OSMOTIC DEHYDRATION OF *TERUNG ASAM* (*Solanum lasiocarpum* Dunal)

CHIU MOI THIN

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CHIU MOI THIN
MN1211006T

(Tandatangan Pustakawan)

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Penyelia

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Chiu Moi Thin
MN1211006T

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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** Signature
   Assoc. Prof. Dr. Lee Jau Shya

2. **CO-SUPERVISOR**
   Dr. Tham Heng Jin

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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^{o}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 x 10^{-10} m^2s^{-1} to 1.16 x 10^{-9} m^2s^{-1} and the solid diffusivity from 3.54 x 10^{-10} m^2s^{-1} to 7.85 x 10^{-10} m^2s^{-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^{o}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 mengkaji 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* 7.59×10^{-10} m^2s^{-1} *hingga* 1.16×10^{-9} m^2s^{-1} *dan difusi bahan larut dari* 3.54×10^{-10} m^2s^{-1} *hingga* 7.85×10^{-10} m^2s^{-1}*, manakala nilai tenaga pengaktifan difusi air mencatat nilai 4.27* $kJmol^{-1}$ *hingga 8.71* $kJmol^{-1}$*dan tenaga pengaktifan difusi bahan larut dari 10.46* $kJmol^{-1}$ *hingga 14.25* $kJmol^{-1}$*. 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.*

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LIST OF ABBREVIATIONS

DPPH	-	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	-	Trolox Equivalent
TFC	-	Total Flavonoid Content
TPC	-	Total Phenolic Content
WL	-	Water Loss

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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).

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 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 star-like 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.

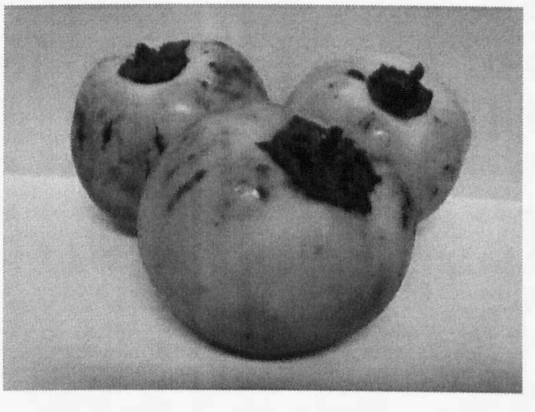

Figure 2.1: Ripe *Terung Asam*.