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APPLICATION OF SHORTWAVE NEAR INFRARED SPECTROSCOPY IN DETERMINING PHYSICOCHEMICAL PROPERTIES OF JACKFRUIT

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By

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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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APPLICATION OF SHORTWAVE NEAR INFRARED SPECTROSCOPY IN DETERMINING PHYSICOCHEMICAL PROPERTIES OF JACKFRUIT

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Faculty : Engineering

Jackfruit *(Artocarpus heterophyllus)* is a tropical fruit which belongs to Moraceae family. Jackfruit has a very good market in Malaysia for fresh consumption. The fruit have also been exported to Asian and European countries due to its premium quality. In order to ensure that only jackfruits at the best quality are exported, the quality of the fruits should be monitored at an orchard regularly. The development of an efficient and rapid measurement technique to assess the quality (sweetness, moisture content and nutritive values) of jackfruit non-destructively are critically needed in the industry. Therefore, this research aimed to investigate the potential application of shortwave near infrared spectroscopy (SWNIRS) to predict the physicochemical properties of jackfruit. In this study, three typical physicochemical properties of jackfruit such as Soluble Solids Content (SSC), pH and moisture content (MC) were measured. A total of 29 fresh jackfruits samples were used in this investigation, giving a total of 870 skin and 798 pulp portions. The SSC and MC of the skin and pulp portions were recorded using a handheld digital refractometer and conventional hot air-drying, respectively. While the pH values of the pulp were measured using ionic pH meter. The spectral data of the both portions were recorded using SWNIRS with the wavelength ranged from 500 to 950 nm. Partial least square (PLS) regression analysis was chosen to establish regression models between the spectral data and the quality parameters. Useful information from the spectral data were extracted by Principal component analysis (PCA). The pre-processing methods, PLS and PCA exercises were run using Unscrambler X 10.3 software to evaluate the performance of the models.From the results, it was found that the values of R^2 and root means square errors for calibration (RMSEC) in

predicting SSC from the skin samples were 0.77 and 0.90 °Brix, respectively. For the prediction model of the same portions, the values of R^2 and root mean square errors of prediction (RMSEP) were 0.69 and 0.97 °Brix, respectively. For the pulp portions, it was found that the values of R^2 and RMSEC were 0.92 and 1.79 °Brix, respectively. In terms of prediction model, the values of R^2 and RMSEP were 0.76 and 3.19 °Brix, respectively. The ability of the spectrometer in predicting MC from the both skin and pulp portions were also investigated. The results showed that R^2 and RMSEC values in predicting MC from the skin samples were 0.65 and 2.18%, respectively. For the prediction model of the same portions, the values of R^2 and RMSEP were 0.69 and 2.81 %, respectively. For the pulp portions, it was found that the values of R^2 and RMSEC were 0.83 and 2.27%, respectively. In terms of prediction model, the values of R^2 and RMSEP were 0.68 and 3.07%, respectively. In addition to SSC and MC, the potential use of the spectrometer in predicting pH values from the pulp samples was also investigated. From the results, it was found that the values of R^2 and RMSEC in predicting pH values form the pulp samples were 0.92 and 0.16, respectively. For the prediction model of the same portions, the values of R^2 and RMSEP were 0.82 and 0.23, respectively. Overall, it is concluded that the SWNIRS has the potential to be used for predicting the physicochemical properties of jackfruit from the skin and pulp portions. The development of rapid and portable SWNIRS will be very helpful for farmers in the jackfruit industry.

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APLIKASI GELOMBANG PENDEK DAN DEKAT INFRAMERAH SPEKTROSKOPI DALAM MENENTUKAN SIFAT FIZIKOKIMIA BUAH NANGKA

Oleh

NAJIDAH BINTI ABDULLAH

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Nangka *(Artocarpus heterophyllus)* adalah buah tropika yang dimiliki oleh keluarga Moraceae. Nangka mempunyai pasaran yang sangat baik di Malaysia untuk kegunaan segar. Buah ini juga dieksport ke negara Asia dan Eropah kerana kualiti premiumnya. Oleh itu untuk memastikan bahawa hanya buah nangka yang berkualiti dieksport, kualiti buah nangka perlu dipantau di kebun secara kerap atau berkala. Dengan itu, pembangunan teknik pengukuran yang cekap dan pantas untuk menilai kualiti (manis, kandungan lembapan dan nilai nutritif) nangka tidak destruktif sangat diperlukan dalam industri. Oleh itu, penyelidikan ini bertujuan untuk mengkaji kemungkinan penggunaan gelombang pendek inframerah spektroskopik (SWNIRS) untuk meramalkan sifat fizikokimia buah nangka. Dalam kajian ini, tiga sifat fizikokimia biasa nangka seperti Kandungan Larut Suluh (SSC), pH dan kandungan lembapan (MC) diukur. Sebanyak 29 sampel buah nangka segar digunakan dalam kajian ini, memberikan sejumlah 870 kulit dan 798 bahagian pulpa. SSC dan MC bahagian kulit dan pulpa dicatatkan menggunakan refractometer digital pegang tangan dan pengering udara udara konvensional. Manakala nilai pH pulpa diukur menggunakan meter pH ionik. Data spektral kedua-dua bahagian tersebut direkodkan dengan menggunakan SWNIRS yang panjang gelombangnya antara 500 hingga 950 nm. Analisis regresi kuadrat (PLS) dipilih untuk menubuhkan model regresi antara data spektral dan parameter kualiti buah nangka. Maklumat berguna daripada data spektrum telah diekstrak oleh analisis komponen utama (PCA). Kaedah pra pemprosesan, latihan PLS dan PCA dijalankan menggunakan perisian Unscrambler X 10.3 untuk menilai prestasi model. Keupayaan spektrometer dalam meramal MC dari kedua-dua bahagian kulit dan pulpa juga disiasat. Keputusan menunjukkan bahawa nilai R^2 dan RMSEC dalam meramalkan MC dari sampel kulit adalah 0.65 dan 2.18%, masing-masing. Bagi model ramalan bagi bahagian yang sama, nilai R^2

dan RMSEP masing-masing adalah 0.69 dan 2.81%. Bagi bahagian pulpa pula, didapati nilai R^2 dan RMSEC masing-masing adalah 0.83 dan 2.27%. Dari segi model ramalan, nilai R^2 dan RMSEP masing-masing adalah 0.68 dan 3.07%.Sebagai nilai tambahan kepada SSC dan MC, potensi penggunaan spektrometer dalam meramalkan nilai pH dari sampel pulpa juga disiasat. Dari hasilnya, didapati nilai R^2 dan RMSEC dalam meramalkan nilai pH membentuk sampel pulpa adalah 0.92 dan 0.16. Bagi model ramalan bagi bahagian yang sama, nilai R^2 dan RMSEP masing-masing adalah 0.82 dan 0.23. Secara keseluruhan, disimpulkan bahawa SWNIRS mempunyai potensi untuk digunakan untuk meramalkan sifat fizikokimia nangka dari bahagian kulit dan pulpa. Pembangunan SWNIRS yang pesat dan mudah alih akan sangat membantu para petani dalam industri nangka.

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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. The members of the Supervisory Committee were as follows:

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Jackfruit (*Artocarpus heterophyllus* L.) is a non-seasonal fruit which has a high demand for its fresh consumption in Malaysia. According to Elevitch and Manner (2006), jackfruit belongs to genus Artocarpus, along with the other species such as breadfruit (*Artocarpus altilis*), dugdug (*Artocarpus mariannensis*) and breadnut (*Artocarpus camansi*). Jackfruit is widely planted in tropical countries such as Brazil, Thailand, Indonesia, India, Philippines and Malaysia (Madruga et al., 2014).

In Malaysia, around 5000 ha of land were cultivated with jackfruit in 2017 to meet a high demand from other Asian countries, mainly Japan. Jackfruit is a high yielding crop, which bears fruit all year round where its peak production is usually around June to December (Ong et al., 2006). Different origin region and species sources influence the physicochemical property of jackfruit, which will lead to diversity (Zhang et al., 2016).

Jackfruit has a benefit for being processed products such as fermented beverages, chips and jam food for commercializing. However, nowadays, consideration of consumers to fruit quality is not limited to the external features such as colour, size and shape (Zhang et al., 2014), but also to its internal attributes such as the nutritional content (Kumar et al., 2015).

Several recent studies focus on the development of technology that can assess and classify the quality of the fruit based on different parameters such as colour, texture, taste, flavour and nutritional values in order to increase the consumer acceptance and satisfaction (Li et al., 2013). However, some of the fruit properties cannot be viewed through naked eyes. Hence, it cannot be inspected just by using visible imaging.

Jackfruit is regarded as fruit that is worthy of research attention because of its wider potential use in nutrition and high demand among consumers. Most of the existing technologies for measuring the physicochemical properties of fruit such orange (Liu et al., 2010) pears (Li et al., 2013) and passion fruit (Maniwara et al., 2014) were already done. Therefore, this research focused on

a non-destructive technique to evaluate the physicochemical properties of jackfruit by using shortwave near infrared spectrometer (SWNIRS).

1.2 Problem statement

Nowadays, jackfruit is an important commercial fruit that is widely cultivated in parts of Asia. From a consumer acceptance perspective, both the physical and physicochemical properties of the fruit contribute to the perceived value and quality of the jackfruit. Thus, it is essential for the proper non-destructive assessment of jackfruit quality.

However, consistent proper assessment on jackfruit is quite challenging since the current assessment method in the field involves the manual procedures. The conventional assessment of jackfruit quality is destructive and depends very much on the ability of manpower and human skills. However, similar research has not been done for jackfruit, therefore, there is a requirement for the application of fast, automatic and non-destructive technology to perform the jackfruit quality assessment. The effective non-destructive approach is desirable to change the application of conventional methods, which apparently are less practical these days.

In recent years, reflectance spectroscopy method has been commonly used to assess food quality and properties of plant tissues. Most studies on the application of reflectance spectroscopy related to agricultural production, which focused both on quality assessment and the reflectance characteristics of plant tissues. Therefore, there is a need for non-destructive techniques for the assessment of internal quality attributes of jackfruit.

1.3 Research Objectives

The goal of this study was to evaluate the potential application of SWNIRS in determining the physicochemical properties of jackfruit.

The specific objectives were:

i. To determine the physicochemical properties of jackfruit skin and pulp.

ii. To measure physicochemical properties of jackfruit skin and pulp using SWNIRS.

iii. To correlate the physicochemical properties of jackfruit skin and pulp with spectral data.

1.4 Scope and limitation

The present study aimed at exploring the potential use of SWNIRS for predicting physicochemical properties of jackfruit J33 variety. This study was conducted to determine the quality of jackfruit by SWNIRS, non-destructively. The samples were equivalent in the maturity stage (90 to 100 days). Besides, this study only focused on reflectance mode. The evaluation of the spectroscopy method on jackfruit on pulp and skin only.

1.5 Thesis layout

The thesis was organized as follows. Chapter 1 describes the background study driving to this work. This chapter also outlines the research objectives, scope and limitation as well as the importance of the study. Chapter 2 provides a literature review of quality evaluation of jackfruit. This chapter also describes the postharvest handling of the fruit, the application of spectrometer to other fruit, ready product from jackfruit and future prospect of the SWNIRS application. Chapter 3 explains the experimental for using SWNIRS as well as the procedure of physicochemical and physical properties measurements, destructive method. Spectral data analyses are also discussed in this chapter. Chapter 4 discusses the result and findings achieved the research objectives. Chapter 5 summarizes the conclusion and achievement of this research, alongside a recommendation for future studies.

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She then continued her study in Faculty of Engineering, UPM. She was awarded a Bachelor of Engineering (Agricultural and Biosystems Engineering). She had worked in mechanization and automation in agriculture related to the paddy industry since her final year project.

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Journal

Abdullah, N., Nawi, N.M., Ding, P., Kassim. M.S.M. and Lazim, S.S.R.M. (2019). Preliminary study to predict moisture content of jackfruit skin using shortwave near infrared spectroscopyFood Research. 3(2):128 – 132.

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