UNIVERSITI PUTRA MALAYSIA

EFFECTS OF DRYING METHODS ON NUTRITIONAL AND ANTIOXIDANT PROPERTIES OF TEA [Camellia sinensis (L.) Kuntze] LEAVES AND DABAI (Canarium odontophyllum Miq.) FRUITS

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By

AHMAD SYAZRIN BIN ROSLAN

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January 2019

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Hot air drying is the most commonly used method of food presevation but the heat from the process usually destroys their beneficial antioxidant compounds. Alternative methods to hot air drying includes superheated steam drying and freeze drying. Therefore, the objective of this study was to investigate and compare the effects of drying methods on the nutritional and antioxidant properties of tea [*Camellia sinensis* (L.) Kuntze] leaves and *dabai* (*Canarium odontophyllum* Miq.) fruits.

Nutrient analysis results for the tea leaves showed significant difference ($p<0.05$) in the nutrient content obtained from each drying method. Freeze dried tea leaves (FDT) had the highest percentage of moisture (78.35 ± 0.10 %) and fat content (4.91 ± 0.57 %), while superheated steam dried tea leaves (SDT) had the highest percentage of ash (6.05 ± 0.01 %), total dietary fibre (38.29 ± 1.49 %), and total available carbohydrate (1.63 ± 0.13 %). Oven dried tea leaves (ODT) had the highest percentage of protein content (21.24 ± 0.62 %). Nutrient analysis results for the *dabai* fruit showed significant difference ($p<0.05$) in the nutrient content obtained from each drying method. Oven dried *dabai* (ODD) showed the highest percentage of ash (4.70 ± 0.07 %), protein (6.8 ± 0.12 %), and fat content (38.79 ± 1.19 %). Freeze dried *dabai* (FDD) showed the highest percentage of moisture content (60.78 ± 0.08 %) and total available carbohydrate (3.94 ± 0.01 %), while superheated steam dried *dabai* (SDD) had the highest percentage of total dietary fibre (55.87 ± 0.13 %).

The highest antioxidant capacity, total phenolic, and total flavonoid content were exhibited by FDT and FDD with significant difference ($p<0.05$). High Performance Liquid Chromatography (HPLC) identified 7 compounds from the tea leaves, and 5 compounds from the *dabai* fruit. FDT and FDD showed significantly higher ($p<0.05$) content of these compounds compared to superheated steam and oven dried samples.

Significantly ($p<0.05$), Gallic acid had the highest concentration in both samples (5.40 ± 0.02 mg per g DW in FDT, 3.42 ± 0.02 mg per g DW in FDD).

At different drying temperatures, SDT dried at 125°C showed significantly higher ($p<0.05$) antioxidant properties than ODT. ODT dried at 150°C and 175°C showed significantly higher ($p<0.05$) antioxidant properties than SDT. ODD dried at 125°C showed significantly higher ($p<0.05$) antioxidant properties than SDD. However, no significant differences ($p>0.05$) were observed in the antioxidant properties of the fruits dried using both methods at 150°C and 175°C. At different drying durations, SDT dried for 60, 75, and 90 minutes showed significantly higher ($p<0.05$) antioxidant properties than ODT. In contrast, ODD dried for 60, 75, and 90 minutes showed significantly higher ($p<0.05$) antioxidant properties than SDD.

Overall, FDT and FDD retained the highest antioxidant properties among the samples dried using the three methods. Superheated steam drying method is a better choice than oven drying method for drying tea leaves at varying drying time. In contrast, oven drying method is more suitable for drying the *dabai* fruit at both varying drying temperature and time.

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

KESAN KAEDAH PENGERINGAN KE ATAS CIRI-CIRI PEMAKANAN DAN ANTIOKSIDAN DAUN TEH [*Camellia sinensis* (L.) Kuntze] DAN BUAH DABAI (*Canarium odontophyllum* Miq.)

Oleh

AHMAD SYAZRIN BIN ROSLAN

Januari 2019

Pengerusi : Prof. Amin bin Ismail, Ph.D.
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Kaedah pengeringan udara panas merupakan kaedah yang paling biasa digunakan tetapi haba daripada kaedah ini kebiasaannya akan memusnahkan kandungan antioksidan pada bahagian tumbuhan yang dikeringkan. Kaedah alternatif kepada pengeringan udara panas termasuklah pengeringan wap panasdan pengeringan beku. Justeru, objektif kajian ini adalah untuk mengkaji dan membandingkan kesan beberapa kaedah pengeringan ke atas ciri-ciri pemakanan dan antioksidan pada daun teh (*Camellia sinensis* (L.) Kuntze) dan buah dabai (*Canarium odontophyllum* Miq.). Sampel kajian telah dikeringkan menggunakan tiga kaedah pengeringan yang berbeza (pengeringan beku, pengeringan ketuhar udara panas, pengeringan wap panas) sebelum ciri-ciri pemakanan serta antioksidan mereka dibandingkan.

Hasil analisis nutrien untuk daun teh menunjukkan perbezaan ketara ($p<0.05$) bagi kandungan nutrien yang diperoleh daripada setiap kaedah pengeringan. Daun yang dikeringkan menggunakan kaedah pengeringan beku (FDT) mempunyai peratusan kelembapan tertinggi (78.35 ± 0.10 %) dan kandungan lemak tertinggi (4.91 ± 0.58 %) manakala daun teh yang dikeringkan menggunakan kaedah pengeringan wap panas (SDT) mempunyai peratusan abu tertinggi (6.05 ± 0.01 %), serat makanan tertinggi (38.29 ± 1.49 %)dan peratusan karbohidrat bebas tertinggi (1.63 ± 0.13 %). Daun teh yang dikeringkan menggunakan kaedah pengeringan ketuhar udara panas (ODT) pula mempunyai kandungan protein tertinggi (21.24 ± 0.62 %). Hasil analisis nutrien untuk buah dabai juga menunjukkan perbezaan ketara ($p<0.05$) bagi kandungan nutrien yang diperoleh daripada setiap kaedah pengeringan. Sampel buah dabai yang dikeringkan menggunakan kaedah pengeringan ketuhar udara panas (ODD) mempunyai peratusan kandungan abu (4.70 ± 0.07 %), protein (6.8 ± 0.12 %), dan lemak (38.79 ± 1.19 %) tertinggi. Buah dabai yang dikeringkan melalui kaedah pengeringan beku (FDD) mempunyai peratusan kelembapan (60.78 ± 0.08 %) dan karbohidrat bebas (3.94 ± 0.01 %) tertinggi, manakala buah yang dikeringkan menggunakan kaedah pengeringan wap panas (SDD) mempunyai peratusan serat makanan tertinggi (55.87 ± 0.13 %).

Kapasiti antioksidan, kandungan fenolik, dan kandungan flavonoid tertinggi diperoleh daripada FDT dan FDD dengan perbezaan ketara ($p<0.05$). Analisis Kromatografi Cecair Prestasi Tinggi (HPLC) telah mengenal pasti 7 sebatian daripada daun the, dan 5 sebatian daripada buah dabai. FDT dan FDD telah menunjukkan kandungan tertinggi sebatian-sebatian tersebut berbanding kaedah pengeringan ketuhar udara panas dan pengeringan wap panas. Asid galik menunjukkan kandungan tertinggi yang ketara dalam kedua-dua sampel (5.40 ± 0.02 mg per g DW bagi FDT, 3.42 ± 0.02 mg per g DW bagi FDD).

Dalam ujian suhu pengeringan yang berbeza-beza, SDT yang dikeringkan pada suhu 125 °C menunjukkan potensi antioksidan yang lebih tinggi ($p<0.05$) berbanding ODT. Walaubagaimanapun, ODT yang dikeringkan pada suhu 150 °C dan 175 °C menunjukkan potensi antioksidan yang lebih tinggi ($p<0.05$) daripada SDT. ODD yang dikeringkan pada suhu 125 °C juga menunjukkan potensi antioksidan yang lebih tinggi ($p<0.05$) berbanding SDD. Walaubagaimanapun, tiada perbezaan ketara ($p>0.05$) antara kedua-dua kaedah pengeringan tersebut dari segi potensi antioksidan pada buah yang dikeringkan pada suhu 150 °C dan 175 °C. Dalam ujian tempoh pengeringan yang berbeza-beza, SDT yang dikeringkan selama 60, 75, dan 90 minit menunjukkan potensi antioksidan yang lebih tinggi ($p<0.05$) berbanding ODT. Sebaliknya, ODD yang dikeringkan selama 60, 75, dan 90 minit menunjukkan potensi antioksidan yang lebih tinggi ($p<0.05$) daripada SDD.

Secara keseluruhannya, FDT dan FDD menunjukkan potensi antioksidan tertinggi di antara sampel yang dikeringkan menggunakan tiga kaedah tersebut. Kaedah pengeringan wap panas lebih sesuai untuk mengeringkan daun teh pada tempoh pengeringan yang berbeza-beza, manakala kaedah pengeringan ketuhar udara panas lebih sesuai untuk mengeringkan buah dabai pada suhu dan tempoh pengeringan yang berbeza-beza.

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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 are as follow:

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LIST OF ABBREVIATIONS

AAPH	Azo-bis(2-amidinopropane) dihydrochloride
DPPH	2,2-Diphenylpicrylhydrazil
DW	Dry Weight
FDD	Freeze dried *dabai*
FDT	Freeze dried tea
FRAP	Ferric reducing activity of plasma
GAE	Gallic Acid Equivalent
ODD	Oven dried *dabai*
ODT	Oven dried tea
ORAC	Oxygen radical absorbance capacity
PGR	Pyrogallol Red
QE	Quercetin Equivalent
SDD	Superheated steam dried *dabai*
SDT	Superheated steam dried tea
SHS	Superheated Steam
TDF	Total Dietary Fibre
TE	TROLOX Equivalent
TFC	Total Flavonoid Content
TPC	Total Phenolic Content
TPTZ	2,4,6-Tris(2-pyridyl)-s-triazine
TROLOX	6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Polyphenols are mainly natural, but also synthetic or semi-synthetic, organic chemicals characterized by the presence of large multiples of phenol structural units. It contributes to antioxidant properties of fruit, vegetables, legumes and cereals (Medina, 2011). Some polyphenols are specific to particular foods (flavanones in citrus fruit, isoflavones in soy, phloridzin in apples); whereas others, such as quercetin, are found in fruit, vegetables, cereals, leguminous plants, tea, and wine. These phytochemicals have various preventive and disease fighting properties due to their antioxidant capabilities (Medina, 2011). Several studies have shown positive association between polyphenols and diseases (Singh et al., 2008; Parkar et al., 2008; & Medina-Remón et al., 2014). Singh et al. (2008) showed that olive leaf polyphenols inhibited platelet activation in healthy, non-smoking males. A study by Parkar et al. (2008) showed a positive association between fruit polyphenols and the colonic microflora in the human gut. In addition, a randomized trial by Medina-Remón et al. (2014) showed a positive correlation between diet rich in polyphenols and reduction of systolic and diastolic blood pressure in subjects with high cardiovascular risk.

Polyphenols can be found in various parts of a plant, from the bark to the fruit. The amount and type of polyphenols present in these parts and among plant species are different. There are many plant species reported to contain considerably high content of polyphenols such as blueberries (*Vaccinium spp.*), pomegranate (*Punica granatum*), and tea (*Camellia sinensis*).*Camellia sinensis* (L.) Kuntze is the species of plant whose leaves and leaf buds are used to produce the popular tea beverage. It is native to East, South and Southeast Asia, but cultivated across the world today, in tropical and subtropical regions.The health benefits of tea and tea extracts have been well documented, especially with respect to chemo-preventive effects on cancers, cardiovascular, and neurodegenerative diseases (Wang et al., 2007). Green tea, prepared from *Camellia sinensis*, is a widely consumed beverage throughout the world second only to water (Coyle et al., 2008). Green tea contains an abundance of polyphenols with antioxidative capacities (Wang et al., 2007) and the major polyphenols present are from the catechin groups, primarily epigallocatechin-3-gallate (Coyle et al., 2008). Other types of tea, such as black and Oolong tea have different types and amount of polyphenols in them as a result of fermentation and processing of the tea leaves. Fermentation produces tea with a stronger flavour and catalyses oxidation and polymerization of catechins & gallocatechins to other polyphenols such as theaflavins & thearubigens (Yuan et al., 2011). Due to its low cost, low cytotoxicity and widespread availability, tea has enormous potential as a chemo-preventive agent for a variety of human diseases. In a large cohort study in the Netherlands by de Koning Gans et al. (2010), 37,514 participants were prospectively followed for 13 years with end points of cardiovascular disease morbidity and mortality. In the study, consuming tea, mainly black tea, around 3 to 6 cups daily was associated with a reduced risk of cardiovascular disease mortality. Another study by Mineharu et al.

(2011) also reported a strong relationship between consumption of more than 6 cups of green tea per day with a lower risk of mortality from cardiovascular disease.

Other than the leaf, fruits are another part of a plant regularly consumed and rich with polyphenols and antioxidant compounds. In addition, certain fruits, such as olive, also contains polyphenol-rich oil that has potential health benefits, such as reducing risk of developing cardiovascular disease (Castañer et al., 2011; Farràs et al., 2013), when consumed. *Canarium odontophyllum* Miq. is a fruit-bearing tree of the genus *Canarium* in the family *Burseraceae*. It is a native of Sarawak and its fruit, known as *dabai* in Malay, is a prized seasonal delicacy in Sarawak. The *dabai* fruit is a potential source of nutrients and antioxidant compounds (Faridah Hanim et al., 2010). Faridah Hanim et al. (2010) found out that the skin of the fruit exhibited the highest level of antioxidant activity compared to other parts of the fruit, while Khoo et al. (2013) detected six anthocyanins in the defatted *dabai* peel, with the peel having the highest antioxidant capacities and oxidative stress inhibition effect. In a study by Nurul Nadirah et al. (2014), the fruit extracts were shown to have hypocholesterolaemic properties, a short-term glucose-lowering effect and improved the lipid profile when tested on obese diabetic rats. Also, carotenoids are present in the fruit and the extract showed good antioxidant capacities (Prasad et al., 2010).

Although fruits are highly nutritious and beneficial to health, it is quite challenging in terms of preserving its nutritional content and freshness. Without preservation techniques, the shelf life of fruits can barely reach a week. Food processing can provide a longer shelf life to the fruits but it also reduces the quality of the end product in terms of nutritional content and physical characteristics. The most common food preservation technique is drying using hot air. Dried fruits can last much longer compared to fresh ones but the heat from the drying process usually destroys the antioxidant compounds in the fruit. Alternatively, there are other methods of drying that can be used instead of conventional hot air drying.

Superheated steam (SHS) drying uses superheated steam instead of hot air or combustion gases in a direct dryer. SHS drying have been applied on a variety of food more regularly these days as no oxidative reactions due to the presence of oxygen can occur, hence preserving the color and nutrients in food. Nathakaranakule et al. (2007) have found out that a combination of SHS drying and heat pump drying is suitable for dying chicken meat used in ready-to-eat noodles. Another study by Zzaman et al. (2013) have found out that SHS roasting method can improve the quality of cocoa beans as higher total phenol and antioxidant properties are preserved compared to conventional method. Also, according to Primo-Martin and van Deventer (2011), the use of SHS is suitable as an alternative to pre-frying in oil, to decrease the oil content of deep-fried battered foods while obtaining crispy crusts. As a new method for food processing, SHS drying is more convenient and flexible than conventional method because higher level of polyphenols and antioxidant properties are preserved, and at the same time, the favorable characteristics of food in terms of antioxidant properties are maintained (Zzaman et al., 2013).

In this study, the SHS drying was used for comparison against freeze drying and conventional oven drying based on the amount of antioxidants present in the samples after subjected to each drying methods. Hence, the most ideal drying method for preserving the highest amount of antioxidants in the samples can be determined based on the results obtained in this study.

1.2 Problem Statements

Southeast Asia possesses a wealth and variety of commercial tropical fruits such as durian, rambutan, mangosteen, mango and banana. In addition to a wide selection of commercialized fruits, there are also underutilized fruits that still grow in the wild or in a semi-cultivated state (Faridah Hanim et al., 2010), mainly used for local consumption and medicinal purposes (Khoo et al., 2010). Malaysia has a rich diversity of tropical fruits which includes common, ornamental, rare, wild and highland fruits, but most of the indigenous fruits are considered to be underutilized (Khoo et al., 2010). Hence, research is needed to be done to investigate the health-promoting compounds present in these underutilized Malaysian fruits.

Despite their health-promoting potentials, fruits and vegetables are easily perishable and have a short shelf life which limits their availability. Conventional drying process using heated air oven is commonly used as a method for preserving food products but often affects the nutritional value, taste, and texture. The heat from the drying process can oxidize and destroy heat-sensitive polyphenols (Kaur & Singh, 2014; Nistor et al., 2017), causing the product to lose a majority of its antioxidant content and potential health benefits (Hwang & Thi, 2014; Li et al., 2017). The super-heated steam drying is said to be potentially better at preserving the nutritional value of the food (Somjai et al., 2009; Rumruaytum et al., 2014). Several researches focusing on the quality of treated agricultural products have reported better quality using superheated steam instead of hot air drying treatment (Zzaman, Bhat, & Tajul, 2013). Hence, the method has been seriously considered to be used in the food processing industry (van Deventer & Heijmans, 2007).

Also, spoilage of product is one of the main problems when exporting fruits and vegetables. The *dabai* fruit is no exception to this problem as it has a high fat content and easily deteriorates in a short period of time. Ding(2011), stated that the shelf life of *dabai* fruit is about 3 days at 27 °C, at which the skin of hard fruit will wrinkle. Heat is the main concern in handling *dabai* fruit and freshly harvested fruit must be kept in well-ventilated baskets and away from the sun to prevent heat from being trapped in the basket and causes spoilage (Ding, 2011). Conventional drying process also causes the oil and fat in the fruit to oxidize and become rancid faster. Hence, a proper method of preserving the fruit for a longer time is still unavailable.

Tea is one of the most popular and widely consumed beverages in the world with more than thirty countries worldwide producing tea for consumption (Laskar & Thappa, 2015). However, there are several challenges faced by tea producer nowadays. For example, Laskar and Thappa (2018) reported that materials and technology

significantly influence the tea production in Assam, India. As the cost for materials such as fertilizers, electricity, transportation and packaging increases day by day, the overall cost of tea production also increases (Laskar & Thappa, 2015). In addition, some tea production factories still rely on old machineries, which are time consuming, and not energy-efficient (Laskar & Thappa, 2015).

1.3 Significance of the Study

The *dabai* (*Canarium odontophyllum* Miq.) is a fruit endemic to the island of Borneo. Eventhough it is quite common in states of East Malaysia (Sabah and Sarawak), it rarely enters the market in Malaysia. A reason for this is because the fruit easily deteriorate or spoiled in a short time. Fats and oils, which are present in high amount in the fruit, easily oxidize and become rancid, eventually spoiling the fruit and making it hard to be exported out. It is possible the super-heated steam method can be used to preserve the nutritional value and quality of the fruit. In addition, by preventing the fruit's deterioration, longer storage duration can be achieved for marketing and research purposes. In addition, this may open a new opportunity in commercializing this fruit, which possess health-promoting properties, in the market. It also will open new grounds for further research on understanding the fruit's potential benefits to the community.

Tea is well known for its antioxidant properties and is a commonly consumed beverage in Malaysia. However, some of these antioxidants are lost during tea leaves production. Therefore, it would be beneficial to the industry if the antioxidants in tea can be retained better during processing through an alternative method. This way, the food industry can produce tea and tea-based products with significant antioxidant content.

Each part of a plant contains varying amount and types of compounds which may react differently when drying process is applied to them. For example, the *dabai* fruit is rich in fat, whereas the tea leaf that has a low fat content. In contrast, tea leaves have a higher protein content than *dabai* fruit. Hence, it would be interesting to observe whether the presence of compounds such as fat and protein, either in low or high amount, could have an effect on the samples during the drying process.

The results from this study can be used as evidence to support the use of super-heated steam drying as an alternative to conventional oven drying in terms of faster drying rate and lower energy consumption. This in turn can reduce the overall production cost of food by reducing the energy and time consumed during the manufacturing process. It also can be used as a reference for future studies involving super-heated steam drying. Also, if the nutritional value of the food can be preserved better through the super-heated steam drying, more nutritious food product can be developed for the market which would positively affect the economy's growth.

1.4 Objectives

1.4.1 General Objectives

To study the effect of drying methods on the nutritional and antioxidant properties of *Camellia sinensis* (L.) Kuntze leaves and *Canarium odontophyllum* Miq. fruits.

1.4.2 Specific Objectives

1. To compare the nutritional and antioxidant properties of *Camellia sinensis* (L.) Kuntze leaves and *Canarium odontophyllum* Miq. fruits after undergoing freeze drying, conventional oven drying and super-heated steam drying.

2. To identify and compare selected compounds in the samples after undergoing freeze drying, conventional oven drying and super-heated steam drying using HPLC.

3. To compare the effect of drying temperature and time on the antioxidant properties of samples undergoing conventional oven drying with super-heated steam drying.

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LIST OF PUBLICATIONS

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