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COLOR AND FLAVOR DEVELOPMENT OF ROASTED JACKFRUIT (Artocarpus hetrophyllus L.) SEEDS

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By

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Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

COLOR AND FLAVOR DEVELOPMENT OF ROASTED JACKFRUIT (*Artocarpus hetrophyllus* L.) SEEDS

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Chairman : Associate Professor Lasekan Olusegun Olaniyi, PhD
Faculty : Food Science and Technology

Jackfruit (*Artocarpus hetrophyllus*) seed is known to be an underutilized seed. It has many potentials and applications in food, cosmetics, pharmaceuticals and bio-nanotechnology industries. Most studies on jackfruit seed (JFS) have been focused on the chemical, functional, and nutritive values of both raw and processed (cooked) jackfruit seed flour. The increasing demand for under-utilized seeds as alternative cheap source of nutritious food snack is making JFS gain more attention in the recent years. The aim of this research therefore was to investigate the flavor and color development in JFS during roasting, through; chemical analysis, sugar profiling and amino acid profiling of both raw and roasted JFS; color development analysis using response surface methodology (RSM); effect of roasting condition on the structural changes of the starch granules using scanning electron microscopy (SEM) and Fourier Transform Infrared spectroscopy (FTIR); and lastly flavor development analysis using gas chromatography-olfactometry (GC-O) and gas chromatography-mass spectrometry (GC-MS) coupled with aroma extract dilution analysis (AEDA) for the identification of key odorants. For chemical analysis of the three cultivars of jackfruit seed analyzed, results showed that the starchy seeds were very high in moisture (53.16-62.41%) and starch (15.95-32.04%), moderately high in protein (7.62-8.46%), dietary fiber (2.80-7.19%), ash content (3.19-3.70%), but low in fat (1.09-1.48%). Analyses of the color and flavor precursors (amino acids, sugar and fatty acids) of JFS cultivars showed that cultivar J31 had the highest contents of amino acids such as methionine, leucine, alanine and threonine. Fatty acids linoleic and linolenic were also the highest. Although, the sugar contents were low, fructose and sucrose were significantly higher in cultivar J31. The effect of roasting conditions on the color development (L^*, a^*, b^* and browning intensity) and fracturability (measured using Universal Texture Analyzer) using a three factor central composite rotatable design (CCRD) gave R square of 0.81, 0.96, 0.93, 0.92, and 0.74, respectively. The optimum roasting conditions were found to be at temperature of 153.4 ^{o}C, time 34.4 minutes, pH 6.34 and a composite desirability of 0.95. The micro-structural studies of both raw and roasted JFS at different roasting levels showed a B-type category of starch granules with semi-oval to round/bell shapes (5-9µm in diameter), which became flattened as the roasting temperature and time increased. The IR spectra was in the 4000-1000 cm^{-1} region and it was described by five main modes; O-H, C-H stretching, C=C, C-H bending and C-O. The major functional group with the highest intensity in both raw and roasted JFS was

the C-O bond stretch of esters. A total of 95 compounds were identified using the gas chromatography-olfactometry (GC-O) on a diphenyl dimethyl polysiloxane (DB-5) and free fatty acid phase (FFAP) columns. The major classes of aroma compounds include aldehyde, esters, alcohols, alkanes, monoterpenes and ketones. Application of aroma extract dilution analysis (AEDA) to the flavor extract from both raw and roasted JFS revealed 16 and 26 odor-active compounds respectively in the flavor dilution (FD) range of 16-32. Aromas perceived on the GC-O were dominated by Flowery, green, pungent-sulforous, and sweet-caramel and woody aromas, which were more persistent in the roasted seed. Roasted jackfruit seeds can be used as an alternative healthy snack product due to its good source of dietary nutrients. Also, the most needed literature on the optimum roasting conditions for color and flavor development can be exploited by researchers and food industries at large.

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

PEMBANGUNAN WARNA DAN PERISA BIJI NANGKA (*Artocarpus hetrophyllus* L.) SEMASA PEMANGGANGAN

Oleh

SHAKIRAH OMOTOKE AZEEZ

Disember 2015

Pengerusi : Profesor Madya Lasekan Olusegun, PhD
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Biji nangka (*Artocarpus hetrophyllus*) ialah tanaman yang kurang digunakan dan diperhatikan. Ia mempunyai banyak potensi dan aplikasi dalam bidang makanan, kosmetik , farmaseutikal dan industri nano bioteknologi. Kebanyakan kajian yang mengenai biji nangka (JFS) telah memberi tumpuan kepada fiziko -kimia, fungsi, dan nilai-nilai pemakanan untuk kedua-dua biji nangka sebelum dan selepas proses (telah masak) dalam bentuk tepung. Permintaan daripada konsumer yang semakin meningkat membolehkan biji nangka yang kurang digunakan ini dijadikan sebagai sumber alternatif makanan snek yang murah dan berkhasiat, oleh itu, JFS telah mendapat lebih tumpuan pada tahun- tahun kebelakangan ini. Tujuan kajian ini adalah untuk mengkaji pembangunan rasa dan warna dalam JFS semasa pemanggangan melalui analisis kimia , profil gula dan profil asid amino bagi kedua-dua JFS sempel sebelum dan selepas pemanggangan; analisis pembangunan warna menggunakan kaedah permukaan respons (RSM); kesan memanggang kepada perubahan struktur granul kanji dengan menggunakan mikroskop imbasan elektron (SEM) dan Fourier Transform spektroskopi inframerah (FTIR); dan akhir sekali analisis pembangunan rasa menggunakan gas kromatografi - olfaktometri (GC-O) dan gas kromatografi - spektrometri jisim (GC-MS) bersama dengan analisis pencairan ekstrak aroma (AEDA) untuk mengenal pasti kompaun yang utama. Bagi analisis kimia daripada tiga jenis kultivar biji nangka, keputusan menunjukkan bahawa biji nangka mangandungi kelembapan (53.16-62.41%) dan kandungan kanji (15.95-32.04%), yan amat tinggi (7.62-8.46%), serat (2.80-7.19 %), kandungan abu (3.19-3.70%), tetapi rendah dalam kandungan lemak (1.09-1.48%). Analisis warna dan rasa prekursor (asid amino, gula dan asid lemak) untuk kultivar JFS menunjukkan bahawa kultivar J31 mempunyai kandungan tertinggi dalam asid amino seperti methionin, leusin, alanin dan threonin. Asid lemak linoleik dan linolenik juga didapati paling tinggi. Walaupun kandungan gula adalah rendah , tetapi fruktosa dan sukrosa adalah tinggi dalam kultivar J31 . Kesan keadaan pemangganggan untuk pembangunan warna (L *, a * b * dan intensiti pemerangan) dan kerangupan dengan menggunakan tiga faktor utama reka bentuk putaran komposit (CCRD) telah menunjukkan R kuasa dua adalah bernilai 0.81 , 0.96 , 0.93, 0.92 dan 0.74 masing-masing. Keadaan pemanggangan yang paling optimum didapati adalah pada suhu 153.4°C untuk 34.4 minit dengan pH 6.34 dan komposit penerimaan bernilai 0.95. Kajian mikro-struktur bagi kedua-dua JFS sebelum dan selepas pemanggangan di bawah tahap pemanggangan yang berbeza menunjukkan jenis kategori B granul

berkanji adalah berbentuk separa bujur hingga bulat/ loceng (5-9 μm diameter), yang menjadi leper semasa suhu dan masa pemanggangan meningkat. Spektrum IR adalah di antara bahagian 4000-1000 cm^{-1} dan ia telah dihuraikan dengan lima model utama iaitu O-H, C-H regangan, C = C, C-H lentur dan C-O. Kumpulan fungsian yang utama dengan intensiti tertinggi dalam kedua- dua sampel JFS sebelum dan selepas pemanggangan adalah ikatan C-O ester. Sebanyak 95 kompaun telah dikenal pastikan menggunakan gas kromatografi-olfaktometri (GC-O) DB-5 dan FFAP. Kelas-kelas utama bagi kompaun aroma termasuk aldehid, ester, alkohol, alkana, monoterpenes dan keton. Penggunaan analisis pencairan ekstrak aroma (AEDA) untuk ekstrak perisa daripada kedua- dua JFS sebelum dan selepas pemanggangan telah mendedahkan 16 dan 26 sebatian bau-aktif masing- masing dalam nilai pencairan rasa (FD) di antara 16-32. Aroma yang berjaya dikesan dengan GC-O diutamakan oleh bunga, hijau, pedas-sulforous, dan gula-karamel dan aroma berkayu, yang berterusan dalam biji nangka selepas proses pemanggangan. Biji nangka telah dipanggang boleh digunakan sebagai sumber alternatif bagi menghasilkan produk makanan ringan yang sihat kerana ia ialah sumber nutrienmakanan yang baik. Oleh itu, kajian ini adalah penting untuk mengkaji keadaan optimum proses pemanggangan bagi pembangunan warna dan rasa boleh dieksploitasi oleh para penyelidik dan pihak industri makanan.

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I certify that a Thesis Examination Committee has met on 4 December 2015 to conduct the final examination of Shakirah Omotoke Azeez on her thesis entitled "Color and Flavor Development of Roasted Jackfruit (*Artocarpus hetrophyllus* L.) Seeds" in accordance with the Universities and University Colleges 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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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science.

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013)are adhered to.

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LIST OF ABBREVIATIONS

cm	Centimeter
^{o}C	Celcius
g	Gram
Kg	Kilogram
mg	Milligram
µm	Micrometre
Kcal	Kilocalorie
KJ	Kilojoule
mL	Milliliter
µL	Microliter
min	Minutes
h	Hour
I.U	International Unit
mm	Millimeter
M	Molarity
nm	Nanometer
HCl	Hydrochloric acid
HPLC	High-pressured liquid chromatography
RP	Reversed phase
dwb	Dry weight basis
i.d	Diameter
v/v	Volume per volume
w/v	Weight per volume
Na_2CO_3	Sodium carbonate
2-D	Two-dimensional
3-D	Three-dimensional

CHAPTER 1

INTRODUCTION

Nowadays, there is increasing search for cheap and under-utilized tropical fruits which have high nutritional benefits. Tropical fruits such as mango, papaya, durian, rambutan, jackfruit, longan, chempedak, passion fruit, sour soup, citrus and banana are now majorly grown in Asian countries. They are popularly known for their large scale commercial cultivation (Araro & Rao, 1995). They are also called exotic fruits owing to their unique flavor and aroma. Generally, when these fruits are consumed, their seeds are usually discarded. However, several investigations in the past have shown their potential application in food products due to their high nutritive value (Shuangliet al. 2014; Singh et al. 2013; Okolie et al. 2012; Zaini et al. 2009).

Jackfruit (*Arthocarpus heterophyllus Lam*.) is said to have originated from the Western Ghats of India and it is been cultivated throughout the tropical countries in South and Southeast Asia (APAARI, 2012). Jackfruit is becoming a more staple tropical exotic fruit grown in Malaysia and widely grown in Bangladesh, Burma, Sri Lanka, Indonesia, Philippines, Brazil and other countries (Rahman et al. 1999; Narasimham, 1990). The tree bore its fruits on the side branches with average weight ranging from 3.5 kg to 10 kg reaching up to 25 kg sometimes (Swami et al. 2012). A recent report recorded the highest weight of 81 kg from Panrutti, India (APAARI, 2012). It is considered a poor man's food in India owing to the numerous culinary uses for the unripe, tender fruits (immature fruit) and its abundance fruiting during summer when crops are scarce (Jagtap et al. 2010; Rahman et al. 1995; Samaddar, 1985). Jackfruit is a low calorie fruit which is rich in protein, starch, calcium, potassium and thiamine with a unique flavor (Mukprasirt & Sajjaanantakul, 2004; Burkill, 1997; Samaddar, 1985). Jackfruit can be regarded as a multi-purpose crop providing food, wood, fuel, latex, nutraceutical and industrial products (APAARI, 2012).

The seeds may be boiled, or roasted and eaten or boiled and preserved in syrup like chestnuts. Roasted jackfruit seeds are ground and used to produce composite flour blends with wheat for baking (Morton, 1987). Singh et al. (1991) reported that jackfruit seeds are fairly rich in starch. It has been reported that jackfruit seed flour contains 6.09 % moisture content, 2.70% ash and 1.27% fat contents (dry matter basis), while the protein content, fiber content and carbohydrate content were 13.50 %, 3.19 % and 79.34 %, respectively (Ocloo et al. 2010). Jackfruit seed contains phytonutrients such as lignans, isoflavones, and saponins that have health benefits ranging from anticancer, antihypertensive, antioxidant, antifungal, antibacteria, antiulcer to antiaging properties (Swami et al. 2012; Karthy et al. 2009; Trindade et al. 2006; Swoong & Barlow, 2004). Despite all these health and nutritional benefits, large quantities of jackfruit seeds are usually discarded after pulp consumption.

Roasting can be referred to as a basic unit operation that bring about important physical, chemical, structural and sensorial changes and develops the flavor and texture of food product (Pittia et al. 2001; Saklar et al. 2001; Ozdemir & Devres, 2000). The flavor, color, texture and appearance of nuts and seeds can be changed and significantly enhanced during roasting process. This increases their overall palatability and these changes are mainly related to non-enzymatic browning (Perren & Escher, 1996a, b;

Mayer, 1985; Buckholz et al. 1980). The effects of different thermal processing especially roasting on the changes in chemical composition, color and aroma of seeds and nuts have been studied (Kim et al. 2000; Shin et al. 1981). Findings showed that the changes are related to series of complex chemical reactions called Maillard reaction occurring during heat processing.

Several researches have been carried out on the jackfruit seed compositions, functional properties, flour, and other health and value-added benefits (Swami et al. 2012). Literature is however lacking in the flavor and color development mechanism of jackfruit seeds. Hence, the importance of this research will not only increase knowledge in the field of Food Science but in the longer term, the development of more nutritious and health friendly snack.

The objectives of this study therefore are;

1. To determine the chemical components, color and flavor precursors of three jackfruit seeds cultivars.
2. To determine the effect of roasting conditions on color development using response surface methodology and the structural changes of jackfruit seed.
3. To investigate the changes in flavor precursors and their effects on the characteristic flavor of roasted jackfruit seeds and the identification of the flavor compounds.

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