OSMOTIC DEHYDRATION OF TERUNG ASAM (Solanum lasiocarpum Dunal)

CHIU MOI THIN

THESIS SUBMITTED IN FULFILLMENT FOR THE DEGREE OF MASTER OF SCIENCE

UNIVERSITI MALAYSIA SABA

FACULTY OF FOOD SCIENCE AND NUTRITION UNIVERSITI MALAYSIA SABAH 2017

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN STATUS TESIS

JUDUL: OSMOTIC DEHYDRATION OF TERUNG ASAM (Solanum lasiocarpum Dunal)

IJAZAH: IJAZAH SARJANA SAINS (TEKNOLOGI MAKANAN)

Saya <u>CHIU MOI THIN</u>, Sesi <u>2012 / 2013</u>, mengaku membenarkan tesis Sarjana ini disimpan di Perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:

- 1. Tesis ini adalah hak milik Universiti Malaysia Sabah.
- 2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk tujuan pengajian sahaja.
- 3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
- 4. Sila tandakan (/):



(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA 1972)

(Mengadungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

TIDAK TERHAD UNIVERSITI MALAYSIA SABA

Disahkan Oleh,

NURULAIN BINTI ISMAIL LIBRARIAN VERSTI MALAYSIA SABAH

(Tandatangan Pustakawan)

(Assoc. Prof. Dr. Lee JauShya) Penyelia

CHIU MOI THIN MN1211006T

Tarikh: 10 Jun 2017

DECLARATION

I hereby declare that this dissertation is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that no part of this dissertation has been previously or concurrently submitted for a degree at this or any other university.

20 May 2017

Chiu Moi Thin MN1211006T



CERTIFICATION

NAME : CHIU MOI THIN

MATRIC NO. : MN1211006T

- TITLE : OSMOTIC DEHYDRATION OF TERUNG ASAM (Solanum lasiocarpum Dunal)
- DEGREE : MASTER OF SCIENCE (FOOD TECHNOLOGY)
- VIVA DATE : 20 MARCH 2017

CERTIFIED BY;

1. SUPERVISOR Assoc. Prof. Dr. Lee Jau Shya Signature

2. CO-SUPERVISOR Dr. Tham Heng Jin

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to my supervisor, Associate Professor Dr. Lee Jau Shya for her continuous guidance, insightful comments, helpful advice and valuable suggestions throughout the period of this research work. I would also sincerely thank my co-supervisor, Dr. Tham Heng Jin for her supervision, comments and advice during the completion of this thesis. My sincere appreciation extends to all the lecturers in Faculty of Food Science and Nutrition for their constructive critisms which widen my knowledge from various perspectives. I am also grateful to all the staff members of the laboratory of Food Science and Nutrition for their co-operation and help during the period of this research work. A special appreciation to all my friends, Tee Ping, Chin Hean, Pei Teng, Jia Qin, Kok Heung, Liyana, Nurul'azah and Roy who always lend me a helping hand and inspired me to stay positive all the time. I would also like to acknowledge Universiti Malaysia Sabah for funding this research project. Last but not least, I would like to express my heartfelt gratitude to my parents and family for their unconditional love, support and encouragement, and also to all who supported my study directly and or indirectly.



ABSTRACT

The present study was designed to determine the effect of osmotic dehydration (OD) on the Terung Asam (Solanum lasiocarpum Dunal) slices. Two major aspects were investigated in this study, the mass transfer kinetics and the optimization of the osmotic process condition. Analytical solution of Fick's law was used to estimate the effective diffusivities of water and solute. Response Surface Methodology (RSM) with Central Composite Design was applied to investigate the influence of OD process temperature $(35 - 55^{\circ}C)$, sucrose concentration (40 - 60% w/w) and immersion time (90 - 210 min) on the antioxidant activities, proximate composition and sensory quality of the dehydrated sample. Results obtained indicated that the water loss (WL) increased with temperature and sucrose concentration. Similarly, solid gain also increased with temperature elevation. The effective moisture diffusivity ranged from $7.59 \times 10^{-10} \text{ m}^2\text{s}^{-1}$ to $1.16 \times 10^{-9} \text{ m}^2\text{s}^{-1}$ and the solid diffusivity from $3.54 \times 10^{-10} \text{ m}^2\text{s}^{-1}$ to $7.85 \times 10^{-10} \text{ m}^2\text{s}^{-1}$. Meanwhile, the activation energy for moisture diffusion varied from 4.27 kJmol⁻¹ to 8.71 kJmol⁻¹, and for solid diffusion from 10.46 kJmol⁻¹ to 14.25 kJmol⁻¹. Results of RSM showed that the antioxidant activities, proximate composition and mineral content of the osmo-dried sample reduced after the OD process, predominantly due to leaching. Nonetheless, osmotic treatment could significantly (p<0.05) improve the sensory quality of the final product. The optimum process parameters obtained for maximum WL and maximum retention of antioxidants. potassium and sensory acceptability were identified at process temperature 38.5°C, sucrose concentration 54.4% and immersion time 90 minutes.





ABSTRAK

PENDEHIDRATAN OSMOSIS TERUNG ASAM (Solanum lasiocarpum Dunal)

Kajian ini dijalankan untuk mengkaji kesan pendehidratan osmosis terhadap Terung Asam (Solanum lasiocarpum Dunal). Penyelesaian Fick's law diguna untuk mendapatkan nilai difusi air dan difusi bahan larut. Metodologi Permukaan Respon dengan Reka Bentuk Komposit Pusat diaplikasi untuk mengkali kesan suhu larutan (35 – 55°C), kepekatan sukrosa (40 - 60% w/w) dan tempoh osmosis (90 – 210 min) terhadap aktiviti antioksida, kandungan proksimat dan kualiti sensori sampel dehidrasi. Keputusan menunjukkan kehilangan air meningkat apabila suhu dan kepekatan larutan meningkat. Pengambilan gula juga meningkat apabila suhu larutan meningkat. Difusi air mencatat nilai dari 7.59 x 10^{10} m²s¹ hingga 1.16 x 10^{9} m²s¹ dan difusi bahan larut dari 3.54 x 10¹⁰ m²5¹ hingga 7.85 x 10¹⁰ m²5¹, manakala nilai tenaga pengaktifan difusi air mencatat nilai 4,27 kJmol¹ hingga 8,71 kJmol¹dan tenaga pengaktifan difusi bahan larut dari 10.46 kJmol¹ hingga 14.25 kJmol¹, Aktiviti antioksida, kandungan proksimat dan mineral bagi sampel Terung Asam didapati menurun selepas proses osmosis, hasil daripada perpindahan nutrien dari sampel ke larutan osmosis. Namun demikian, pendehidratan osmosis dapat meningkatkan kualiti sensori (p<0.05) produk Terung Asam. Keadaan optima proses osmosis bagi kehilangan air, aktiviti antioksida, kandungan kalium serta kualiti sensori yang maksima adalah pada suhu larutan 38.5°C, kepekatan sukrosa 54.4% dan tempoh osmosis 90 minit.

TABLE OF CONTENT

		Page
TITL	E	i
DEC	LARATION	ii
CER	TIFICATION	
ACK	NOWLEDGEMENTS	iv
ABS	TRACT	v
ABS	TRAK	vi
TAB	LE OF CONTENT	vii
LIST	OF TABLES	xi
LIST	OF FIGURES	xiv
LIST	OF ABBREVIATIONS	xvii
LIST	OF APPENDICES	xviii
СНА	PTER 1: INTRODUCTION	1
1.1	Study Background	1
1.2	Importance of Study	3
1.3	Study Objectives	4
CHA	PTER 2: LITERATURE REVIEW	5
2.1	Terung Asam (Solanum lasiocarpum Dunal)	5
2.2	Market of Dehydrated Fruits and Vegetables	7
2.3	Water and Food Quality	8
2.4	Food Preservation by Removal of Water	10
	2.4.1 Quality Changes during Drying	11
2.5	Osmotic Dehydration	12
	2.5.1 Benefits of Osmotic Dehydration	15
	a. Quality Improvement	15
	b. Energy Efficiency	15
	c. Elimination of Chemical Treatment Step	16
	d. Product Stability	16

	2.5.2	Limitations of Osmotic Dehydration	17	
		a. Alteration of the Original Product	17	
		b. Osmotic Solution Management	18	
	2.5.3	Factors Affecting the Mass Transfer during Osmotic	18	
		Dehydration		
		a. Type of Osmotic Agent	18	
		b. Solution Concentration	20	
		c. Process Temperature	22	
		d. Agitation	22	
		e. Osmotic Solution to Food Mass Ratio	23	
		f. Sample Size and Geometry	24	
		g. Osmotic Duration	25	
2.6	Mass ⁻	Transfer Kinetics during Osmotic Dehydration	25	
СНА	PTER 3:	: MATERIALS AND METHODS	29	
3.1	Raw M	Material	29	
3.2	Sampl	ple Preparation		
3.3	Osmo	notic Solution Preparation		
3.4	Mass	Transfer Kinetics during Osmotic Dehydration	30	
	3.4.1	Osmotic Process UNIVERSITI MALAYSIA SABAH	30	
	3.4.2	Determination of Moisture Content	31	
	3.4.3	Determination of Water Loss and Solid Gain	31	
	3.4.4	Determination of Effective Diffusion Coefficients of	32	
		Water and Solute		
	3.4.5	Determination of Activation Energy	33	
3.5	Proces	ss Optimization Using Response Surface Methodology	33	
	3.5.1	Experimental Design	34	
	3.5.2	Osmotic Process	34	
	3.5.3	Hot Air Drying	35	
	3.5.4	Determination of Water Activity	35	
	3.5.5	Colour Measurement	35	
	3.5.6	Hardness Measurement	36	
	3.5.7	Sample Extraction for Antioxidant Tests	36	

	3.5.8 Determination of Total Phenolic Content	36
	3.5.9 Determination of Total Flavonoid Content	37
	3.5.10 Determination of 1,1-diphenyl-2-picrylhydrazyl (DPPH)	37
	Radical Scavenging Activity	
	3.5.11 Determination of Ferric Reducing Antioxidant Power	38
	3.5.12 Determination of Ash	38
	3.5.13 Determination of Protein	39
	3.5.14 Determination of Fat	40
	3.5.15 Determination of Crude Fiber	40
	3.5.16 Determination of Carbohydrate	41
	3.5.17 Determination of Mineral	41
	3.5.18 Sensory Evaluation	42
3.6	Statistical Analysis	42
3.7	Optimization and Verification	43
CHA	PTER 4: RESULTS AND DISCUSSION	45
4.1	Mass Transfer Kinetics during Osmotic Dehydration	45
	4.1.1 Water Loss	45
	4.1.2 Solid Gain	47
	4.1.3 Effective Diffusion Coefficients of Water	48
	4.1.4 Effective Diffusion Coefficients of Solute	49
	4.1.5 Activation Energy	50
4.2	Process Optimization Using Response Surface Methodology	51
	4.2.1 Water Loss	51
	4.2.2 Solid Gain	53
	4.2.3 Colour	57
	4.2.4 Hardness	60
	4.2.5 Total Phenolic Content	62
	4.2.6 Total Flavonoid Content	64
	4.2.7 DPPH Radical Scavenging Activity	65
	4.2.8 Ferric Reducing Antioxidant Power	67
	4.2.9 Ash	69
	4.2.10 Protein	71

	4.2.11 Crude Fat	72
	4.2.12 Crude Fiber	73
	4.2.13 Carbohydrate	75
	4.2.14 Mineral	77
	4.2.15 Sensory Evaluation	82
	a. Colour	84
	b. Surface Dryness	85
	c. Shrinkage	87
	d. Aroma	89
	e. Hardness	91
	f. Sweetness	93
	g. Overall Acceptability	95
4.3	Optimization	97
CHA	PTER 5: CONCLUSION	99
5.1	Conclusion	99
5.2	Recommendations	101
REFE	ERENCES	103
APPI	ENDICES UNIVERSITI MALAYSIA SABAH	118

LIST OF TABLES

		Page
Table 2.1:	The nutrient composition of Terung Asam	7
Table 2.2:	Summary of novel and conventional drying technique for vegetables	11
Table 2.3:	Osmotic dehydrated fruits and vegetables	14
Table 2.4:	Different osmotic agents and their effectiveness	19
Table 3.1:	Experimental runs generated by Central Composite Design for the osmotic dehydration of <i>Terung Asam</i> slices	34
Table 4.1:	The effective diffusion coefficients of water under different process conditions	49
Table 4.2:	The effective diffusion coefficients of solute under different process conditions	50
Table 4.3:	The activation energy for water and solid diffusivity	51
Table 4.4:	Estimated regression coefficients of predicted model for the water loss of osmotic dehydrated <i>Terung</i> Asam	52
Table 4.5:	Estimated regression coefficients of predicted model for the solid gain of osmotic dehydrated <i>Terung</i> Asam	55
Table 4.6:	Estimated regression coefficient of predicted models for the lightness (L^*) of osmotic dehydrated <i>Terung Asam</i>	57
Table 4.7:	Estimated regression coefficient of predicted models for the redness (<i>a*</i>) of osmotic dehydrated <i>Terung Asam</i>	57

Table 4.8:	Estimated regression coefficient of predicted models for the yellowness (<i>b*</i>) of osmotic dehydrated <i>Terung</i> Asam	58
Table 4.9:	Estimated regression coefficient of predicted models for the hardness of osmotic dehydrated <i>Terung Asam</i>	60
Table 4.10:	Estimated regression coefficients of predicted model for the total phenolic content of osmotic dehydrated <i>Terung Asam</i>	62
Table 4.11:	Estimated regression coefficients of predicted model for the total flavonoid content of osmotic dehydrated <i>Terung Asam</i>	64
Table 4.12:	Estimated regression coefficients of predicted model for the IC_{50} of osmotic dehydrated <i>Terung Asam</i>	66
Table 4.13:	Estimated regression coefficients of predicted model for the ferric reducing antioxidant power of osmotic dehydrated <i>Terung Asam</i>	67
Table 4.14:	Estimated regression coefficients of predicted model for the ash content of osmotic dehydrated <i>Terung</i> Asam	69
Table 4.15:	Estimated regression coefficients of predicted model for the protein content of osmotic dehydrated <i>Terung Asam</i>	71
Table 4.16:	Estimated regression coefficients of predicted model for the fat content of osmotic dehydrated <i>Terung Asam</i>	73
Table 4.17:	Estimated regression coefficients of predicted model for the crude fiber content of osmotic dehydrated <i>Terung Asam</i>	74
Table 4.18:	Estimated regression coefficients of predicted model for the carbohydrate content of osmotic dehydrated <i>Terung Asam</i>	76

Table 4.19:	Estimated regression coefficients of predicted model for the potassium content of osmotic dehydrated <i>Terung Asam</i>	78
Table 4.20:	Estimated regression coefficients of predicted model for the calcium content of osmotic dehydrated <i>Terung Asam</i>	78
Table 4.21:	Estimated regression coefficients of predicted model for the magnesium content of osmotic dehydrated <i>Terung Asam</i>	79
Table 4.22:	The mean values (N=7) of sensory attributes for OD treated <i>Terung Asam</i> slices when compared to the control	83
Table 4.23:	Estimated regression coefficients of predicted model for the colour of osmotic dehydrated <i>Terung Asam</i>	84
Table 4.24:	Estimated regression coefficients of predicted model for the surface dryness of osmotic dehydrated <i>Terung</i> <i>Asam</i>	86
Table 4.25:	Estimated regression coefficients of predicted model for the shrinkage of osmotic dehydrated <i>Terung Asam</i>	88
Table 4.26:	Estimated regression coefficients of predicted model for the aroma of osmotic dehydrated <i>Terung Asam</i>	90
Table 4.27:	Estimated regression coefficients of predicted model for the hardness of osmotic dehydrated <i>Terung Asam</i>	92
Table 4.28:	Estimated regression coefficients of predicted model for the sweetness of osmotic dehydrated <i>Terung Asam</i>	94
Table 4.29:	Estimated regression coefficients of predicted model for the overall acceptability of osmotic dehydrated <i>Terung Asam</i>	96
Table 4.30:	The predicted and verification values of responses	98

LIST OF FIGURES

		Page
Figure 2.1:	Ripe Terung Asam	5
Figure 2.2:	Cross section of Terung Asam	6
Fogure 2.3:	Food stability map as a function of water activity	9
Figure 2.4:	Schematic cellular material tissue representation and mass transfer pattern	13
Figure 2.5:	Effect of sucrose concentration on the water loss and solid gain of watermelon slabs (10 mm thickness) at 40°C	21
Figure 2.6:	Effect of slice thickness on the water loss and solid gain of watermelon (immersed in 50°B sucrose at 40°C)	24
Figure 4.1:	Water loss of <i>Terung Asam</i> at different osmotic process conditions	46
Figure 4.2:	Solid gain of <i>Terung Asam</i> at different osmotic A SABAH process conditions	47
Figure 4.3:	Response surface plot for the water loss of <i>Terung Asam</i> during osmotic dehydration (hold at temperature 45°C)	53
Figure 4.4:	Response surface plot for the water loss of <i>Terung Asam</i> during osmotic dehydration (hold at immersion time 150 min)	54
Figure 4.5:	Response surface plot for the solid gain of <i>Terung Asam</i> during osmotic dehydration (hold at sucrose concentration 50%)	56
Figure 4.6:	Response surface plot for the solid gain of <i>Terung Asam</i> during osmotic dehydration (hold at temperature 45°C)	56

Figure 4.7:	Response surface plot for the L^* of osmotic dehydrated <i>Terung Asam</i> (hold at temperature 45°C)	59
Figure 4.8:	Response surface plot for the b^* of osmotic dehydrated <i>Terung Asam</i> (hold at temperature 45°C)	60
Figure 4.9:	Response surface plot for the hardness of osmotic dehydrated <i>Terung Asam</i> (hold at immersion time 150 min)	61
Figure 4.10:	Response surface plot for the TPC of osmotic dehydrated <i>Terung Asam</i> (hold at concentration 50%)	63
Figure 4.11:	Response surface plot for the TFC of osmotic dehydrated <i>Terung Asam</i> (hold at concentration 50%)	65
Figure 4.12:	Response surface plot for the IC ₅₀ of osmotic dehydrated <i>Terung Asam</i> (hold at concentration 50%)	67
Figure 4.13:	Response surface plot for the FRAP of osmotic dehydrated <i>Terung Asam</i> (hold at concentration 50%)	68
Figure 4.14:	Response surface plot for the ash content of osmotic dehydrated <i>Terung Asam</i> (hold at temperature 45°C)	70
Figure 4.15:	Response surface plot for the protein content of osmotic dehydrated <i>Terung Asam</i> (hold at concentration 50%)	72
Figure 4.16:	Response surface plot for the crude fiber content of osmotic dehydrated <i>Terung Asam</i> (hold at immersion time 150 min)	75
Figure 4.17:	Response surface plot for the carbohydrate content of osmotic dehydrated <i>Terung Asam</i> (hold at concentration 50%)	77

Figure 4.18:	Response surface plot for the potassium content of osmotic dehydrated <i>Terung Asam</i> (hold at temperature 45°C)	80
Figure 4.19:	Response surface plot for the calcium content of osmotic dehydrated <i>Terung Asam</i> (hold at temperature 45°C)	80
Figure 4.20:	Response surface plot for the magnesium content of osmotic dehydrated <i>Terung Asam</i> (hold at temperature 45°C)	81
Figure 4.21:	Response surface plot for the colour of osmotic dehydrated <i>Terung Asam</i> slices obtained from sensory evaluation (hold at immersion time 150 min)	85
Figure 4.22:	Response surface plot for the surface dryness of osmotic dehydrated <i>Terung Asam</i> slices obtained from sensory evaluation (hold at temperature 45°C)	87
Figure 4.23:	Response surface plot for the shrinkage of osmotic dehydrated <i>Terung Asam</i> slices obtained from sensory evaluation (hold at temperature 45°C)	89
Figure 4.24:	Response surface plot for the aroma of osmotical SABAH dehydrated <i>Terung Asam</i> slices obtained from sensory evaluation (hold at immersion time 150 min)	91
Figure 4.25:	Response surface plot for the hardness of osmotic dehydrated <i>Terung Asam</i> slices obtained from sensory evaluation (hold at immersion time 150 min)	93
Figure 4.26:	Response surface plot for the sweetness of osmotic dehydrated <i>Terung Asam</i> slices obtained from sensory evaluation (hold at immersion time 150 min)	95
Figure 4.27:	Response surface plot for the overall acceptability of osmotic dehydrated <i>Terung Asam</i> slices obtained from sensory evaluation (hold at immersion time 150 min)	97

LIST OF ABBREVIATIONS

DPPH	100	1,1-diphenyl-2-picrylhydrazyl
FRAP	•	Ferric Reducing Antioxidant Power
GAE		Gallic Acid Equivalent
OD		Osmotic Dehydration
QE	-	Quercetin Equivalent
RDA	-	Recommended Dietary Allowance
RSM	-	Response Surface Methodology
SG	-	Solid Gain
TE	29 ¹¹	Trolox Equivalent
TFC		Total Flavonoid Content
ТРС	Plane	Total Phenolic Content
WL	- A B	Water Loss

LIST OF APPENDIX

		Page
Appendix A	Raw Material Preparation	118
Appendix B	Sensory Evaluation Sheet	119
Appendix C	Sucrose Solution Before and After Osmotic Treatment	120
Appendix D	Physical Appearance of Fresh, Air-dried and Osmotic Dehydrated Samples	121



CHAPTER 1

INTRODUCTION

1.1 Study Background

Native fruits and vegetables have appeared as part of the daily diet of indigenous people in most of the developing countries, likewise Malaysia, which is renowned with its rich biodiversity (Ng, Chye and Mohd Ismail, 2012). In recent years, a number of studies have focused on the native plant species for their possible nutritional and medicinal values as to broaden the diversity of human diets (Flyman and Afolayan, 2007; Afolayan and Jimoh, 2009). For example, a study by Voon and Kueh (1999) on the indigenous fruits and vegetables in Sarawak showed that the nutritional values of these indigenous vegetables are comparable to those commercial species. Maisuthisakul, Suttajit and Pongsawatmanit (2007) also found that the indigenous plants in Thailand contain a substantial amount of polyphenolics, which responsible for the outstanding antioxidant capacity of these plants. These native vegetables not only possess an important socioeconomic impact through their uses in foods, but also in medicines and cultural ceremonies (Flyman and Alfolayan, 2006).

UNIVERSITI MALAYSIA SAE

Among the numerous existed native vegetables, *Terung Asam* (*Solanum lasiocarpum* Dunal) is one of the popular native vegetables. It is originated from Sarawak. This vegetable has a distinct sour taste which makes it as a favorite among the locals (Shariah, 2013). *Terung Asam* is traditionally planted with hill paddy by local farmers but currently, it has been promoted as a cash crop in the state due to the good market prices. In 2011, it was granted with Geographical Indications (GI) branding characterized by consistent high quality and good reputation (Shariah, 2012). Besides that, the Department of Agriculture Sarawak has also made *Terung Asam* as its key focus activity in recent years. Many research works have been carried out to discover the hidden qualities of this native vegetable. Report ascertained that it contains better mineral content compared to its cultivated relatives (Voon and Kueh, 1999).

It is indisputable that apart from the pleasant organoleptic properties and high nutritional value, fresh fruits and vegetables are highly appreciated by consumers for their rich bioactive compounds that directly related to health benefits (Giampieri, Tulipani, Alvarez-Suarez, Quiles, Mezzetti and Battino, 2012). However, these fresh commodities are highly perishable. In order to extend their shelf life and to reduce post-harvest losses, they are frequently preserved by different preservation techniques. Drying is one of the most common and widely used preservation techniques (Fernandes, Gallao and Rodrigues, 2008) by reducing the amount of water available for undesirable chemical and enzymatic reactions as well as microbial proliferation (Gowen, 2012). Nevertheless, most conventional drying methods are energy intensive, coupled with an introduction of unfavorable degradation on the food quality, mainly oxidative damage, browning, loss of flavor and extensive shrinkage as a repercussion of thermal treatment. These have led to the exploration of new minimal processing technique.

Enormous techniques have been explored, among which, osmotic dehydration (OD) has received great attention. OD can be an autonomous process or as a pretreatment step in food processing (Eren and Kaymak-Ertekin, 2007). The process commences when a foodstuff is immersed in a hypertonic aqueous solution. Compared to single drying process, OD is more distinctive as it brings a twofold transformation on the food item, by both a decrease in water content and solute incorporation, resulted from the concentration gradient between the hypertonic solution and the intracellular fluid (Torreggiani, 1993). The reduction of water content extends the shelf life of food and adds convenience to packaging and distribution (Tortoe, 2010). On the other hand, enzymatic and oxidative browning can also be prevented ascribed to the protective action of saccharides (Maltini, Pizzocaro, Torreggiani and Bertolo, 1991). In addition, the water removal process under low temperature can also minimize thermal degradation of food quality as well as reducing the total energy consumption during processing (Konopacka, Jesionkowska, Klewicki and Bonazzi, 2009).

OD is very much beneficial to a wide range of fruits and vegetables, such as tomato (Souza, Medeiros, Magalhães, Rodrigues and Fernandes, 2007), peach (Yadav, Yadav and Jetain, 2012), pumpkin (Mayor, Moreira and Sereno, 2011) and potato (Khin, Zhou and Perera, 2006). It is well noted that both the rate of osmosis and the quality of dehydrated product are affected by a number of factors. These include the concentration of osmotic solution, type of osmotic agents, size and geometry of food, process temperature, agitation rate, product to solution mass ratio and duration of osmotic process (Derossi, Severini and Cassi, 2011). A wide number of scientific papers have focused on the topic of OD, such as the evaluation of the effect of osmotic treatment on the color, flavor (Osorio, Franco, Castano, González-Miret, Heredia and Morales, 2007), chemical and structural changes (Castro-Giraldez, Tylewic, Fito, Dalla Rosa and Fito, 2011) of fruit; determination of the effect of process variables on the mass diffusion (Kowalska and Lenart, 2001; Falade, Igbeka and Ayanwuyi, 2007) and food quality (Heredia, Peinado, Barrera and Andre's Grau, 2009; Atares, Sousa Gallagher and Oliveira, 2011); as well as the optimization of the osmotic process conditions (Singh, Panesar, Nanda and Kennedy, 2010; Jain, Verma, Murdia, Jain and Sharma, 2011). In spite of the numerous studies that have been carried out on this subject, to date, there has been no study on the OD of *Terung* Asam. Hence, this study aimed to develop a healthy and nutritious dehydrated Terung Asam snack through the OD process. In this study, the mass transfer during OD would be investigated as all the mass exchanges may significantly affect the organoleptic and nutritional quality of the dehydrated product (Sablani, Rahman and Al-Sadeiri, 2001). In addition, the effect of different combination treatments on the antioxidant, proximate composition, mineral content and sensory quality of the dehydrated product would also be evaluated, followed by process optimization.

1.2 Importance of Study

Under the key focus activity, many efforts have been made to commercialize and to diversify the use of *Terung Asam* as a means to increase the market demand and rural income. Several value-added products, such as *Terung Asam* juice, ice-creams, jams and cakes have shown good market potential. This is in parallel with the current trend of the demand for agricultural produce, where exotic food products have met higher demand due to the increased consumer familiarity with different cultures. In

3

the meantime, increased health awareness among the consumers has also opened the avenue for minimally processed food. Dehydrated fruits and vegetables, particularly through OD, are gaining popularity due to their pleasant organoleptic properties and high vitamins, minerals, fiber and antioxidant content as a result of concentration during processing. The large amount of dehydrated fruit production not only to fulfill direct consumers' demand, but also to address for the elaboration of bakery, desserts and confectionary products (Megias-Perez, Gambao-Santos, Soria, Villamiel and Montilla, 2014). Based on the above perspectives, it is evident that *Terung Asam* has a great potential to be further developed into a healthy dehydrated product with potential commercial value.

The present study shows a noteworthy contribution towards the development of new product from a nutritious indigenous plant species, which favorably meets the present market demand for healthy, natural, exotic and convenient food. The explorations of native plant species not only bring about the discovery of new sources of functional nutrients, but also broaden the diversity of the human diet. On the other hand, this study may also enrich scientific knowledge on OD and its application. Investigation of the mass transfer during OD and evaluation of the product quality not only allow us to have a deeper understanding of the operational design, but it also leads to insights into the possible mechanism of changes in food, which in turn leads to product improvement. On the other hand, process optimization enables us to identify the optimal process conditions that result in end product with high nutritional and sensory quality.

1.3 Study Objectives

The objectives of this study are:

- a. To investigate the mass transfer kinetics during the OD of Terung Asam.
- b. To evaluate the effect of OD process temperature, sucrose concentration and immersion time on the water loss, solid gain, colour, firmness, antioxidant, proximate composition, mineral content and sensory quality of the dehydrated *Terung Asam*.
- c. To optimize the OD process conditions for the maximum retention of antioxidant, mineral and sensory quality of the dehydrated *Terung Asam*.

CHAPTER 2

LITERATURE REVIEW

2.1 Terung Asam (Solanum lasiocarpum Dunal)

Terung Asam or scientifically known as *Solanum lasiocarpum* Dunal is a popular native vegetable in Sarawak. *Terung Asam* is also known as *Terung Dayak* or *Terung Iban* by the local communities. In Brunei, it is called as *Terung Pasai* and in Indonesia, Thailand and Myanmar, it is known as *Cung Bulu, Muuk* and *Sinkade* respectively. *Terung Asam* is grouped under the *Solanaceae* family. It is very similar to *Terung Bulu*, which is more common in West Malaysia.

Terung Asam is a thorny and woody perennial herb with 1.0 to 2.5 m tall and is densely pubescent throughout the plant. Both the erect and spreading shoots of the plant will bear large green leaves with an alternate arrangement. The inflorescence on the other hand consists of two to six small white flowers with starlike petal arrangement. It will develop into a round to oval sourish fruit. Immature fruit is green in colour and it will turn yellow when ripen (Figure 2.1) (Shariah, 2013). The cross section of ripen *Terung Asam* fruit is shown in Figure 2.2.



Figure 2.1: Ripe *Terung Asam*.