COMPARISON OF TWO DIFFERENT DRYING METHODS ON PHYTOCHEMICAL CONTENT, ANTIOXIDANT PROPERTIES, AND ANTI-INFLAMMATORY ACTIVITY OF *Melicope pteleifolia*

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ABSTRACT

Melicope pteleifolia (Champ. ex Benth) T.G.Hartley, which is a member of the Rutaceae family and locally known as *tenggek burung*, is one of the most common medicinal herbs found in Peninsular Malaysia and other Asian countries. This herbal plant contains various nutrients that have been practiced by the local population. The different drying methods were studied because they have an important effect on plant compounds and lead to the best drying method for an herbal industry. To evaluate the effect of drying methods on *Melicope pteleifolia* quality, the content of bioactive compounds, antioxidant activity, and anti-inflammatory activity of *M. pteleifolia* dried leaves through oven drying (40˚C) and vacuum drying (60˚C/30 mbar, 60˚C/70 mbar, 75˚C/30 mbar, and 75˚C/70 mbar) were compared. Vacuum drying (60˚C/30 mbar, 60˚C/70 mbar, 75˚C/30 mbar, and 75˚C/70 mbar) showed a significant difference ($p < 0.05$) in phytochemical content, antioxidant activity, and anti-inflammatory activity. Meanwhile, the increase in temperature of vacuum drying potent in increment of the phytochemical compound of *M. pteleifolia* with significant difference ($p < 0.05$) was evidenced with 166.61 mg GAE/g, 35.52 mg QE/g, 168.46 mg TAE/g, and 95.67%, respectively to TPC, TFC, TTC, and TTeC, although lower in TSC (81.73%). However, the lower temperature resulted in high antioxidant with significant difference in DPPH (IC_{50} 18.39), ABTS (IC_{50} 38.42), FRAP (192.99 mg TEAC/g), and anti-inflammatory activity at 250 µg/ml (96.73%). This study provides evidence on how drying processes affect the content and activity of *M. pteleifolia* bioactive compounds. The selection of a specific drying method for *'tenggek burung'* leaves can now be chosen based on the intended application such as the preparation of functional foods as well as nutraceutical and pharmaceutical products enriched in bioactive compounds, antioxidant capacity, and anti-inflammatory activity.

ABSTRAK

Melicope pteleifolia (Champ. ex Benth) T.G.Hartley yang merupakan famili Rutaceae dan dikenali sebagai tenggek burung adalah salah satu herba perubatan yang paling biasa ditemui di Semenanjung Malaysia dan negara-negara Asia yang lain. Tumbuhan herba ini mengandungi pelbagai nutrien yang telah diamalkan oleh penduduk tempatan. Kaedah pengeringan yang berbeza telah dikaji kerana ia mempunyai kesan penting terhadap sebatian tumbuhan dan membawa kepada kaedah pengeringan terbaik untuk industri herba. Untuk menilai kesan kaedah pengeringan terhadap kualiti *Melicope pteleifolia*, kandungan sebatian bioaktif, aktiviti antioksidan dan aktiviti anti-radang daun kering *M. pteleifolia* melalui pengeringan ketuhar (40˚C) dan pengeringan vakum (60°C/30 mbar, 60°C/70 mbar, 75°C/30 mbar dan 75°C/70 mbar) dibandingkan. Pengeringan vakum (60°C/30 mbar, 60°C/70 mbar, 75°C/30 mbar dan 75°C/70 mbar) menunjukkan perbezaan ketara ($p < 0.05$) dalam kandungan fitokimia, aktiviti antioksidan, dan aktiviti anti-radang. Dalam pada itu, peningkatan suhu pengeringan vakum yang kuat dalam peningkatan sebatian fitokimia *M. Pteleifolia* menunjukkan perbezaan ketara ($p < 0.05$) dibuktikan dengan 166.61 mg GAE/g, 35.52 mg QE/g, 168.46 mg TAE/g dan 95.67%, masing-masing kepada TPC, TFC, TTC, dan TTeC, walaupun lebih rendah dalam TSC (81.73%). Walau bagaimanapun, suhu yang lebih rendah menghasilkan antioksidan yang tinggi dengan perbezaan ketara dalam DPPH (IC50 18.39), ABTS (IC50 38.42), FRAP (192.99 mg TEAC/g) dan aktiviti anti-radang pada 250 µg/ml (96.73%). Kajian ini memberikan bukti bagaimana proses pengeringan mempengaruhi kandungan dan aktiviti sebatian bioaktif *M. pteleifolia*. Pemilihan kaedah pengeringan khusus untuk daun ‘tenggek burung’ kini boleh dipilih berdasarkan aplikasi yang ditetapkan seperti penyediaan makanan berfungsi serta produk nutraseutikal dan farmaseutikal yang diperkaya dengan sebatian bioaktif, kapasiti antioksidan dan aktiviti anti-radang.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	-	Percentage
˚C	-	Degree Celsius
c	-	Concentration
IC_{50}	-	Concentration at 50% inhibition
g	-	Grams
m	-	Mass
µL	-	Microlitre
min	-	Minute
mL	-	Millilitre
mg	-	Milligram
mM	-	Millimolar
min	-	Minute
mbar	-	Millibar
M	-	Molarity
nm	-	Nanometre
rpm	-	Revolutions per minute
Na_2CO_3	-	Sodium carbonate
V	-	Volume
v/v	-	Volume/volume
w/v	-	Weight/volume
ABTS	-	2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid
ANOVA	-	Analysis of variance
DMSO	-	Dimethyl sulfoxide
FRAP	-	Ferric reducing antioxidant power
GAE	-	Gallic Acid Equivalent
HPODE	-	Hydroperoxyoctadecadienoic acid
LOX	-	Lipoxygenase

NDGA	-	Nordihydroguaiaretic acid
QE	-	Quercetin Equivalent
SD	-	Standard Deviation
SEM	-	Standard Error of Mean
TAE	-	Tannic Acid Equivalent
TFC	-	Total Flavonoid Content
TPC	-	Total Phenolic Content
TSC	-	Total Saponin Content
TTC	-	Total Tannin Content
TTeC	-	Total Terpenoid Content
UV-Vis	-	Ultraviolet-visible

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CHAPTER 1

INTRODUCTION

1.1 Research background

Melicope pteleifolia, also known as ‘tenggek burung’ is one of the most widely distributed medicinal herbs and a popular traditional fresh vegetable that belongs to the Rutaceae family in Malaysia especially in Peninsular Malaysia, as well as several other Asian countries (Mahadi *et al*., 2016). Young leaves and twigs are eaten fresh with rice and are said to be useful for itching and wound treatment. The roots and bark are used as an appetizer, digestive, and emmenagogue (Abas *et al*., 2010). Furthermore, some research found that the fresh leaves have a slightly crunchy texture and a mildly pungent lemon-lime aroma, which makes them popular in vegetable salads. *Melicope pteleifolia* has traditionally been used to treat a wide range of conditions, including stomach aches, wounds, fever, and itches (Kabir *et al*., 2017). Pharmacologically, many studies have proven that the leaf extracts of this medicinal herb have bioactive properties. In fact, leaf extracts have been shown to have anti-inflammatory, antipyretic, analgesic, antioxidant, and antimicrobial properties (Mahadi *et al*., 2016). For instance, Zareen *et al*., (2013) reported that the leaves possess the antibacterial, fungicidal, antioxidant, and inhibitory activities. As such, the benefits from the bioactive compounds of *M. pteleifolia* can be obtained through the leaf extraction method as has been carried out by other researchers.

Sample drying is important before proceeding with sample extraction because it affects the amount of yield and chemical compound extractions needed. Dried samples will produce more phenolic compounds than fresh samples. As evidenced by Fatariah, Zulkhairuazha, & Rosli (2014), *Benincasa hispida* drying and heating extract recorded the highest gallic acid concentration of 0.272 mg/100 g, followed by low heating extract (0.050 mg/100 g) and fresh extract (0.036 mg/100 g). At the cellular level, the phenolic compounds are located in the vacuoles and are separated from oxidative enzymes in an intact fruit (Sulaiman *et al*., 2011). This structure collapses during the drying process, releasing more phenolic constituents as well as oxidative enzymes that may destroy the phenolic compounds (Fatariah *et al*., 2014). Furthermore, the drying process is essential in ensuring high phytochemical recovery during extraction. Drying provides opportunities for extending shelf-life, quality preservation, product enhancement, simplifying handling, storage, and transport, besides acting as a pre-treatment for subsequent processes (Kyriakopoulou *et al*., 2013). Many high-tech drying techniques have been developed in recent years, offering significant benefits such as reduced drying time, energy saving, low cost, and high-quality end products. Vacuum drying, for instance, is a drying technique 0-used to dry a variety of products while retaining colour and vitamin content. According to Alibas (2007), low processing temperature, less energy consumption and increased energy conservation, enhanced drying times, and, in some cases, less product shrinkage are all important characteristics of vacuum drying. Since no research has used the drying method for *M. pteleifolia* in particular, this study was conducted to see the effect of drying conditions by vacuum oven on the bioactivity compound of the plant.

The first stage in separating preferred natural products from raw materials is extraction, which refers to acquiring pure extracts. Generations of indigenous practitioners have used the plant’s crude material or pure compounds to treat a variety of ailments thus, the study of medicinal plants often begins with extraction procedures, which are critical to the extraction outcomes and subsequent assays (Stéphane *et al*., 2021). According to the extraction principle, extraction methods include solvent extraction, distillation, pressing, and sublimation. The most common method is solvent extraction (Zhang, Lin, & Ye, 2018). Methanol and ethanol have been widely used to extract antioxidant compounds from a variety of plants and plant-based foods, including plum, strawberry, pomegranate, broccoli, sage, rosemary, rice bran, sumac, wheat grain and bran, mango seed kernel, citrus peel, and a variety of other fruit peels (Sultana, Anwar, & Ashraf, 2009). Similarly, *M. pteleifolia* was mostly found to be great in extraction yield by using methanol as solvent extraction (Mahadi *et al*., 2019).

Phytochemicals are important nutrients found in medicinal plants that are not necessary for normal human body function but are active and have beneficial effects on health or disease treatment. Süntar & Yakıncı (2020) reported that plants contain phytochemicals, and their consumption has been shown to improve health. Thus, preclinical, clinical, and epidemiological research suggests that phytochemicals, due to their antioxidant and anti-inflammatory properties, may be useful in the treatment of a variety of diseases. Likewise, these bioactive compounds are found in *M. pteleifolia*. Apart from being consumed raw by consumers, it can also be used as the main ingredient in food supplements. However, the processing in making a product based on *M. pteleifolia* can cause negative changes in the product's physical and chemical properties. Drying can harm the inherent nutrients and bioactive compounds, depending on the drying method and treatment conditions. Therefore, selecting a drying method and optimizing the drying process are critical for bioactive compound retention (Ozay-Arancioglu *et al*., 2022). Hence, the purpose of this study is to determine the effects of different drying methods on the phytochemical analysis, antioxidant, and anti-inflammatory properties of *M. pteleifolia* leaf extracts.

1.2 Problem statement

Post-harvesting of medicinal plants is critical in the manufacturing process because it directly affects the quality and quantity of active ingredients in the products sold. Moisture determines the physical and chemical properties of aromatic and medicinal plants. The first step in many postharvest operations is water removal also known as drying, which is defined as the reduction of plant moisture content with the goal of preventing enzymatic and microbial activity, thus preserving the products to extend shelf life (Rocha, Melo, & Radünz, 2011). Drying is also the most common method of storing medicinal and aromatic plants and preserving their biochemical compounds (Rahimi & Farroki, 2019). Different methods can be used to dehydrate herbs. Natural drying methods, such as drying in the shade and hot air drying, remain popular due to their low cost. However, it has many drawbacks due to the inability to handle large quantities while maintaining consistent quality standards (Sellami *et al*., 2011).

Bhardwaj *et al*., (2021) reported that people accept drying in an open environment because it is inexpensive and relaxed and despite a small venture, it results in a significant reduction in product quality. Drying is not done scientifically in this case because the environmental conditions change dramatically from day to night. Furthermore, this process is observed by untrained farmers (Bhardwaj *et al*., 2021). As harvest is repeatedly exposed to solar radiation, essential ingredients could be depleted. Direct contact with solar radiation has an effect on desirable properties such as texture, colour, and aroma (Seerangurayar *et al*., 2019; Tomar, Tiwari, & Norton, 2017). Besides, when traditional procedures are followed, dehydration cannot be effectively controlled, resulting in a fairly low-quality product (Afriyie *et al*., 2009; Singh, Vyas, & Yadav, 2019). Shade drying also takes longer, which is already considered an excessively long-time process and may result in significant loss of functional properties in some herbs such as the total antioxidant activity of peppermint and lemon balm, as well as loss of ascorbic acid and carotenoids in dried samples (Thamkaew, Sjöholm, & Galindo, 2021). Based on the literature by Babu *et al*., (2018), to prevent mould growth, the drying process to sensitive humidity should be completed as soon as possible. In fact, colour, nutritional composition, and organizational structure all suffer from lengthy drying time to final moisture (Babu *et al*., 2018).

Moreover, convective drying is the most common method of drying; nonetheless, increasing the temperature usually results in a decrease in the quality of the dried herbs. A low-pressure method of removing water from moist materials is vacuum drying, the vacuum causes the air and water vapor in food to expand, creating a frothy structure. Compared to traditional drying methods, this method offers benefits such as faster drying rates, lower drying temperatures, and high-quality products (Hee & Chong, 2015). Moreover, many studies on *Melicope pteleifolia* had used air drying method as the common procedure in the post-harvest process (Hairiah *et al*., 2016; Kabir *et al*., 2017; Li *et al*., 2019; Shuib *et al*., 2011) but studies on the different drying methods using vacuum oven drying are scare. Therefore, this study was conducted using vacuum oven drying to improve the drying treatments and conditions as well as retain the bioactivity compounds of *Melicope pteleifolia* in producing nutraceutical and pharmaceutical products. *Melicope pteleifolia* was chosen in this study because it has a tremendous potential value in therapeutic properties for healing itchiness and wound as well as possesses important use for antioxidant, anti-inflammatory, antimicrobial and antinociceptive properties (Mohd Din *et al*., 2019).

1.3 Research objectives

This study aims to examine the effects of different drying methods on the phytochemical analysis, antioxidant and anti-inflammatory activities of *Melicope pteleifolia* leaf extracts. Meanwhile, the specific objectives are as follows:

i. To analyse the effects of different drying methods of *Melicope pteleifolia* methanolic leaf extracts on the qualitative and quantitative phytochemical content.
ii. To evaluate the effects of different drying methods of *Melicope pteleifolia* methanolic leaf extracts on antioxidant activities by DPPH, ABTS, and FRAP assays.
iii. To establish an anti-inflammatory activity on the different drying methods of *Melicope pteleifolia* methanolic leaf extracts using lipoxygenase assay.

1.4 Scopes of the study

To achieve the objectives, the scopes of this study are outlined as follows:

i. Fresh plant samples were collected from the local market.
ii. Oven drying and vacuum oven drying were used for the drying methods of the samples, whereas different temperatures and pressures were applied to the vacuum oven.
iii. Methanol was used as a solvent for extraction of the leaf sample.
iv. Phytochemical analysis was evaluated based on the Total Phenolic Content (TPC), Total Flavonoid Content (TFC), Total Tannin Content (TTC), Total Saponin Content (TSC), and Total Terpenoid Content (TTeC).
v. Methods for antioxidant activities were determined with 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), and ferric-reducing antioxidant power (FRAP).
vi. The anti-inflammatory activity of *Melicope pteleifolia* leaf extracts was measured using a lipoxygenase assay method.

1.5 Significance of the study

The investigation of different drying methods is important to see how they affect the phytochemical, antioxidant, and anti-inflammatory activities of *M. pteleifolia*. If suitable drying methods are used, *M pteleifolia* extracts of the highest quality can be obtained. In addition, it is also possible to improve *M. pteleifolia* bioactive properties by determining the most suitable parameter, and the findings will consequently aid in increasing their phytochemical content, antioxidant, and anti-inflammatory properties. As a result, the medicinal industry, particularly in the production of ancillary medicines, as well as consumers, may stand to gain significantly.

This study will shed new light on the medicinal properties of ‘tenggek burung’ (*Melicope pteleifolia*) by focusing on its antioxidant and anti-inflammatory properties. Accordingly, the community will benefit from this study by promoting the use of medicinal plants, particularly ‘tenggek burung’, as a preventive measure against various diseases. Furthermore, the analysis presented in this study will provide useful information for future research regarding the various medicinal benefits of ‘tenggek burung’ and other medicinal plants. Moreover, this study could also help the national economy by producing nutraceutical and pharmaceutical products.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter covers a review of the literature relevant to the research title. In this chapter, information regarding plant species, drying methods, phytochemical, antioxidant, and anti-inflammatory properties of *M. pteleifolia* methanolic extracts from the previous studies were discussed, including the effects of different drying methods with respect to these properties. The correlation effects and statistical analysis are also briefly explained in this chapter.

2.2 *Melicope pteleifolia* (Cham. ex Benth.) T.G.Hartley)

Melicope contains approximately 233 species that range from Madagascar and the Indo-Himalaya region east to the Hawaiian and Marquesas islands, and south to New Zealand (Shuib *et al*., 2011). *Melicope pteleifolia* (Champ Ex. Benth) T.G.Hartley, a member of the Rutaceae family and locally known as ‘tenggek burung’, is one of the most common medicinal herbs found in Peninsular Malaysia and other Asian countries (Sulaiman *et al*., 2010). Besides, it is also known as ‘pauh-pauh’, ‘medang beberas’, ‘cabang tiga’, and ‘tapak itik’. Javanese people in Indonesia called it as ‘sampang’, while the Siamese called it ‘Uam, Sam Ngam’ (Mahadi *et al*., 2016). Table 2.1 shows the taxonomic hierarchy of *M. pteleifolia*.

According to Yao *et al*., (2020) *M. pteleifolia* can be found in a variety of habitats, including mountains, hills, and plains. *M. pteleifolia* usually entails a shrub or tree with a height of 1-14 m, and it is rarely scandent, dioecious, or monoclinous. In the third internode, the juvenile branchlet is 2.5-4 mm broad. The leaves are normally 3-foliolate, although they can also be 1-foliolate, with a petiole that is 1.5-14 cm long and glabrous to hairy.

Table 2.1: The taxonomic hierarchy of *Melicope pteleifolia*.

Kingdom	Plantae
Phylum	Tracheophyta
Class	Magniolopsida
Order	Sapindales
Family	Rutaceae
Genus	*Melicope*
Species	*Melicope pteleifolia*

Young leaves are eaten fresh as a traditional salad or "ulam", a favorite Malay appetizer (Zareen *et al*., 2013; Shuib *et al*., 2011). The extract prepared from *M. pteleifolia*, known locally as "Ba chac", is empirically used in the treatment of high fever, colds, and other inflammatory conditions in Vietnamese traditional medicine (Nguyen *et al*., 2016). In China traditional uses, the leaves in decoction were used in Guangxi and Guangdong area for treating early encephalitis, exogenous disease, dermatitis, eczema, snake bite or insect sting also fresh *M. pteleifolia* leaves mashed solution for trauma haemostasis (Yao *et al*., 2020). In traditional medicine, the entire plant is used to heal itching and sores, aid digestion, and act as an emmenagogue. Moreover, according to a number of studies, the leaf extracts have antioxidant, antibacterial, fungicidal, nitric oxide inhibitory, and antinociceptive activities. Hence, *M. pteleifolia* has many medicinal potentials in terms of curing itching and sores (Mohd Din *et al*., 2019). Mahadi *et al*., (2016) also proved that this plant provides a wide range of health benefits and the leaves have grown in popularity as a traditional fresh vegetable among Malaysians over the years. Anti-inflammatory, antipyretic, analgesic, antioxidant and antibacterial effects have been shown in their leaf extracts. Figure 2.1 shows the whole plant of *M. pteleifolia*.

Figure 2.1: *Melicope pteleifolia* (Lee *et al*., 2021)

According to Shaari *et al*., (2011), phytochemical research on *Melicope pteleifolia* leaves from Sri Lanka found the presence of furoquinoline alkaloids and acetophenones, whereas leaves from Vietnam revealed the presence of benzopyrans as a prominent ingredient. The presence of p-O-geranylcoumaric acid is a prominent ingredient, and various polyprenylated acetophenones and benzylisoquinoline alkaloids were discovered in the leaves of a Malaysian plant by previous studies (Shaari *et al*., 2011). The leaves also yielded two stereoisomeric substances called melicolone A (±) and melicolone B (±), while their stems were used to isolate four novel chroman derivatives (pteleifolones A-D) and nine additional chemicals, including acronyculatin B, dictamnine, acronylin, marmesin, 5-methoxymarmesin, evolitrine, (+)-peucedanol, N-methylatanine, and atanine (Xu *et al*., 2016).

2.3 Drying methods

Drying is an ancient and unrivalled physical method of food preservation that is utilized in the food business for both direct preparation and later processing of food products. Drying has traditionally been a vital and frequent conservation practice, enabling the year-round availability of food and medical goods. The process of drying used to be natural and simple because it was powered by solar energy, but it has since become more advanced and optimized at every level. In terms of chemical and biological changes in the products during the dehydration process, the development of innovative approaches has been thoroughly researched. Medicinal and aromatic plants can be supplied fresh or dried, depending on their intended use, while fresh plants cannot be delivered profitably to every area in the country. Thus, according to Sellami *et al*., (2011), drying medicinal plants has the primary goal of extending product shelf life, reducing packaging requirements, and lowering shipping weights.

Consumer desire for processed products that retain most of the unique features of fresh plants has risen in recent years. As a result, drying must be done with care in order to preserve as much of the flavour, aroma, colour, appearance, and nutritional content of the plants as possible (Jin *et al*., 2018). This is the process of eliminating moisture from a product via evaporation up to a specified threshold value. Since the activities of bacteria, enzymes, and ferments in the material are repressed, the product can be preserved for a long time (Alibas, 2007). In addition, within a fresh food item, there are two forms of moisture: bound moisture, which is defined as liquid retained in the microstructure of the solid portion, and unbound moisture, which is defined as a liquid solution retained in the solid matrix. As a result, numerous activities coexist during the heat drying of fresh food products (Calin-Sanchez *et al*., 2020). Energy is first transmitted from the hot drying agent to the new product. Next, unbounded moisture (free water) evaporates, and water particles bound inside the cellular structure, prone to diffusion and hence migration, are eventually moved to the product’s surface, where the water evaporates (Setty & Murthy, 2003).

Many different drying methods, such as freeze drying, hot air drying, vacuum drying, and microwave drying were used to remove moisture from fresh materials, and drying conditions such as time, temperature, microwave power level, and air velocity, have been linked to various energy consumption and have a significant effect on phytochemicals and antioxidant properties of the samples (Saifullah *et al*., 2019). The most common drying method is hot air drying or oven drying; however, this can cause thermal damage and drastically alter the volatile composition of herbs as well as their colour (Rubinskienė *et al*., 2015). Moreover, this drying method results in dried items that are shrunken and tough, with obvious browning, limited rehydration potential, and low nutritional content. In order to improve quality and or efficiency, various studies have compared the quality, drying kinetics, and energy consumption of generating dried items by hot air drying to other drying processes (Pallas & García, 2011). Some researchers found that thermolabile chemicals and or oxidizable substrates such as carotenoids, tocochromarols, and lipids are frequently degraded by oven drying, which

REFERENCES

Abas, F., Shaari, K., Israf, D. A., Syafri, S., Zainal, Z., & Lajis, N. H. (2010). LC–DAD–ESI-MS analysis of nitric oxide inhibitory fractions of tenggek burung (*Melicope ptelefolia* Champ. ex Benth.). *Journal of Food Composition and Analysis*, *23*(1), 107-112.

Abbas, F., Ke, Y., Yu, R., Yue, Y., Amanullah, S., Jahangir, M. M., & Fan, Y. (2017). Volatile terpenoids: Multiple functions, biosynthesis, modulation and manipulation by genetic engineering. *Planta*, *246*, 803-816.

Abdallah, I. I., & Quax, W. J. (2017). A Glimpse into the Biosynthesis of Terpenoids. *KnE Life Sciences*, 81-98.

Abu Bakar, F. I., Abu Bakar, M. F., Abdullah, N., Endrini, S., & Rahmat, A. (2018). A review of Malaysian medicinal plants with potential anti-inflammatory activity. *Advances in pharmacological sciences*, *2018*.

Afriyie, J. K., Nazha, M. A., Rajakaruna, H., & Forson, F. K. (2009). Experimental investigations of a chimney-dependent solar crop dryer. *Renewable energy*, *34*(1), 217-222.

Akoglu, H. (2018). User’s guide to correlation coefficients. *Turkish Journal of Emergency Medicine*, *18*(3), 91–93. https://doi.org/10.1016/j.tjem.2018.08.001

Ali, S. S., Ahsan, H., Zia, M. K., Siddiqui, T., & Khan, F. H. (2020). Understanding oxidants and antioxidants: Classical team with new players. *Journal of food biochemistry*, *44*(3), e13145.

Alibas, I. (2007). Energy consumption and colour characteristics of nettle leaves during microwave, vacuum and convective drying. *Biosystems Engineering*, *96*(4), 495-502.

Alibas, I. (2009). Microwave, vacuum, and air drying characteristics of collard leaves. *Drying Technology*, *27*(11), 1266–1273. https://doi.org/10.1080/07373930903267773

Alibas, I., & Köksal, N. (2014). Convective, vacuum and microwave drying kinetics of mallow leaves and comparison of color and ascorbic acid values of three drying methods. *Food Science and Technology*, *34*(2), 358–364. https://doi.org/10.1590/S0101-20612014005000033

Ananias, N. K. (2015). *Antioxidant activities, phytochemical, and micro-nutrients analysis of African Moringa (Moringa Ovalifolla)* (Doctoral dissertation, University of Namibia).

Antolovich, M., Prenzler, P. D., Patsalides, E., McDonald, S., & Robards, K. (2002). Methods for testing antioxidant activity. *Analyst*, *127*(1), 183–198. https://doi.org/10.1039/b009171p

Asif, M. (2015). Chemistry and antioxidant activity of plants containing some phenolic compounds. *Chemistry International*, *1*(1), 35–52.

Babu, A. K., Kumaresan, G., Raj, V. A. A., & Velraj, R. (2018). Review of leaf drying: Mechanism and influencing parameters, drying methods, nutrient preservation, and mathematical models. *Renewable and sustainable energy reviews*, *90*, 536-556.

Barimah, J., Yanney, P., Laryea, D., & Quarcoo, C. (2017). Effect of drying methods on phytochemicals, antioxidant activity and total phenolic content of dandelion leaves. *American Journal of Food and Nutrition*, *5*(4), 136–141. https://doi.org/10.12691/ajfn-5-4-4

Barve, K. H., Laddha, K. S., & Jayakumar, B. (2010). Extraction of saponins from Safed Musli. *Pharmacognosy Journal*, *2*(13), 561–564. https://doi.org/10.1016/S0975-3575(10)80060-4

Bergman, M. E., Davis, B., & Phillips, M. A. (2019). Medically useful plant terpenoids: Biosynthesis, occurrence, and mechanism of action. *Molecules*, *24*(21), 3961.

Bhardwaj, A. K., Kumar, R., Kumar, S., Goel, B., & Chauhan, R. (2021). Energy and exergy analyses of drying medicinal herb in a novel forced convection solar dryer integrated with SHSM and PCM. *Sustainable Energy Technologies and Assessments*, *45*(February), 101119. https://doi.org/10.1016/j.seta.2021.101119

Botterweck, A. A. M., Verhagen, H., Goldbohm, R. A., Kleinjans, J., & Van Den Brandt, P. A. (2000). Intake of butylated hydroxyanisole and butylated hydroxytoluene and stomach cancer risk: results from analyses in the Netherlands Cohort Study. *Food and Chemical Toxicology*, *38*(7), 599–605. https://doi.org/10.1016/S0278-6915(00)00042-9

Branisa, J., Jomova, K., Porubska, M., Kollar, V., Simunkova, M., & Valko, M.

(2017). Effect of drying methods on the content of natural pigments and antioxidant capacity in extracts from medicinal plants: A spectroscopic study. *Chemical Papers*, *71*(10), 1993–2002. https://doi.org/10.1007/s11696-017-0193-9

Chen, Z., & Lamb, F. M. (2001). Investigation of boiling front during vacuum drying of wood. *Wood and Fiber Science*, *33*(4), 639–647.

Chuyen, H. V., Roach, P. D., Golding, J. B., Parks, S. E., & Nguyen, M. H. (2017). Effects of four different drying methods on the carotenoid composition and antioxidant capacity of dried Gac peel. *Journal of the Science of Food and Agriculture*, *97*(5), 1656–1662. https://doi.org/10.1002/jsfa.7918

Cox-Georgian, D., Ramadoss, N., Dona, C., & Basu, C. (2019). Therapeutic and medicinal uses of terpenes. *Medicinal Plants: From Farm to Pharmacy*, 333–359. https://doi.org/10.1007/978-3-030-31269-5_15

De Cássia da Silveira e Sá, R., Andrade, L. N., & De Sousa, D. P. (2013). A review on anti-inflammatory activity of monoterpenes. *Molecules*, *18*(1), 1227–1254. https://doi.org/10.3390/molecules18011227

De Santis, G., Maddaluno, C., D'Ambrosio, T., Rascio, A., Rinaldi, M., & Troisi, J. (2016). Characterisation of quinoa (*Chenopodium quinoa* Willd.) accessions for the saponin content in Mediterranean environment. *Italian Journal of Agronomy*, *11*(4), 277-281.

Devi, C. B., Bains, K., & Kaur, H. (2019). Effect of drying procedures on nutritional composition, bioactive compounds and antioxidant activity of wheatgrass (*Triticum aestivum* L). *Journal of Food Science and Technology*, *56*(1), 491–496. https://doi.org/10.1007/s13197-018-3473-7

ElBordiny, H. S., El-Miligy, M. M., Kassab, S. E., Daabees, H., Abdelhamid Mohamed El-Hawash, S., & Mohamed Ali, W. A. (2018). Design, synthesis, biological evaluation and docking studies of new 3-(4,5-dihydro-1H-pyrazol/isoxazol-5-yl)-2-phenyl-1H-indole derivatives as potent antioxidants and 15-lipoxygenase inhibitors. *European Journal of Medicinal Chemistry*, *145*, 594–605. https://doi.org/10.1016/j.ejmech.2018.01.026

Elgorashi, E. E., & McGaw, L. J. (2019). African plants with in vitro anti-inflammatory activities: A review. *South African Journal of Botany*, *126*, 142–169. https://doi.org/10.1016/j.sajb.2019.06.034

Faizal, A., & Geelen, D. (2013). Saponins and their role in biological processes in plants. *Phytochemistry Reviews*, *12*(4), 877–893. https://doi.org/10.1007/s11101-013-9322-4

Farahmandfar, R., Tirgarian, B., Dehghan, B., & Nemati, A. (2020). Comparison of different drying methods on bitter orange (*Citrus aurantium* L.) peel waste: Changes in physical (density and color) and essential oil (yield, composition, antioxidant and antibacterial) properties of powders. *Journal of Food Measurement and Characterization*, *14*(2), 862–875. https://doi.org/10.1007/s11694-019-00334-x

Fatariah, Z., Zulkhairuazha, T. Y. T., & Rosli, W. I. W. (2014). Quantitative HPLC analysis of gallic acid in *Benincasa hispida* prepared with different extraction techniques. *Sains Malaysiana*, *43*(8), 1181–1187.

Fidrianny, I., Aristya, T., & Hartati, R. (2015). Antioxidant capacities of various leaves extracts from three species of legumes and correlation with total flavonoid, phenolic, carotenoid content. *International Journal of Pharmacognosy and Phytochemical Research*, *7*(3), 628–634.

Gasmalla, M. A. A., Yang, R., Amadou, I., & Hua, X. (2014). Nutritional composition of Stevia rebaudiana bertoni leaf: Effect of drying method. *Tropical Journal of Pharmaceutical Research*, *13*(1), 61–65. https://doi.org/10.4314/tjpr.v13i1.9

Ghasemzadeh, A., & Ghasemzadeh, N. (2011). Flavonoids and phenolic acids: Role and biochemical activity in plants and human. *Journal of Medicinal Plant Research*, *5*(31), 6697–6703. https://doi.org/10.5897/JMPR11.1404

Ghasemzadeh, A., Jaafar, H. Z. E., & Rahmat, A. (2016). Variation of the phytochemical constituents and antioxidant activities of *Zingiber officinale* var. *rubrum* Theilade associated with different drying methods and polyphenol oxidase activity. *Molecules*, *21*(6). https://doi.org/10.3390/molecules21060780

Ghosh, D. (2015). Tannins from foods to combat diseases. *International Journal of Pharma Research & Review*, *4*(April), 40–44.

Gu, C., Howell, K., Dunshea, F. R., & Suleria, H. A. R. (2019). LC-ESI-QTOF/MS characterisation of phenolic acids and flavonoids in polyphenol-rich fruits and vegetables and their potential antioxidant activities. *Antioxidants*, *8*(9), 1–15. https://doi.org/10.3390/antiox8090405

Gulcin, İ. (2020). Antioxidants and antioxidant methods: An updated overview. In *Archives of Toxicology* (Vol. 94). https://doi.org/10.1007/s00204-020-02689-3

Hairiah, N., Mohamad, N., Maskam, N. A., Hawa, H., & Hassan, M. (2016).

Phytochemicals screening and antioxidant activities of aqueos leaves extract of *Euodia ridleyi* and *Colubrina asiatica*. *International Journal of Science and Research (IJSR)*, *5*(4), 2004–2007. https://doi.org/10.21275/v5i4.nov163034

Haralampidis, K., Trojanowska, M., & Osbourn, A. E. (2002). Biosynthesis of triterpenoid saponins in plants. *Advances in Biochemical Engineering/Biotechnology*, *75*, 31–49. https://doi.org/10.1007/3-540-44604-4_2

Hassanp our, S., Maheri-Sis, N., Eshratkhah, B., Baghbani Mehmandar Shahin Hassanpour, F., & Baghbani Mehmandar, F. (2011). Plants and secondary metabolites (Tannins): A Review. *International Journal of Forest, Soil and Erosion Int. J. Forest, Soil and Erosion*, *1*(11), 47–53. Retrieved from www.ijfse.com

Hazrati, S., Lotfi, K., Govahi, M., & Ebadi, M. T. (2021). A comparative study: Influence of various drying methods on essential oil components and biological properties of *Stachys lavandulifolia*. *Food Science & Nutrition*, *9*(5), 2612-2619.

Hee, Y. Y., & Chong, G. H. (2015). Drying behaviour of *Andrographis paniculata* in vacuum drying. *International Food Research Journal*, *22*(1), 393.

Irakli, M., Chatzopoulou, P., & Ekateriniadou, L. (2018). Optimization of ultrasound-assisted extraction of phenolic compounds: Oleuropein, phenolic acids, phenolic alcohols and flavonoids from olive leaves and evaluation of its antioxidant activities. *Industrial Crops and Products*, *124*(August), 382–388. https://doi.org/10.1016/j.indcrop.2018.07.070

Ismail, H. F., Hashim, Z., Soon, W. T., Rahman, N. S. A., Zainudin, A. N., & Majid, F. A. A. (2017). Comparative study of herbal plants on the phenolic and flavonoid content, antioxidant activities and toxicity on cells and zebrafish embryo. *Journal of Traditional and Complementary Medicine*, *7*(4), 452–465. https://doi.org/10.1016/j.jtcme.2016.12.006

Izzany, F., Bakar, A., Fadzelly, M., Bakar, A., Abdullah, N., Endrini, S., & Rahmat, A. (2018). A review of Malaysian medicinal plants with potential antidiabetic. *Advances in Pharmacological Sciences*, *2018*, 1–13.

Jamshidi-Kia, F., Wibowo, J. P., Elachouri, M., Masumi, R., Salehifard-Jouneghani, A., Abolhassanzadeh, Z., & Lorigooini, Z. (2020). Battle between plants as antioxidants with free radicals in human body. *Journal of HerbMed Pharmacology*, *9*(3), 191–199. https://doi.org/10.34172/jhp.2020.25

Jin, W., Mujumdar, A. S., Zhang, M., & Shi, W. (2018). Novel Drying Techniques for Spices and Herbs: a Review. *Food Engineering Reviews*, *10*(1), 34–45. https://doi.org/10.1007/s12393-017-9165-7

Jimoh, M. O., Afolayan, A. J., & Lewu, F. B. (2019). Antioxidant and phytochemical activities of Amaranthus caudatus L. harvested from different soils at various growth stages. *Scientific Reports*, *9*(1), 1-14.

Kabir, M. F., Mohd Ali, J., Abolmaesoomi, M., & Hashim, O. H. (2017). *Melicope ptelefolia* leaf extracts exhibit antioxidant activity and exert anti-proliferative effect with apoptosis induction on four different cancer cell lines. *BMC Complementary and Alternative Medicine*, *17*(1), 1–18. https://doi.org/10.1186/s12906-017-1761-9

Karabacak, A. Ö., Suna, S., Tamer, C. E., & Çopur, Ö. U. (2018). Effects of oven, microwave and vacuum drying on drying characteristics, colour, total phenolic content and antioxidant capacity of celery slices. *Quality Assurance and Safety of Crops & Foods*, *10*(2), 193-205.

Kareru, P. G., Keriko, J. M., Gachanja, A. N., & Kenji, G. M. (2008). Direct detection of triterpenoid saponins in medicinal plants. *African Journal of Traditional, Complementary and Alternative Medicines*, *5*(1), 56-60.

Kedare, S. B., & Singh, R. P. (2011). Genesis and development of DPPH method of antioxidant assay. *Journal of Food Science and Technology*, *48*(4), 412–422. https://doi.org/10.1007/s13197-011-0251-1

Kefeli., V. I., Kalevitch., M. V., & Borsari, B. (2003). 17871.Pdf. *Journal of Cell and Molicular Biology*, Vol. 2, pp. 13–18.

Khoddami, A., Wilkes, M. A., & Roberts, T. H. (2013). Techniques for analysis of plant phenolic compounds. *Molecules*, *18*(2), 2328–2375. https://doi.org/10.3390/molecules18022328

Kumar, N., & Goel, N. (2019). Phenolic acids: Natural versatile molecules with promising therapeutic applications. *Biotechnology Reports*, *24*. https://doi.org/10.1016/j.btre.2019.e00370

Kumar, S., & Pandey, A. (2015). Free Radicals: Health implications and their mitigation by herbals. *British Journal of Medicine and Medical Research*, *7*(6), 438–457. https://doi.org/10.9734/bjmmr/2015/16284

Kyriakopoulou, K., Pappa, A., Krokida, M., Detsi, A., & Kefalas, P. (2013). Effects of drying and extraction methods on the quality and antioxidant activity of sea buckthorn (*Hippophae rhamnoides*) berries and leaves. *Drying Technology*, *31*(9), 1063–1076. https://doi.org/10.1080/07373937.2013.773907

Lee, B. W., Quy Ha, T. K., Park, E. J., Cho, H. M., Ryu, B., Doan, T. P., … Oh, W. K. (2021). Melicopteline A-E, unusual cyclopeptide alkaloids with antiviral activity against influenza A virus from *Melicope pteleifolia*. *Journal of Organic Chemistry*, *86*(2), 1437–1447. https://doi.org/10.1021/acs.joc.0c02137

Lee, K. J., Oh, Y. C., Cho, W. K., & Ma, J. Y. (2015). Antioxidant and anti-inflammatory activity determination of one hundred kinds of pure chemical compounds using offline and online screening HPLC assay. *Evidence-Based Complementary and Alternative Medicine*, *2015*.

Li, W., Rao, L., Liu, Y., He, Q., Fan, Y., You, Y. X., … Zhang, C. R. (2019). (±)-Melivitticines A and B: Rearranged prenylated acetophenone derivatives from *Melicope viticina* and their antimicrobial activity. *Bioorganic Chemistry*, *90*(April). https://doi.org/10.1016/j.bioorg.2019.103099

Liu, X., Qiu, Z., Wang, L., & Chen, Y. (2010). Food and bioproducts processing quality evaluation of *Panax notoginseng* extract dried by different drying methods. *Food and Bioproducts Processing*, *89*(1), 10–14. https://doi.org/10.1016/j.fbp.2010.03.008

Lourenço, S. C., Moldão-Martins, M., & Alves, V. D. (2019). Antioxidants of natural plant origins: From sources to food industry applications. *Molecules*, *24*(22), 14–16. https://doi.org/10.3390/molecules24224132

Ludwiczuk, A., Skalicka-Woźniak, K., & Georgiev, M. I. (2017). Terpenoids. In *Pharmacognosy: Fundamentals, Applications and Strategy*. https://doi.org/10.1016/B978-0-12-802104-0.00011-1

Łukowski, A., Jagiełło, R., Robakowski, P., Adamczyk, D., & Karolewski, P. (2022). Adaptation of a simple method to determine the total terpenoid content in needles of coniferous trees. *Plant Science*, *314*, 111090. https://doi.org/10.1016/j.plantsci.2021.111090

Macáková, K., Kolečkář, V., Cahlíková, L., Chlebek, J., Hošt'álková, A., Kuča, K., ... & Opletal, L. (2014). Tannins and their influence on health. In *Recent advances in medicinal chemistry* (pp. 159-208). Elsevier.

Mahadi, M., Abdul Rahman, N., Viswanathan, D., Taib, I. S., Sulong, A., Hakeem, W. A., … Yusuf, Z. (2016). The potential effects of *Melicope ptelefolia* root extract as an anti-nociceptive and anti-inflammatory on animal models. *Bulletin of*

Faculty of Pharmacy, Cairo University, *54*(2), 237–241. https://doi.org/10.1016/j.bfopcu.2016.06.005

Mahirah, Y. S., Rabeta, M. S., & Antora, R. A. (2018). Effects of different drying methods on the proximate composition and antioxidant activities of *Ocimum basilicum* leaves. *Food Res*, *2*(5), 421-428.

Majid, H., & Rining, H. A. (2018). The effect of drying techniques on the antioxidant capacity, flavonoids and phenolic content of fermented local cocoa. *Journal of Advanced Research in Applied Mechanics*, *1*(1), 11–19.

Malik, A., Anis, I., Khan, S. B., Ahmed, E., Ahmed, Z., Nawaz, S. A., & Choudhary, M. I. (2004). Enzymes inhibiting lignans from *Vitex negundo*. *Chemical and Pharmaceutical Bulletin*, *52*(11), 1269-1272.

Marchi, L. B., Monteiro, A. R., Mikcha, J., Santos, A., Chinelatto, M., Marques, D., ... & Costa, S. C. (2015). Evaluation of antioxidant and antimicrobial capacity of pomegranate peel extract (*Punica granatuml*.) Under different drying temperatures. *Chemical engineering transactions*, *44*, 121-126. https://doi.org/10.3303/CET1544021

Mediani, A., Abas, F., Tan, C. P., & Khatib, A. (2014). Effects of different drying methods and storage time on free radical scavenging activity and total phenolic content of *Cosmos caudatus*. *Antioxidants*, *3*(2), 358–370. https://doi.org/10.3390/antiox3020358

Meng, Q., Fan, H., Li, Y., & Zhang, L. (2018). Effect of drying methods on physico-chemical properties and antioxidant activity of *Dendrobium officinale*. *Journal of Food Measurement and Characterization*, *12*(1), 1–10. https://doi.org/10.1007/s11694-017-9611-5

Miller, N. J., Rice-Evans, C., Davies, M. J., Gopinathan, V., & Milner, A. (1993). A novel method for measuring antioxidant capacity and its application to monitoring the antioxidant status in premature neonates. *Clinical Science*, *84*(4), 407–412. https://doi.org/10.1042/cs0840407

Mogana, R., Teng-Jin, K., & Wiart, C. (2013). The medicinal timber *Canarium patentinervium* Miq. (*Burseraceae Kunth*.) is an anti-inflammatory bioresource of dual inhibitors of Cyclooxygenase (COX) and 5-Lipoxygenase (5-LOX) . *ISRN Biotechnology*, *2013*, 1–8. https://doi.org/10.5402/2013/986361

Mohammad Faujul, K. (2019). *Characterisation of Melicope ptelefolia bioactivities antioxidant, anticancer, anticadmium-induced cytotoxicity and microarray* *transcriptome profiling/Mohammad Faujul Kabir* (Doctoral dissertation, University of Malaya).

Moharram, H. A., & Youssef, M. M. (2016). Methods for Determining the Antioxidant Activity : A Review = طرق تقدير النشاط المضاد للأكسدة: استعراض مرجعي. *Alexandria Journal of Food Science and Technology*, *11*(1), 31–41. https://doi.org/10.12816/0025348

Mohd Din, A. R. J., Hanapi, S. Z., Futamata, H., & Sarmidi, M. R. (2019). Utilization of compost tea for biochemical response assessment associated with resistance to phytopathogen causing leaf spot in *Melicope ptelefolia*. *Organic Agriculture*, *9*(4), 445–456. https://doi.org/10.1007/s13165-018-0235-9

Murugesan, D., & Deviponnuswamy, R. (2014). Innovare academic sciences potential anti-inflammatory medicinal plants - A review. *International Journal of Pharmacy and Pharmaceutical Sciences*, *6*(4), 43–49.

Mustafa, R. A., Hamid, A. A., Mohamed, S., & Bakar, F. A. (2010). Total phenolic compounds, flavonoids, and radical scavenging activity of 21 selected tropical plants. *Journal of Food Science*, *75*(1). https://doi.org/10.1111/j.1750-3841.2009.01401.x

Mzindle, N. B. (2017). *Properties of selected South African medicinal plants Submitted in fulfillment for the Degree of Master of Applied Sciences in*. 133.

Nagegowda, D. A. (2010). Plant volatile terpenoid metabolism : Biosynthetic genes , transcriptional regulation and subcellular compartmentation. *FEBS Letters*, *584*(14), 2965–2973. https://doi.org/10.1016/j.febslet.2010.05.045

Neoh, Y. Y., Matanjun, P., & Lee, J. S. (2021). Effects of various drying processes on malaysian brown seaweed, *Sargassum polycystum* pertaining to antioxidants content and activity. *2021. Transactions on Science and Technology*, *8*(1), 25–37. Retrieved from http://tost.unise.org/

Ng, Z. X., Than, M. J. Y., & Yong, P. H. (2021). Peperomia pellucida (L.) Kunth herbal tea: Effect of fermentation and drying methods on the consumer acceptance, antioxidant and anti-inflammatory activities. *Food chemistry*, *344*, 128738.

Nguyen, N. H., Ha, T. K. Q., Choi, S., Eum, S., Lee, C. H., Bach, T. T., … Oh, W. K. (2016). Chemical constituents from *Melicope pteleifolia* leaves. *Phytochemistry*, *130*, 291–300. https://doi.org/10.1016/j.phytochem.2016.06.011

Nguyen, K. Q., Vuong, Q. V., Nguyen, M. H., & Roach, P. D. (2018). The effects of drying conditions on bioactive compounds and antioxidant activity of the Australian maroon bush, *Scaevola spinescens*. *Journal of Food Processing and Preservation*, *42*(10).

Nguyen, V. T., Pham, N. M. Q., Vuong, Q. Van, Bowyer, M. C., van Altena, I. A., & Scarlett, C. J. (2016). Phytochemical retention and antioxidant capacity of xao tam phan (*Paramignya trimera*) root as prepared by different drying methods. *Drying Technology*, *34*(3), 324–334. https://doi.org/10.1080/07373937.2015.1053566

Nn, A. (2015). A review on the extraction methods use in medicinal plants, principle, strength and limitation. *Medicinal & Aromatic Plants*, *04*(03), 3–8. https://doi.org/10.4172/2167-0412.1000196

Okwunodulu, F. U., Onuchi, M. M., & Nwachukwu, M. N. (2020). Comparative studies on the proximate and phytochemical analysis of *Talinum triangulare* as a function of drying techniques. *Journal Of Chemical Society Of Nigeria*, *45*(2).

Omojokun, O. S., Oboh, G., Ademiluyi, A. O., Oladele, J. O., & Boligon, A. A. (2021). Impact of drying processes on *Bryophyllum pinnatum* phenolic constituents and its anti-inflammatory and antioxidative activities in human erythrocytes. *Journal of Food Biochemistry*, *45*(3), 1–10. https://doi.org/10.1111/jfbc.13298

Ondua, M., Njoya, E. M., Abdalla, M. A., & McGaw, L. J. (2019). Anti-inflammatory and antioxidant properties of leaf extracts of eleven South African medicinal plants used traditionally to treat inflammation. *Journal of ethnopharmacology*, *234*, 27-35.

Ozay-Arancioglu, I., Bekiroglu, H., Karadag, A., Saroglu, O., Tekin-çakmak, Z. H., & Karasu, S. (2022). Effect of different drying methods on the bioactive, microstructural, and in-vitro bioaccessibility of bioactive compounds of the pomegranate arils. *Food Science and Technology (Brazil)*, *42*, 1–9. https://doi.org/10.1590/fst.06221

Padma, R., Parvathy, N. G., Renjith, V., & Rahate, K. P. (2013). Quantitative estimation of tannins, phenols and antioxidant activity of methanolic extract of *Imperata cylindrica*. *International Journal of Research in Pharmaceutical Sciences*, *4*(1), 73–77.

Pallas, V., & García, J. A. (2011). How do plant viruses induce disease? Interactions and interference with host components. *Journal of General Virology*, *92*(12), 2691–2705. https://doi.org/10.1099/vir.0.034603-0

Panche, A. N., Diwan, A. D., & Chandra, S. R. (2016). CAS: 528: DC%2BC1cXlsVCmsLc% 3D: Flavonoids: an overview. vol. 5. *J Nutr Sci*. https://doi.org/10.1017/jns.2016.41

Paramanandam, V., Jagadeesan, G., Muniyandi, K., Manoharan, A. L., Nataraj, G., Sathyanarayanan, S., & Thangaraj, P. (2021). Comparative and variability analysis of different drying methods on phytochemical, antioxidant and phenolic contents of *Ficus auriculata* Lour. fruit. *Phytomedicine Plus*, *1*(3), 100075. https://doi.org/10.1016/j.phyplu.2021.100075

Pereira, A. V., Santana, G. M., Góis, M. B., & Sant'Ana, D. G. (2015). Tannins obtained from medicinal plants extracts against pathogens: Antimicrobial potential. *Battle Against Microb. Pathog. Basic Sci. Technol. Adv. Educ. Programs*, 228-235.

Perera, H. D. S. M., Samarasekera, J. K. R. R., Handunnetti, S. M., & Weerasena, O. V. D. S. J. (2016). In vitro anti-inflammatory and anti-oxidant activities of Sri Lankan medicinal plants. *Industrial Crops and Products*, *94*, 610–620. https://doi.org/10.1016/j.indcrop.2016.09.009

Pham, H., Nguyen, V., Vuong, Q., Bowyer, M., & Scarlett, C. (2015). Effect of extraction solvents and drying methods on the physicochemical and antioxidant properties of *Helicteres hirsuta* Lour. leaves. *Technologies*, *3*(4), 285–301. https://doi.org/10.3390/technologies3040285

Pichersky, E., & Raguso, R. A. (2018). Why do plants produce so many terpenoid compounds? *New Phytologist*, *220*(3), 692–702. https://doi.org/10.1111/nph.14178

Poós, T., & Varju, E. (2017). Drying characteristics of medicinal plants. *International Review of Applied Sciences and Engineering*, *8*(1), 83-91.

Prior, R. L., Wu, X., & Schaich, K. (2005). Standardized methods for the determination of antioxidant capacity and phenolics in foods and dietary supplements. *Journal of Agricultural and Food Chemistry*, *53*(10), 4290–4302. https://doi.org/10.1021/jf0502698

Puranik, V., Chauhan, D. K., Mishra, V., & Rai, G. K. (2012). Effect of drying techniques on the physicochemical and bioactive components of selected medicinal herbs. *Ann Phytomed*, *1*, 23-29.

Rababah, T. M., Alhamad, M., Al-Mahasneh, M., Ereifej, K., Andrade, J., Altarifi, B., ... & Yang, W. (2015). Effects of drying process on total phenolics, antioxidant activity and flavonoid contents of common mediterranean herbs. *International Journal of Agricultural and Biological Engineering*, *8*(2), 145-150.

Ravi, N. H., Maskam, N. A., Hassan, H. H. M., & Nor, M. M. (2013). Phytochemicals screening and antioxidant activities of aqueous leaves extract of *Euodia ridleyi* and *Colubrina asiatica*. *International Journal of Science and Research*, *5*(4), 2004-2007.

Rhim, J. W., Xi, Y., Jeong, W. C., Ham, K. S., Chung, H. S., & Kim, E. S. (2009). Effect of drying method on antioxidant activity of Jiwhang (*Rehmannia glutinosa*). *Food Science and Biotechnology*, *18*(6), 1464–1469.

Rining, H. A., & Majid, H. (2018). The effect of drying techniques on the antioxidant capacity, flavonoids and phenolic content of fermented local cocoa bean. *Journal of Advanced Research in Applied Mechanics*, *47*(1), 11-19.

Rocha, R. P., Melo, E. C., & Radünz, L. L. (2011). Influence of drying process on the quality of medicinal plants: A review. *Journal of Medicinal Plant Research*, *5*(33), 7076–7084. https://doi.org/10.5897/JMPRx11.001

Roshanak, S., Rahimmalek, M., & Goli, S. A. H. (2016). Evaluation of seven different drying treatments in respect to total flavonoid, phenolic, vitamin C content, chlorophyll, antioxidant activity and colour of green tea (*Camellia sinensis* or *C. assamica*) leaves. *Journal of food science and technology*, *53*, 721-729.

Rubinskienė, M., Viškelis, P., Dambrauskienė, E., Viškelis, J., & Karklelienė, R. (2015). Džiovinimo būdų įtaka pipirmėtės (Mentha × piperita L.) lapų cheminei sudėčiai ir spalvai. *Zemdirbyste*, *102*(2), 223–228. https://doi.org/10.13080/z-a.2015.102.029

Sadeghian, H., & Jabbari, A. (2016). 15-Lipoxygenase inhibitors: A patent review. *Expert Opinion on Therapeutic Patents*, *26*(1), 65–88. https://doi.org/10.1517/13543776.2016.1113259

Saifullah, M., McCullum, R., McCluskey, A., & Vuong, Q. (2019). Effects of different drying methods on extractable phenolic compounds and antioxidant properties from lemon myrtle dried leaves. *Heliyon*, *5*(12), e03044. https://doi.org/10.1016/j.heliyon.2019.e03044

Sarveswaran, R., Jayasuriya, W. J. A. B. N., & Suresh, T. S. (2017). In vitro assays to investigate the anti-inflammatory activity of herbal extracts: A review. *Jayasuriya et Al. World Journal of Pharmaceutical Research*, *6*(17), 131–141. https://doi.org/10.20959/wjpr201717-10058

Savithramma, N., Rao, M. L., & Suhrulatha, D. (2011). Screening of medicinal plants for secondary metabolites. *Middle-East Journal of Scientific Research*, *8*(3), 579-584.

Seeranguraya r, T., Al-Ismaili, A. M., Jeewantha, L. J., & Al-Habsi, N. A. (2019). Effect of solar drying methods on colour kinetics and texture of dates. *Food and Bioproducts Processing*, *116*, 227-239.

Sellami, I. H., Wannes, W. A., Bettaieb, I., Berrima, S., Chahed, T., Marzouk, B., & Limam, F. (2011). Qualitative and quantitative changes in the essential oil of *Laurus nobilis* L. leaves as affected by different drying methods. *Food Chemistry*, *126*(2), 691–697. https://doi.org/10.1016/j.foodchem.2010.11.022

Sen, S., Chakraborty, R., Sridhar, C., Reddy, Y. S. R., & De, B. (2010). Free radicals, antioxidants, diseases and phytomedicines: Current status and future prospect. *International Journal of Pharmaceutical Sciences Review and Research*, *3*(1), 91–100.

Setty, Y. P., & Murthy, J. V. (2003). Development of a model for drying of solids in a continuous fluidized bed dryer.

Shaari, K., Suppaiah, V., Wai, L. K., Stanslas, J., Tejo, B. A., Israf, D. A., … Lajis, N. H. (2011). Bioassay-guided identification of an anti-inflammatory prenylated acylphloroglucinol from *Melicope ptelefolia* and molecular insights into its interaction with 5-lipoxygenase. *Bioorganic and Medicinal Chemistry*, *19*(21), 6340–6347. https://doi.org/10.1016/j.bmc.2011.09.001

Shaari, K., Zareen, S., Akhtar, M. N., & Lajis, N. H. (2011). Chemical constituents of *Melicope ptelefolia*. *Natural Product Communications*, *6*(3), 343–348. https://doi.org/10.1177/1934578x1100600308

Shah, P., & Modi, H. A. (2015). Comparative Study of DPPH, ABTS and FRAP assays for determination of antioxidant activity. *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, *3*(6), 636–641. Retrieved from www.ijraset.com

Sharanya, C. S., Arun, K. G., Sabu, A., & Haridas, M. (2020). Aloe emodin shows high affinity to active site and low affinity to two other sites to result consummately reduced inhibition of lipoxygenase. *Prostaglandins & Other Lipid Mediators*, *150*, 106453.

Sharma, V., & Paliwal, R. (2013). Isolation and characterization of saponins from *Moringa oleifera* (moringaceae) pods. *Int J Pharm Pharm Sci*, *5*(1), 179-183.

Shuib, N. H., Shaari, K., Khatib, A., Maulidiani, Kneer, R., Zareen, S., … Neto, V. (2011). Discrimination of young and mature leaves of *Melicope ptelefolia* using 1H NMR and multivariate data analysis. *Food Chemistry*, *126*(2), 640–645. https://doi.org/10.1016/j.foodchem.2010.10.043

Sieniawska, E., & Baj, T. (2017). Tannins. In *Pharmacognosy: Fundamentals, Applications and Strategy*. https://doi.org/10.1016/B978-0-12-802104-0.00010-X

Singh, B., & Kaur, A. (2018). Control of insect pests in crop plants and stored food grains using plant saponins: A review. *Lwt*, *87*, 93–101. https://doi.org/10.1016/j.lwt.2017.08.077

Singh, P., Vyas, S., & Yadav, A. (2019). Experimental comparison of open sun drying and solar drying based on evacuated tube collector. *International Journal of Sustainable Energy*, *38*(4), 348-367.

Škrovánková, S., Mišurcová, L., & Machů, L. (2012). Antioxidant activity and protecting health effects of common medicinal plants. *Advances in food and nutrition research*, *67*, 75-139.

Soni, A., & Sosa, S. (2013). Phytochemical analysis and free radical scavenging potential of herbal and medicinal plant extracts. *Journal of Pharmacognosy and Phytochemistry JPP*, *22*(24), 22–29.

Sulaiman, M. R., Mohd Padzil, A., Shaari, K., Khalid, S., Shaik Mossadeq, W. M., Mohamad, A. S., ... & Lajis, N. (2010). Antinociceptive activity of Melicope ptelefolia ethanolic extract in experimental animals. *Journal of biomedicine and biotechnology*, *2010*.

Sulaiman, S. F., Yusoff, N. A. M., Eldeen, I. M., Seow, E. M., Sajak, A. A. B., Supriatno, & Ooi, K. L. (2011). Correlation between total phenolic and mineral contents with antioxidant activity of eight Malaysian bananas (*Musa* sp.). *Journal of Food Composition and Analysis*, *24*(1), 1–10. https://doi.org/10.1016/j.jfca.2010.04.005

Sultana, B., Anwar, F., & Ashraf, M. (2009). Effect of extraction solvent/technique on the antioxidant activity of selected medicinal plant extracts. *Molecules*, *14*(6), 2167–2180. https://doi.org/10.3390/molecules14062167

Suna, S. (2019). Effects of hot air, microwave and vacuum drying on drying characteristics and in vitro bioaccessibility of medlar fruit leather (pestil). *Food Science and Biotechnology*, *28*(5), 1465–1474. https://doi.org/10.1007/s10068-

019-00588-7

Swallah, M. S., Sun, H., Affoh, R., Fu, H., & Yu, H. (2020). Antioxidant potential overviews of secondary metabolites (Polyphenols) in fruits. *International Journal of Food Science*, *2020*. https://doi.org/10.1155/2020/9081686

T Gamal, A., & Z Ali, M. (2022). Production and Evaluation of healthy drinks prepared from dried willow leaves (*Salix safsaf* L.). *International Journal of Family Studies, Food Science and Nutrition Health*, *3*(1), 145-176.

Takashima, M., Horie, M., Shichiri, M., Hagihara, Y., Yoshida, Y., & Niki, E. (2012). Assessment of antioxidant capacity for scavenging free radicals in vitro: A rational basis and practical application. *Free Radical Biology and Medicine*, *52*(7), 1242–1252. https://doi.org/10.1016/j.freeradbiomed.2012.01.010

Thamkaew, G., Sjöholm, I., & Galindo, F. G. (2021). A review of drying methods for improving the quality of dried herbs. *Critical Reviews in Food Science and Nutrition*, *61*(11), 1763–1786. https://doi.org/10.1080/10408398.2020.1765309

Tomar, V., Tiwari, G. N., & Norton, B. (2017). Solar dryers for tropical food preservation: Thermophysics of crops, systems and components. *Solar Energy*, *154*, 2–13. https://doi.org/10.1016/j.solener.2017.05.066

Trouillas, P., Calliste, C. A., Allais, D. P., Simon, A., Marfak, A., Delage, C., & Duroux, J. L. (2003). Antioxidant, anti-inflammatory and antiproliferative properties of sixteen water plant extracts used in the Limousin countryside as herbal teas. *Food Chemistry*, *80*(3), 399–407. https://doi.org/10.1016/S0308-8146(02)00282-0

Truong, D. H., Nguyen, D. H., Ta, N. T. A., Bui, A. V., Do, T. H., & Nguyen, H. C. (2019). Evaluation of the use of different solvents for phytochemical constituents, antioxidants, and in vitro anti-inflammatory activities of *Severinia buxifolia*. *Journal of Food Quality*, *2019*. https://doi.org/10.1155/2019/8178294

Uribe, E., Vega-Gálvez, A., Heredia, V., Pastén, A., & Di Scala, K. (2018). An edible red seaweed (*Pyropia orbicularis*): Influence of vacuum drying on physicochemical composition, bioactive compounds, antioxidant capacity, and pigments. *Journal of Applied Phycology*, *30*, 673-683.

Vattem, D. A., Ghaedian, R., & Shetty, K. (2005). Enhancing health benefits of berries through phenolic antioxidant enrichment: Focus on cranberry. *Asia Pacific Journal of Clinical Nutrition*, *14*(2), 120–130.

Veeriah, S. (2007). *Effects of apple polyphenols on modulation of detoxifying enzyme* *systems as biomarkers of chemoprevention in human colon cells* (Doctoral dissertation).

Vidinamo, F., Fawzia, S., & Karim, M. A. (2021). Effect of drying methods and storage with agro-ecological conditions on phytochemicals and antioxidant activity of fruits: A review. *Critical Reviews in Food Science and Nutrition*, *62*(2), 353–361. https://doi.org/10.1080/10408398.2020.1816891

Vincken, J. P., Heng, L., de Groot, A., & Gruppen, H. (2007). Saponins, classification and occurrence in the plant kingdom. *Phytochemistry*, *68*(3), 275–297. https://doi.org/10.1016/j.phytochem.2006.10.008

Vuolo, M. M., Lima, V. S., & Maróstica Junior, M. R. (2018). Phenolic compounds: Structure, classification, and antioxidant power. *Bioactive Compounds: Health Benefits and Potential Applications*, 33–50. https://doi.org/10.1016/B978-0-12-814774-0.00002-5

Wang, T. yang, Li, Q., & Bi, K. shun. (2018). Bioactive flavonoids in medicinal plants: Structure, activity and biological fate. *Asian Journal of Pharmaceutical Sciences*, *13*(1), 12–23. https://doi.org/10.1016/j.ajps.2017.08.004

Wang, X. H., & Dai, J. T. (2012). A comparative study on antioxidant activity of water and ethanol extracts of ten Chinese herbs. *Journal of Medicinal Plants Research*, *6*(11), 2210-2215.

Widodo, H., Sismindari, S., Asmara, W., & Rohman, A. (2019). Antioxidant activity, total phenolic and flavonoid contents of selected medicinal plants used for liver diseases and its classification with chemometrics. *Journal of Applied Pharmaceutical Science*, *9*(6), 099-105.

Willcox, J. K., Ash, S. L., & Catignani, G. L. (2004). Antioxidants and prevention of chronic disease. *Critical Reviews in Food Science and Nutrition*, *44*(4), 275–295. https://doi.org/10.1080/10408690490468489

Xiu-Qin, L., Chao, J., Yan-Yan, S., Min-Li, Y., & Xiao-Gang, C. (2009). Analysis of synthetic antioxidants and preservatives in edible vegetable oil by HPLC/TOF-MS. *Food Chemistry*, *113*(2), 692-700.

Xu, J., Sun, X., Liu, X., Peng, M., Li, S., Jin, D. Q., … Guo, Y. (2016). Phytochemical constituents from *Melicope pteleifolia* that promote neurite outgrowth in PC12 cells. *Journal of Functional Foods*, *23*, 565–572. https://doi.org/10.1016/j.jff.2016.03.011

Yadav, R. N. S., & Agarwala, M. (2011). Phytochemical analysis of some medicinal plants. *Journal of phytology*, *3*(12).

Yao, Q., Gao, Y., Lai, C., Wu, C., Zhao, C. L., Wu, J. L., & Tang, D. X. (2020). The phytochemistry, pharmacology and applications of *Melicope pteleifolia*: A review. *Journal of ethnopharmacology*, *251*, 112546.

Yoo, K. M., Kim, D. O., & Lee, C. Y. (2007). Evaluation of different methods of antioxidant measurement. *Food science and biotechnology*, *16*(2), 177-182.

Zainol, M. K. M., Abdul-Hamid, A., Bakar, F. A., & Dek, S. P. (2009). Effect of different drying methods on the degradation of selected flavonoids in *Centella asiatica*. *International Food Research Journal*, *16*(4), 531–537.

Zareen, S., Ismail, I. S., Shaari, K., Yusof, K. N., & Akhtar, M. N. (2013). Quantitative HPLC analysis of benzene derivatives of *Melicope ptelefolia* leaves. *International Journal of Food Properties*, *16*(8), 1830–1838. https://doi.org/10.1080/10942912.2011.609952

Zhang, H., & Tsao, R. (2016). Dietary polyphenols, oxidative stress and antioxidant and anti-inflammatory effects. *Current Opinion in Food Science*, *8*, 33–42. https://doi.org/10.1016/j.cofs.2016.02.002

Zhang, M., Li, L., Han, T., Wang, J., Fang, H., & Lin, D. (2022). Appearance, microstructure and bioactive components of *Bletilla striata* tuber as affected by different drying methods.

Zhang, Q. W., Lin, L. G., & Ye, W. C. (2018). Techniques for extraction and isolation of natural products : A comprehensive review. *Chinese Medicine*, 1–26. https://doi.org/10.1186/s13020-018-0177-x

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