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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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April 2019

Chair : Yus Aniza Yusof, PhD
Faculty : Engineering

Carica Papaya is a tropical fruit which is widely consumed around the world. The waste by-products produced are underutilized although they show good nutritional properties. Rather than having the waste disposed into the environment, efforts can be made to convert them into value added products by further processing. Thus, this research focuses on producing papaya peel powder, followed by its application in stirred yogurt for the purpose of investigating its effects on yogurt properties. Papaya peel was first dried using a convection oven at 45, 55, and 65 ^{o}C and a microwave oven at 250, 440, and 600 W to study its drying kinetics and behaviours. Seven semi-empirical drying models, namely Lewis, Page, Modified Page, Henderson and Pabis, Logarithmic, Two-Term, and Approximation of Diffusion models, were used to fit the drying data obtained. This was followed by characterization of the obtained papaya peel powders, that is, proximate analysis, colour, flow behaviour and antioxidant capacity was investigated. Papaya peel powder was added as a source of dietary fibre to plain stirred yogurt at 0, 1.5 and 3.0% concentration to study its effects on quality properties and sensory profile of yogurt. Results indicated that for oven drying and microwave drying, Page model and Approximation of Diffusion model was the best fit, respectively, with highest coefficient of determination (R^2). Effective moisture diffusivity (D_{eff}) was estimated to compare the two drying methods and it was concluded that microwave drying at 600 W exhibited with highest D_{eff}. Additionally, the value of D_{eff} for oven drying and microwave drying was 6.7 x 10^{-08} to 4.4 x 10^{-07} and 2.4 x 10^{-07} to 6.7 x 10^{-07}, respectively. Activation energy was recorded at 61 kJ/mol for oven and 47 W/g for microwave. After drying behaviour was investigated using drying models, characterization of peel powder obtained was done. The powders showed moisture content below 10% and high total dietary fibre content. Colour of each powder sample was analysed which showed that the lightness parameter, L^*, reduced as the temperature and power intensity was raised. As per Carr index and Hausner ratio, flowability properties indicated that all the powders had poor to excellent flow. Antioxidant analysis of papaya peel powder was done by DPPH and ABTS assay which showed that all the powders have potential antioxidant properties. After enrichment of stirred yogurt with selected papaya peel powders, quality properties were determined for 21 days storage at 4°C. It was observed that the viscosity values increased during storage while pH values decreased. For colour parameters, it was noted that the values remained generally the same throughout storage. Sensory analysis was conducted for the five stirred yogurt samples prepared at Day 0. Sensory attributes were assessed using nine-point hedonic scale. Stirred yogurt prepared with papaya peel powder dried at 55°C gave the best sensory scores.

This research concludes that waste by-products can be utilized after further processing since they are potential sources of nutrients. Application in stirred yogurt is one of the excellent ways of feasible utilization of papaya peels. Additionally, basic foundation for understanding the drying behaviour of papaya peels is provided which can help to choose and design an ideal dryer for papaya peels.

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

PERBANDINGAN ANTARA KETUHAR PEROLAKAN DAN GELOMBANG MIKRO BAGI PENGERINGAN KULIT *Carica papaya* L. DAN PENGKELASAN SERBUK KULITNYA

Oleh

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Betik *Carica* adalah sejenis buah-buahan tropika yang sering dimakan oleh masyarakat di serata dunia. Namun, sisa bahan buangannya kurang digunakan walaupun mempunyai sifat nutrisi yang baik. Usaha dalam menjadikan sisa bahan betik sebagai produk yang bernilai melalui proses lanjutan perlu dilaksanakan supaya sisa tersebut tidak dibuang begitu sahaja. Oleh itu, tujuan penyelidikan ini adalah untuk menghasilkan dan mengkelaskan kulit betik dan aplikasinya dalam dadih teraduk bagi menyiasat keberkesanannya terhadap sifat dadih. Kulit betik dikeringkan menggunakan ketuhar perolakan pada suhu 45 ^oC, 55 ^oC, dan 65 ^oC manakala ketuhar gelombang mikro pada kuasa 250W, 440W, dan 600 W bagi mempelajari pengeringan kinetik dan sifatnya. Tujuh model pengeringan iaitu Lewis, Page, Modified Page, Henderson dan Pabis, Logarithmic, Two-Term, serta Anggaran Resapan telah digunakan untuk memadankan data pengeringan. Pengkelasan serbuk kulit betik melalui analisis proksimat, ciri kebolehan aliran dan kapasiti antioksidan juga telah dikaji. Serbuk kulit betik kemudian dicampurkan di dalam dadih teraduk asli sebagai sumber serat makanan pada kepekatan 0, 1.5 and 3.0% dalam mengkaji kesannya terhadap kualiti dan profil deria dadih teraduk. Hasil kajian telah menunjukkan bahawa model Page dan model Anggaran Resapan adalah model yang paling tepat bagi pengeringan ketuhar perolakan dan ketuhar gelombang mikro kerana mempunyai nilai tertinggi pekali penentuan (R^2). Selain itu, keberkesanan kemeresapan kelembapan (D_{eff}) juga dianggarkan bagi membandingkan dua jenis teknik pengeringan dan ia dapat disimpulkan bahawa pengeringan ketuhar gelombang mikro pada 600 W memperolehi nilai D_{eff} yang tertinggi. Tambahan pula, nilai D_{eff} bagi ketuhar perolakan adalah 6.7 x 10^{-08} hingga 4.4 x 10^{-07} manakala ketuhar gelombang mikro adalah di antara 2.4 x 10^{-07} hingga 6.7 x 10^{-07}. Tenaga pengaktifan telah dicatat pada 61 kJ/mol untuk ketuhar perolakan dan 47 W/g bagi ketuhar gelombang mikro. Setelah kajian pengeringan dilaksanakan menggunakan model pengeringan, pengkelasan terhadap serbuk kulit betik dijalankan.

Serbuk tersebut didapati mempunyai 10% kandungan lembapan dan juga kandungan jumlah serat makanan yang tinggi. Warna bagi setiap sampel serbuk telah dikaji dan hasil keputusan menunjukkan faktor kecerahan, *L** berkurangan apabila suhu dan keamatan kuasa meningkat. Bagi indeks Carr and nisbah Hausner, faktor kebolehan aliran menunjukkan semua serbuk yang asalnya mempunyai kebolehan aliran yang rendah berubah mempunyai kebolehan aliran yang amat baik. Analisis antioksidan untuk serbuk kulit betik turut dijalankan melalui ujian DPPH dan ABTS dan telah membuktikan kesemua serbuk mempunyai potensi ciri-ciri antioksidan. Setelah penambahbaikan terhadap dadih teraduk menggunakan serbuk kulit betik yang terpilih dijalankan, ciri kualiti terhadap penyimpanan selama 21 hari pada suhu 4^{o}C dikaji. Melalui pemerhatian, nilai kelikatan semakin meningkat semasa penyimpanan manakala nilai pH menurun. Dari segi warna pula, nilai warna kekal sama sepanjang penyimpanan. Analisis deria juga turut dijalankan untuk lima jenis sampel dadih teraduk yang telah disediakan pada Hari 0. Jenis-jenis deria telah dijalankan menggunakan skala hedonic sembilan mata. Dadih teraduk yang dicampurkan dengan serbuk kulit betik yang telah dikeringkan pada suhu 55^{o}C mendapat markah terbaik dalam pemarkahan analisis deria. Kesimpulannya, selepas menjalani proses lanjutan, sisa bahan betik boleh digunakan dan berpotensi sebagai sumber nutrisi. Salah satu cara yang terbaik dalam penggunaan kulit betik adalah pada aplikasinya dalam dadih teraduk. Selain itu, asas ilmu dalam memahami sifat pengeringan pada kulit betik telah disediakan bagi memudahkan untuk memilih dan mereka cipta pengering kulit betik yang sesuai.

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I certify that a Thesis Examination Committee has met on 30th April, 2019 to conduct the final examination of Sama Manzoor on her thesis entitled "Comparison between Convection and Microwave Oven Drying of *Carica papaya* L. Peel and Characterization of the Powdered Peel" 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. The members of the Supervisory Committee were as follows:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

D_{eff}	Effective moisture diffusivity (m/s^2)
D_o	Pre-exponential factor of Arrhenius equation (m^2/s)
E_a	Activation energy (kJ/mol or W/g)
L	Thickness of slab (m)
R^2	Coefficient of determination
MR	Dimensionless moisture ratio
M_e	Equilibrium moisture content
M_i	Initial moisture content
m	Mass of sample
v	Volume of sample
ρ_B	Bulk density
ρ_T	Tapped density
ρ_v	True density
$\mathcal{E}_p$	Porosity
A_w	Water activity
g	Gram
kg	Kilogram
N	Normality
%	Percentage
TEAC	Trolox equivalent antioxidant capacity
rpm	Rotations per minute
^oC	Degree Celsius
mL	Millilitre
L	Litre
mmol	Milimole
CI	Carr Index
HR	Hausner Ratio
BI	Browning Index
DM	Dry matter

CHAPTER 1

INTRODUCTION

This chapter starts with an introduction to the background of study. The problem statement has been concisely highlighted, followed by the main objectives and thesis outline at the end.

1.1 Research Background

Papaya (*Carica papaya*) is a short-lived, rapidly growing plant with long stalked leaves and hollow stem. It is widely cultivated in many tropical countries. The fruit has a buttery taste and appearance with a yellow-orange to pinkish-orange flesh. It is popular due to its nutritional and nutraceutical properties. Papaya is a rich source of many bioactive compounds namely carotenoids, phenolic compounds, flavonoids, vitamins such as A, B, C and E, potassium and magnesium minerals and dietary fibre (Milind & Gurditta, 2011; Pathak et al., 2018). Its popularity had led it to be grown rapidly in recent years with a global production next to mango, banana, citrus fruits and pineapple. Papaya fruit is generally consumed as fresh and ripe, but can also be cooked particularly in immature stage to successfully prepare salads, preserves, pies and sauces. Numerous papaya products are developed by drying, canning and processing. Puree, juice, jam, jelly, pickle, candied fruit, canned slices, concentrated fruit leather, powder, toffees and rolls are just some of the products which are developed from papaya fruit (Devaki. et al., 2015).

1.2 Problem Statement

It is of no doubt that the large consumption of papaya, in fresh and processed form, has led to an immense generation of waste by-products. Papaya fruit comprises of 20-25% of waste by weight, which includes 12% as peels and 8.5% as seeds (Pavithra et al., 2017; Medina et al., 2003). While another study reports that chopping of papaya into dices results in 8.5% of peel, 6.5% of seeds and 32% of unusable pulp waste (Sagar et al., 2018). These papaya wastes are generally discarded from households, restaurants and industries. According to Rachtanapun, (2009), papaya waste was recorded more than one thousand tons per year. Papaya peels are mostly discarded as they do not receive sufficient attention for utilization or recycling. This may be because there is a lack of its application for commercial use (Jamal et al., 2017). Conventionally, they are used in animal feeds and home remedies. Besides being hazardous to the environment, they also have a potential to be used and converted after biological treatments into value-added products. Papaya peels have a good amount of dietary fibre present in them which can allow it to be used for the generation of innovative products (Calvache et al., 2016).

The high moisture content (75 to 80%) in papaya peels consequently impacts the handling, storage, collection and transportation processes. Papaya peel, thus, in this state can encourage the growth of microorganisms and degradation of chemical compounds. For an industrial scale production of value-added products derived from papaya peels, it is essential that there is a continuous supply which is cost-effective. Therefore, drying of papaya peel becomes crucial so that their full potential can be exploited (Pathak et al., 2018). Drying is a method for food preservation by removing moisture which helps in retardation of microbial growth, thus improving the shelf life of the product (Omolola et al., 2015; Yaldiz et al., 2001). Taking this into account, a proper methodology has to be used that will allow us to re-utilize papaya peel for the development of beneficial products.

Many complications are faced during the drying process of fruits due to their complex structure, composition and biological variability. Drying rates are also influenced by the geometry, thickness and structure of agricultural material. Such problems can be solved by the use of mathematical modelling and simulation. Modelling of drying kinetics is an effective process control tool which is quick and inexpensive. It uses mathematical equations for the prediction of drying behaviour and simulation of drying experimental data (Castro et al., 2018; Karathanos & Belessiotis, 1999). Mathematical modelling allows design engineers to better understand the drying mechanism. Thus, they can select the most optimum operating conditions and achieve a dryer equipment that meets such suitable conditions which in turn will help to reduce any experimentation repetitiveness and cost (Demir et al., 2007). As a result, the dried product obtained can then be further analysed. No previous studies have been found on describing the drying behaviour of papaya peels.

Characterization of food is crucial for product and process development to ensure consumer acceptance. It is essential for food engineers to learn what sources are available, into which existing products can these be incorporated and what new products can be developed. Such knowledge is important for quality control, process control and design of process equipment (Fikry, 2016).

Yogurt is a well-known fermented milk product prepared by *Streptococcus thermophilus* and *Lactobacillus delbrueckii* spp. *Bulgaricus*. However, they still lack when it comes to dietary fibre or polyphenols. Since it is consumed all over the globe in such large quantities, it can present as a suitable way to deliver nutrients into the diet of population. Furthermore, consumers are becoming more and more conscious of what nutrients goes into their body, thus yogurt can act as a good candidate for fortification with dietary fibres (Gahruie et al., 2015; Hashim et al., 2009). Dietary fibre will not only improve the nutritional status of a yogurt, but also help to improve its texture, viscosity and in this way shelf life (Elleuch et al., 2011).

Limited information is available in the literature related to drying kinetics and analysis of papaya peels and their application in dairy products. Therefore, this study will help to provide information necessary to design new products from an otherwise underutilised by-product of papaya.

1.3 Objectives

The main objective of this study is to produce and characterize papaya peel powder using different drying methods, specifically;

i. To investigate the drying kinetics of *Carica papaya* peel using convection oven and microwave oven.
ii. To produce and characterize the physicochemical and flowability properties of powder made from *Carica papaya* peels.
iii. To study the effect of fortifying *Carica papaya* peel powder on physical and sensory properties of stirred yogurt.

1.4 Scope of Study

Papaya peels are stored with nutrients, bioactive compounds and dietary fibre (see section 2.3). They can be promising as a source of dietary additives, food additives, nutraceutical supplements and pharmaceutical products. Therefore, there is a need to develop such bio-production and recovery processes of these waste that would not only be economically valuable to the agriculture sector but also have a positive effect on the environment (Horuz & Maskan, 2013; Laufenberg et al., 2003; Pathak et al., 2018).

Therefore, the main focus of this study is to produce and characterize papaya peel powder using two drying methods. Their physicochemical and flowability properties will be determined and compared. Finally, its application in dairy product, that is, yogurt will be investigated.

The scope of present research is shown in Figure 3.1 (see section 3.2).

1.5 Organization of Thesis

The thesis consists of five chapters which begins with the introductory chapter 1. Here a comprehensive introduction is given with an outline of the research project. The background of study and carefully formulated objectives is presented.

Chapter 2 gives a meticulous *r*eview of literature in this field to obtain sufficient information to design the experiment. *Carica papaya* peel, drying kinetics and modelling, physicochemical properties of fruit by-products, flowability of powder and fortification of yogurt using fruit by-products is reviewed in depth.

Chapter 3 explains the materials and procedural techniques used in this research study. The overall work flow adopted to carry out the experiments is thoroughly presented. All chemicals and laboratory equipments used are mentioned in this chapter.

Chapter 4 reveals the results obtained from the experiments with clear summarization in tables and figures. The explanation of the results is given in detail in this chapter. Data has been presented as mean values with standard deviation and analysed in SPSS software and Microsoft Excel 2016.

Chapter 5 is presented as a conclusion to this research work along with brief experimental results achieved and recommendations for future studies.

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LIST OF PUBLICATIONS

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Manzoor, S., Yusof, Y. A., Chin, N. L., Tawakkal, I. S. M. A., Fikry, M., Chang, L.S. (2019). Thin-layer Drying Characteristics of Papaya (*Carica papaya*) Peel using Convection Oven and Microwave Drying. Pertanika Journal of Science & Technology. (Published)

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