit dan isi buah. Kanji pada kulit kebanyakan berbentuk kecil dan berbutir manakala kanji pada isi berbentuk cakera dan besar serta rata permukaannya. Adalah sangat jelas bahawa pisang Rastali menunjukkan satu corak pertumbuhan sigmoid dan perubahan fiziko-kimia didapati semasa pertumbuhan dan perkembangan buah. Pisang Rastali menunjukkan kematangan fisiologi pada minggu ke-11 and 12 selepas kemunculan tangan pertama dan bersedia untuk dituai.

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I certify that a Thesis Examination Committee has met on 24 February 2012 to conduct the final examination of Tee Yei Kheng on her thesis entitled “Anatomical and Physico-Chemical Changes in Rastali Banana (*Musa AAB Rastali*) During Fruit Growth and Ripening” in accordance with the Universities and University College 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.

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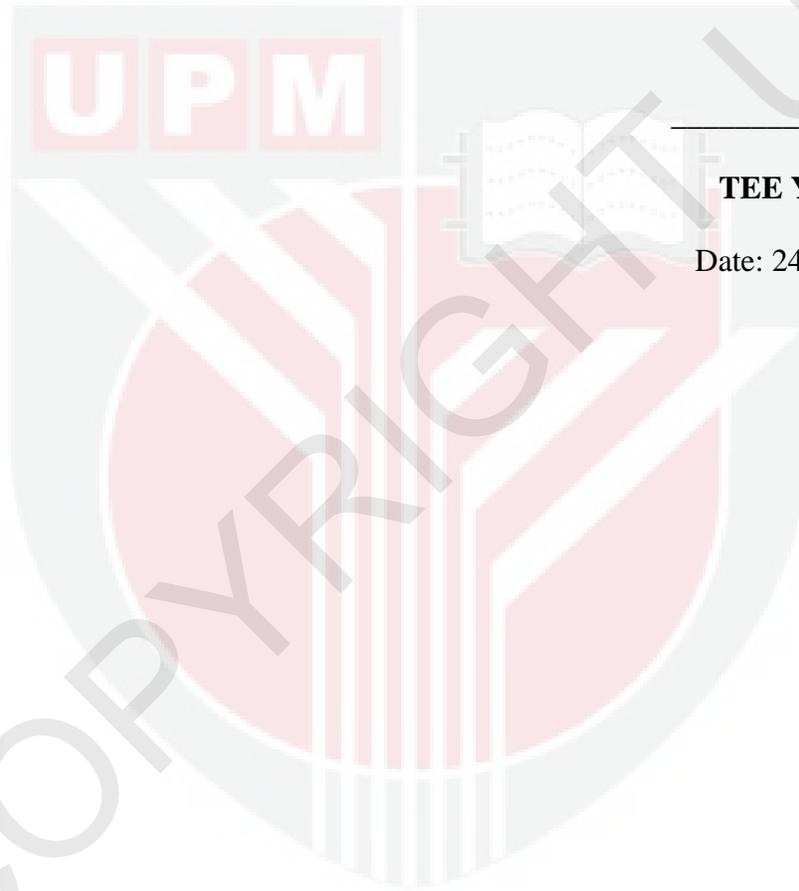
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Date: 24 February 2012

## DECLARATION

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 concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.



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**TEE YEI KHENG**

Date: 24 February 2012

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## LIST OF ABBREVIATIONS

D	-	Day
LM	-	Light microscopy
SEM	-	Scanning electron microscopy
PG	-	Polygalacturonase
PME	-	Pectin methyl-esterase
H <sup>+</sup>	-	Hydrogen ion
K <sup>+</sup>	-	Potassium ion
Cl <sup>-</sup>	-	Chloride ion
ATPase	-	Adenosine triphosphatase
AdoMet	-	S-adenosyl-L-methionine
ACC	-	1-aminocyclopropane-1-carboxylic acid
AVG	-	Aminoethoxyvinylglycine
1-MCP	-	1-methylcyclopropene
GA	-	Gibberellic acid
ABA	-	Abscisic acid
TBO	-	Toluidine Blue O
PEPC	-	Phosphoenolcarboxylate
-COOH	-	Carboxyl group
G-1-P	-	Glucose-1-phosphate
TSS	-	Total soluble solid

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