UNIVERSITI PUTRA MALAYSIA

EFFECTS OF SOLID-STATE FERMENTATION AND DRYING ON STARCH PROPERTIES AND FLAVOUR OF NANGKA (Musa paradisiaca L., AAB) AND TANDUK (Musa paradisiaca L., ABB) PLANTAIN FLOURS

SHITTU RAFIAT MOROLAYO

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By

SHITTU RAFIAT MOROLAYO

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirements for the Degree of Master of Science

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DEDICATION

This thesis is dedicated to Almighty Allah (S.W.T)

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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

EFFECTS OF SOLID-STATE FERMENTATION AND DRYING ON STARCH PROPERTIES AND FLAVOUR OF NANGKA (*Musa paradisiaca* L., AAB) AND TANDUK (*Musa paradisiaca* L., ABB) PLANTAIN FLOURS

By

SHITTU RAFIAT MOROLAYO

July 2016

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

Plantain plays an important role in the nutritional and economic wellbeing of humans. Nonetheless, plantain is readily susceptible to spoilage due to its high moisture content. Thus, processing plantain to prevent postharvest losses is warranted. The current study examined the effect of solid-state fermentation and drying methods on starch properties and flavor of Nangka and Tanduk plantain flours. The study was conducted in two phases.

The first phase of the study appraised the effect of drying methods [Hot air drying (HAD) and Microwave finish drying (MFD)] and solid-state fermentation (SSF) on the physicochemical, functional, physical, rheological and gelatinization properties and aroma compounds of flours of Nangka and Tanduk plantain cultivars. Drying methods and SSF did not affect the fat, dietary fiber and carbohydrate contents of the plantain flours. However, both treatments significantly ($p < 0.05$) affected the pH and titratable acidity of the flours. In addition, SSF coupled with MFD significantly ($p < 0.05$) increased the water absorption and oil absorption capacities of the flours more than the flours obtained from the hot air drying. Similar trend was observed with the swelling power and solubility of the flours. The flow behaviour index of all the flour pastes were less than 1 which is an indication of a typical non-Newtonian shear thinning (pseudo plastic) behaviour. The gas chromatography mass spectrophotometry revealed that fermented microwave-finish dried Tanduk plantain flour had 11 (4 alcohols, 1 ketone, 4 esters, 1 sulphur compound and 1 acid) aroma compounds while unfermented microwave-finish dried Tanduk plantain flour had 10 (2 alcohols, 6 acids, and 2 esters) aroma compounds. The fermented microwave-finish dried Nangka plantain flour had 13 (5 alcohols, 2 ester, 2 phenolic compounds, I sulphur compound, 2 acids and 1 sterol) aroma compounds while the unfermented microwave-finish dried Nangka flour had 16 (3 aldehydes, 5 esters, 6 acids and 2 alcohols) aroma compounds. The green pulp of Nangka and Tanduk plantain cultivars subjected to microwave-finish drying and solid-state fermentation produced flour with reduced color degradation and improved functional properties.

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The second phase of the study assessed the physicochemical, morphological, thermal, textural and functional properties of native starches and starches from fermented microwave finish dried flours of Nangka and Tanduk plantain cultivars. Native and fermented Nangka starches had lower amylose, hardness, cohesiveness, guminess, springiness, and adhesiveness and greater swelling power, solubility, crystallinity, gelatinization temperatures and granular size compared to those of Tanduk. Regardless of cultivar, fermented starches had higher degree of crystalinity, gelatinization properties, and swelling power and solubility but lower amylose content, granular size and textural properties compared with native starches.

The X-ray diffraction patterns of fermented and native starches showed an A-type pattern which is rarely reported for plantain starches. The FTIR spectra of the plantain starches present the same characteristic bands in the finger print region of 4000–280 cm^{-1}. The starch granule birefringence did not differ. The scanning electron micrograph revealed that fermented starches had a slightly disrupted and small clustered granules compared with the native starches. Processing conditions influenced the starch properties of Nangka and Tanduk plantain cultivars.

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

KESAN KEADAAN PEPEJAL PENAPAIAN DAN PENGERINGAN PADA HARTANAH KANJI DAN FLAVOUR DARIPADA NANGKA (*Musa paradisiaca* L., AAB) DAN TANDUK (*Musa paradisiaca* L., ABB) TEPUNG PISANG

Oleh

SHITTU RAFIAT MOROLAYO

Julai 2016

Pengerusi : Profesor Madya Lasekan Olusegun, PhD
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ABSTRAK

Pisang memainkan peranan penting dalam kesejahteraan pemakanan dan ekonomi manusia. Namun begitu, pisang sangat mudah terdedah kepada kerosakan disebabkan oleh kandungan kelembapan yang tinggi. Oleh itu, untuk mengelakkan kerugian lepastuai pemprosesan ke atas pisang perlu dijalankan. Kajian ini mengkaji kesan penapaian dan pengeringan kaedah keadaan pepejal ke atas hartanah kanji dan rasa Nangka dan Tanduk tepung pisang.Kajian ini telah dijalankan dalam dua fasa.

Fasa pertama menilai kesan kaedah pengeringan [pengeringan udara panas (HAD) dan pengeringan udara panas dibantu oleh kemasan pengeringan ketuhar mikro-gelombang (MFD)] dan penapaian keadaan pepejal (SSF) terhadap sifat-sifat fizikokimia, sifat fungsian dan penggelatinan tepung dan sebatian aroma tepung daripada kultivar pisang Nangka dan Tanduk. Kaedah pengeringan dan SSF tidak mmempengaruhi kandungan lemak, serat dan karbohidrat tepung pisang. Walau bagaimanapun, kedua-dua perlakuan memberi kesan yang signifikan ($p \leq 0.05$) terhadap pH dan keasidan tertitrat tepung. Tambahan pula, SSF ditambah dengan MFD meningkatkan kapasiti penyerapan air dan penyerapan minyak secara ketara ($p \leq 0.05$) berbanding dengan tepung yang diperolehi daripada pengeringan udara panas. Tren yang sama dicerap pada ciri-ciri pembengkakkan tepung. Tepung yang ditapai dan MFD mempunyai kuasa pembengkakkan yang lebih tinggi daripada yang diperolehi melalui pengeringan udara panas. Spektrofotometri jisim kromatografi gas menunjukkan bahawa tepung pisang Tanduk tertapai yang dikeringkan dengan kemasan mikro-gelombang mempunyai 11 (4 alkohol, 1 keton, 4 ester, 1 sebatian sulfur dan 1 asid) sebatian beraroma, manakala tepung pisang Tanduk yang tidak tertapai yang dikeringkan dengan kemasan mikro-gelombang mempunyai 10 (2 alkohol, 6 asid, dan 2 ester) sebatian beraroma. Tepung pisang Nangka tertapai yang dikeringkan dengan kemasan mikro-gelombang mempunyai mempunyai 13 (5 alkohol, 2 ester, 2 sebatian fenolik, 1 sebatian sulfur, 2 asid dan 1 sterol) sebatian beraroma, manakala tepung pisang Nangka yang tidak tertapai yang dikeringkan

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dengan kemasan mikro-gelombang mempunyai mempunyai 16 (3 aldehida, 5 ester, 6 asid dan 2 alkohol) sebatian beraroma.

Fasa kedua dinilai fizikokimia itu, morfologi, haba, ciri-ciri tekstur dan fungsi kanji asli dan kanji dari penamat microwave ditapai tepung kering daripada Nangka dan Tanduk kultivar pisang. Anak Negeri dan ditapai kanji Nangka mempunyai amilosa yang lebih rendah dan sifat-sifat tekstur dan kuasa bengkak lebih besar, kelarutan, penghabluran, suhu penggelatinan dan saiz berbutir dibandingkan dengan Tanduk. Tidak kira kultivar, kanji diperam mempunyai tahap yang lebih tinggi Kehabluran, hartanah penggelatinan, dan kuasa bengkak dan kelarutan tetapi kandungan amilosa yang lebih rendah, saiz butiran dan ciri-ciri tekstur berbanding dengan kanji asli. X-ray corak pembelauan kanji ditapai dan asli menunjukkan corak A-jenis yang jarang dilaporkan kanji pisang. Yang FTIR spektrum kanji pisang membentangkan band ciri yang sama di rantau cetak jari 4000-280 cm-1. Kanji biji birefringence tidak berbeza. The mikrograf elektron imbasan mendedahkan bahawa kanji ditapai mempunyai sedikit terganggu dan kecil granul berkelompok berbanding dengan kanji asli. keadaan pemprosesan dipengaruhi sifat kanji Nangka dan Tanduk kultivar pisang.

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I certify that a Thesis Examination Committee has met on 25 July 2016 to conduct the final examination of Shittu Rafiat Morolayo on her thesis entitled "Effects of Solid-State Fermentation and Drying on Starch Properties and Flavour of Nangka (*Musa paradisiaca* L., AAB) and Tanduk (*Musa paradisiaca* L., ABB) Plantain Flours" 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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Name of Member of Supervisory Committee: Dr. Rabiha Sulaiman

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LIST OF ABBREVIATIONS

^{o}C	degree centigrade
FTIR	Fourier transform infrared
MFD	Microwave finish drying
HAD	Hot air dry
S	Solubility
SEM	Scanning electron microscopy
SP	Swelling power
SSF	Solid-state fermentation
T_o	Onset gelatinization temperature
T_p	Peak gelatinization temperature
T_c	Conclusion gelatinization temperature

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CHAPTRE ONE

GENERAL INTRODUCTION

The contribution of plantain to the nutritional and economic wellbeing of humans is incontrovertible in many parts of the world (FAO, 2014; Mebratie *et al*., 2015). Plantain production is an active and dynamic industry that is central to the wellbeing of many people and a crucial part of the economy in the tropical and subtropical regions of the world (Lasekan, 2012; FAO, 2014; Mebratie *et al*., 2015).

Plantain is highly perishable due to its high moisture contents and metabolic activity which persist after harvest (Falade and Olugbuyi, 2010; Erdoğdu *et al*., 2014; Sahoo *et al*., 2015). The postharvest losses are significant especially in developing countries where there is poor or lack of storage facilities or inapt technologies for food processing (Falade and Ogunwolu, 2014; Mebratie *et al*., 2015). In cognizance of the substantial postharvest losses in plantain, a need exists to process plantain into other products such as flour and starch, which could be utilized in various ways.

Green plantain contains up to 70–80% starch on a dry weight basis (Coulibaly *et al*., 2006; Tribess *et al*., 2009; Abdul-Aziz *et al*., 2011). Plantain starch is capable of being a commodity starch due to its unique characteristics and its prospective production from low-cost plantain (Padam *et al*., 2014). This starch could be utilized industrially thereby lessening postharvest losses, environmental pollution and offering employment opportunities and financial returns to farmers (Padey, 2003; Zhang *et al*., 2005; Mohapatra *et al*., 2009; Mohapatra *et al*., 2010).

In order to determine the suitability of plantain starch for specific end use, it is necessary to comprehend its physicochemical and functional properties. Although a great variety of native starches with different functionalities exists in the market, the increasing demand for specific starch properties necessitates new strategies or alternatively, novel sources (Wani *et al*., 2010). In the bid to avoid chemical modifications, scientists increasingly explore starch sources with desirable physicochemical properties (Correia *et al*., 2012; Pelissari *et al*., 2012)

In Malaysia, banana is the second most widely cultivated fruit, with a total production of 530,000 metric tonnes per year covering about 26,000 hectares (Goh *et al*., 2010; Robinson and Saúco, 2010; Mekhilef *et al*., 2011). About 50% of the banana growing land is cultivated with Berangan and Cavendish cultivars, and the remaining popular cultivars are Mas, Rastali, Raja, Awak, Jari, Embun, Nipah, Abu, Lang, Susu, Nangka and Tanduk cultivars (Robinson and Saúco, 2010; Mekhilef *et al*., 2011). Among these, Nangka and Tanduk cultivars are the major cooking bananas (Plantains) in Malaysia (Jamaluddin, 2000; Robinson, and Saúco, 2010). Plantains are a member of the banana family but they are starchier and lower in sugar (Coulibaly *et al*., 2006). Despite their availability, little or no effort has been expended to appraise the starch

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properties of Malaysian grown plantains. Thus, as a part of efforts to promote the utilization of Malaysian-grown plantain starches, it was considered worthwhile to assess the morphological, physicochemical, structural, textural and thermal properties of starches from Nangka and Tanduk plantain cultivars.

Green plantain can be processed into plantain flour (Aurore *et al*., 2009; Mohapatra *et al*., 2010; Oluwalana *et al*., 2011). In addition to the traditional common use of plantain flour for stiff dough particularly in West Africa, there are indications that plantain flour could be used for baked products (Olaoye *et al*., 2006; Oluwalana *et al*., 2011) and as a component of baby foods (Aurore *et al*., 2009; Mohapatra *et al*., 2010).

It is well established that processing conditions such as drying, fermentation and milling, employed in making plantain flour would affect its functional and physicochemical properties (Tribess *et al*., 2009; Falade and Olugbuyi, 2010). These methods increase nutrient density, acceptability, quality, availability, flavour, aroma and palatability of the final products (Hotz and Gibson, 2007; Falade and Olugbuyi, 2010) and reduce viscosity and antinutrients (Nnam, 1995).

Hot air drying is one of the cheapest, commonest and oldest plantain processing methods (Cao *et al*., 2015; Datta *et al*., 2015). Nonetheless, the procedure could have detrimental effect on product quality (Fagbohun *et al*., 2010; Cao *et al*., 2015). For example, the long drying time and high temperature employed in traditional air drying to remove water from sugar containing fruits such as plantain may have negative impacts on the nutrients, flavour and colour and could reduce rehydration capacity and bulk density of the dried products (Maskan, 2000; Sagar and kumar, 2010). In addition, long drying time and low energy efficiency during the falling rate of hot air drying could reduce thermal conductivity (Adu and Otten, 1996; Maskan, 2000; Michailidis and Krokida, 2015) thereby limiting heat transfer to the inner parts of the product (Feng and Tang, 1998). The need to curb the aforementioned shortcomings associated with the traditional hot air drying gave impetus to the use of microwave drying in foods (Feng and Tang, 1998).

Albeit microwave drying ensures product quality, the procedure is expensive and could results in poor product quality if not properly applied (Feng and Tang, 1998; Zhang *et al*., 2006; Michailidis and Krokida, 2015). Thus, harmonizing desirable features of hot air and microwave drying methods is worthwhile. It has been suggested that microwave drying should be applied at low moisture content for finish drying (Feng and Tang, 1998). Thus, we propose that microwave-assisted hot air drying will improve quality of flour from Nangka and Tanduk plantain cultivars.

Fermentation is an important processing method for reducing postharvest losses and can improve flavour, colour and other quality attributes of foods (Oloyede *et al*., 2013; Igbabul *et al*., 2014a; Adebayo-Oyetoro *et al*., 2015). A typical form of fermentation is solid-state fermentation (SSF) which refers to the fermentation involving solids in the near absence or absence of free water; nonetheless, substrate must have sufficient

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moisture to support the metabolism and growth of microbes (Pandey, 2003). The process is a potential technological alternative for processing various foods to enhance their nutritional quality and to obtain edible products with palatable sensory properties (Pandey, 2003; Oloyede *et al*., 2013; Adebayo-Oyetoro *et al*., 2015). Thus, we propose that SSF will improve the quality attributes of Nangka and Tanduk plantain flours.

Albeit it is common knowledge that processing conditions influenced the physicochemical properties of banana flour, information on the properties of starches and flours of Nangka and Tanduk plantain cultivars as influenced by processing conditions remains elusive. In addition, the impact of processing conditions on the flavour compounds in Nangka and Tanduk plantain flours has not been elucidated. Thus, this study was initiated to fill the aforementioned gaps.

The current study is partitioned into five chapters. The first two chapters discussed the framework of the experimental research. Chapter 1 provides the rationale for the focus of the research. Chapter 2 focused on the review of current literature covering, nutritional importance of plantain, postharvest losses in plantain, drying methods and SSF and their effects on the physicochemical properties of plantain flour. Plantain starch and its physicochemical and functional properties were also reviewed. Chapter 3 and 4 present the experimental works for this study, address the major findings and highlight the practical importance. Chapter 5 presents the summary, conclusions and recommendations for future studies.

The objectives of this study were:

1. To determine the effect of drying methods and solid-state fermentation on the physicochemical characteristics and volatile compounds of Nangka and Tanduk plantain flours.
2. To identify the volatile compounds in fermented and unfermented microwave-finish dried Nangka and Tanduk plantain flours.
3. To characterise the functional, morphological, thermal and textural properties of native and fermented microwave–finish dried starches from Nangka and Tanduk plantains.

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