MICROWAVE DRYING CHARACTERISTICS OF MAS COTEK (*Ficus deltoidea*) LEAVES AND ITS EFFECTS ON COLOUR AND ANTIOXIDANT PROPERTIES

by

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ASAE	American Society of Agricultural Engineers
BET	Brunauer, Emmett, Teller
CIE	Commission International de I' Eclairage
DPPH	2, 2-diphenyl-1-picrylhydrazyl
EMC	Equilibrium Moisture Content
EPPs	Entry Point Projects
ETP	Economic Transformation Programme
FCC	Federal Communications Commission
FRAP	Ferric Reducing Antioxidant Power
GAB	Guggenheim – Anderson – deBoer
GAE	Gallic Acid Equivalents
GPS	Global Positioning System
HPLC	High Performance Liquid Chromatography
JMP	John's Macintosh Project
MMP-1	Matrix metalloproteinase-1
MR	Moisture Ratio

NKEAs	National Key Economic Areas
ORAC	Oxygen Radical Absorbance Capacity
OSHA	Occupational Safety & Health Administration
TEAC	Trolox Equivalent Antioxidant Capacity
TPC	Total Phenolic Content
UniMAP	Universiti Malaysia Perlis
UV	Ultraviolet
UVB	Ultraviolet B

LIST OF SYMBOLS

%	percentage
^oC	Celcius
A ,B, C, D	constant parameters for moisture sorption isotherm models
a,b,c,k,n	constant parameters for thin layer drying models
a*	chromacity coordinate (redness or greenness)
a_w	water activity
b*	whromacity coordinate (yellowness or blueness)
cm	centimetre
d.b	dry basis
DM	dry matter
g	gram
GHz	Gegahertz
h	hour
k	drying rate constant
kPa	kiloPascal
L	Liter
L*	chromacity coordinate for lightness

ln	natural log
M	moisture content
M_o	monolayer moisture content
mg	miligram
MHz	Megahertz
min	minute
ml	mililiter
mm	milimeter
mM	miliMolar
nm	nanometer
P	mean relative percent error
R^2	coefficient of Determination
rpm	rotation per minute
RMSE	relative mean standard error
SE	standard error
sec	second
T	temperature
W	Watt
µg	microgram

μL	microliter
χ^2	chi-square
ε’	dielectric constant
ε’’	loss factor

Ciri-ciri Pengeringan Gelombang Mikro Terhadap Daun Mas Cotek (*Ficus deltoidea)* dan Kesan Terhadap Warna Daun Serta Kandungan Antioksida

ABSTRAK

Ficus deltoidea atau dikenali di Malaysia sebagai mas cotek adalah antara 10 herba yang disenarai pendek oleh kerajaan Malaysia dalam Program Transformasi Ekonomi (ETP). Herba ini kaya dengan bahan kimia yang berpotensi dalam perubatan seperti menurunkan kandungan gula dalam darah, menurunkan tekanan darah tinggi, menguatkan otot rahim selepas bersalin, melambatkan putus haid dan mengurangkan risiko kanser. Mas cotek selalunya diguna dan disimpan dalam bentuk kering. Pengguna selalunya mencari daun kering mas cotek yang berkualiti tinggi. Justeru itu, proses pengeringan adalah kaedah yang paling efektif untuk menyah air yang terkandung di dalam daun mas cotek untuk menghasilkan daun kering yang mempunyai jangka hayat yang lama untuk penyimpanan. Dalam kajian ini, ciri-ciri pengeringan lapisan nipis daun mas cotek menggunakan gelombang mikro dikaji dan kualiti daun kering iaitu warna daun, jumlah kandungan fenolik dan kandungan antioksida dinilai dan dibandingkan dengan daun segar mas cotek. Tiga aras kuasa gelombang mikro (300, 600 dan 800 W) dan tiga kadar pengalihudaraan (0.00, 0.013 dan 0.025 m^3/s) adalah kombinasi parameter pengeringan yang digunakan untuk mengkaji ciri-ciri pengeringan dan perubahan kualiti daun kering mas cotek. Sistem pengering gelombang mikro yang telah diubahsuai digunakan di dalam kajian ini. Kajian mendapati bahawa kuasa gelombang mikro memberi kesan yang signifikan ($p < 0.05$) kepada kadar pengeringan dan kualiti daun kering mas cotek. Kadar pengeringan meningkat apabila kuasa gelombang mikro meningkat. Kualiti warna daun kering, jumlah kandungan fenolik, dan kandungan antioksida adalah tinggi pada gelombang kuasa mikro yang dilaras pada 600 dan 800 W berbanding 300 W ($p < 0.05$) tanpa mengambil kira kadar pengalihudaraan.Walau bagaimanapun, kesan kadar pengalihudaraan terhadap kadar pengeringan dan kualiti daun kering mas cotek didapati tidak signifikan ($p > 0.05$) pada semua parameter pengeringan. Ciri-ciri pengeringan lapisan nipis daun mas cotek dinilai dan didapati pengeringan berlaku hanya dalam fasa kadar menurun sahaja. Lima model matematik tertubuh dalam teknik pengeringan lapisan nipis telah dipilih untuk dibandingkan antara kinetik pengeringan eksperimen dan kinetik pengeringan jangkaan menggunakan perisian analisa statistik. Berdasarkan kriteria padanan, model Midili et al. adalah model terbaik dalam meramal pengeringan gelombang mikro secara teknik pengeringan lapisan nipis. Akhir sekali, penilaian terhadap erapan garis sesuhu adalah penting untuk memastikan kestabilan daun kering mas cotek ketika penyimpanan. Kaedah graviti statik digunakan untuk mengkaji lembapan erapan garis sesuhu (penjerapan dan nyahjerapan) daun mas cotek pada dua suhu (5 dan 30 °C) serta lima kelembapan nisbi dalam lingkungan 11.26 sehingga 75.65 %. Lima model matematik erapan garis sesuhu yang tertubuh telah dipilih untuk dibandingkan dengan data eksperimen dan data jangkaan erapan garis sesuhu menggunakan perisian analisa statistik. Berdasarkan kriteria padanan, model Peleg adalah terbaik memadankan data erapan garis sesuhu. Bentuk lengkung erapan garis suhu dikategorikan di bawah kelas kedua. Sebagai rumusan, pengeringan pada 600 W dan 0.013 m^3/s dicadangkan sebagai kondisi pengeringan yang optimum untuk daun mas cotek bagi memastikan kualiti akhir daun kering mas cotek yang terbaik.

Microwave Drying Characteristics of Mas Cotek (*Ficus deltoidea*) Leaves and Its Effects on Colour and Antioxidant Properties

ABSTRACT

Ficus deltoidea or locally known as mas cotek in Malaysia is one of the 10 prioritized herbs shortlisted by the government of Malaysia in its Economic Transformation Programme (ETP). The herb is rich in chemical constituents which are known to have diverse therapeutic potentials such as reducing level of sugar in blood, decreasing blood pressure, contracting the vagina after delivery, delaying menopause and reducing the risk of cancer. *Ficus deltoidea* is commonly consumed, stored and further processed in its dried form. High quality dried *Ficus deltoidea* leaves are therefore sought after by the end-users and drying is therefore the most effective method to remove moisture to preserve and extent the shelf-life of the herb. In this study, the thin layer microwave drying characteristics of *Ficus deltoidea* leaves were investigated and the corresponding quality of the dehydrated leaves such as the colour, total phenolic content and antioxidant properties, were evaluated with respect to the fresh leaves. Three microwave power levels (300, 600 and 800 W) and three ventilation rates (0.00, 0.013 and 0.025 m^3/s) were the combination of drying parameters used to examine the drying characteristics and quality changes of dried *Ficus deltoidea*. A modified domestic microwave heater was used in the study. Microwave power levels were found to significantly ($p < 0.05$) affect the drying rate and the quality of the dehydrated *Ficus deltoidea* leaves. The drying rate increased as the microwave power level increased. The colour quality, total phenolic content and antioxidant properties were higher at the microwave power level of 600 and 800 W as compared to 300 W ($p < 0.05$) irrespective of ventilation rate. On the other hand, the effects of the ventilation rates on the drying rate and quality of dehydrated *Ficus deltoidea* leaves were found to be insignificant ($p > 0.05$) at all drying treatments. The thin layer drying characteristics of *Ficus deltoidea* leaves were evaluated and it was found that the drying took place in the falling rate period only. Five established thin layer drying models were used to compare the experimental and predicted drying kinetics by using statistical software analysis. Based on the fitting criteria, Midili et al. model appeared to best fit the thin layer microwave drying data. Finally, the assessment of sorption isotherm is crucial in order to ensure stability of the dehydrated *Ficus deltoidea* leaves during storage. Static gravimetric method was used to determine the moisture sorption isotherm (adsorption and desorption) of *Ficus deltoidea* leaves at two temperatures (5 and 30 °C) and five relative humidities ranged from 11.26 to 75.65 %. Five established isotherm models were used to compare the experimental and predicted sorption isotherms by using statistical software analysis. Based on the fitting criteria, Peleg model appeared to best fit the sorption isotherms data. The characteristic of the shape of the sorption curves were found to fall under the Type II category. As a conclusion, drying treatment of 600 W and 0.013 m^3/s is suggested as drying conditions of *Ficus deltoidea* leaves for optimum dried leaves quality retention.

CHAPTER 1

INTRODUCTION

1.1 Research background

The mere size of the herbal industry and its market potential to domestic economic development has spurred the Malaysian policy makers to embrace herbs as one of the national agenda in its Economic Transformation Programme (ETP) (Anon, 2010). Launched in 2010, ETP has identified more than 10 local herbs of high commercial potentials as priority crops in its agricultural key economic area. One of the main objectives of the ETP is to produce safe, high quality and efficacious high end herbal product. Mas cotek or scientifically known as *Ficus deltoidea* is one of the 10 prioritized herbs in the ETP.

Ficus deltoidea is known to have diverse therapeutic potential such as reducing the level of sugar in blood, decreasing blood pressure, reducing cholesterol and lipids, migraine, contracting the vagina after delivery, delaying menopause and reducing the risk of cancer (Adam et al., 2007). The medicinal therapeutic properties are due to the presence of natural phenolic compounds and antioxidants in the plant. Researches on the phytochemicals of this plant have extensively been carried out and the findings showed that *Ficus deltoidea* indeed possesses significant amounts of phenolic compounds and antioxidants (Abdulla et al., 2010; Wahid et al., 2010; Shafaei & Ismail, 2010; Seong Wei et al., 2011; Hakiman et al., 2012; Ramamurthy et al., 2014). Due to the superior medicinal value of *Ficus deltoidea,* the local herb industry seeks to expand and commercialize its utilization.

Currently, various types of *Ficus deltoidea* products are available in the market in the form of sachets, capsules, pills, massage oil, extract powder, and cordial juice

(Ramamurthy et al., 2014). Raw materials of these products are commonly processed in dried form and the herb industry needs a continuous supply of high quality dried raw materials.

Herbs in dried form are in demand and drying is the most effective method to preserve and extent the shelf-life of the herb. However, the crucial heat sensitive quality parameters such as colour, aroma and bioactive compounds must be preserved during herb drying to maintain its premium quality end-products. These heat sensitive properties provide high market value to the herbs. Among them, colour as for an instance, is the visual appearance that can provide the first judgement of dried product quality at the point of sale by consumers or customers.

Natural and artificial drying processes have been widely used throughout the world to dry herbal materials. Between them, natural sun drying is one of the cheapest and most popular methods adopted by most small scale herb producers. However, the dried materials can risk contaminations from elements such as the airborne particulate matters and insect infestation from exposure during the longer drying process including microbial growth due to relatively low rate of moisture extraction. The other main drawbacks of sun drying as well as the solar drying are the scale of operation and unpredictable weather conditions. Besides being weather dependent, long duration of exposure will prolong the oxidation causing loss of bioactive substances and alteration of physical appearance such as colour. Since the quality of the dried herb depends on the drying method, it is essential to find the drying method that minimizes changes in the chemical and physical properties of the product.

The modern drying technology introduces artificial drying techniques through the use of mechanical dryers to overcome the limitations of the natural drying process. Several mechanical dryers commonly used in herbs drying are in the form of