EXTRACTION OF *SWIETENIA MACROPHYLLA* SEED BY USING MICROWAVE ASSISTED EXTRACTION TECHNIQUE AND THE CHARACTERISATION OF ITS PHYTOCHEMICAL PROPERTIES

NOOR FADZILAH BINTI ABU BAKAR

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy

School of Chemical and Energy Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

MAY 2019

DEDICATION

This thesis is dedicated to my parents,

Abu Bakar Bin Abdul Rahaman and Aminah Binti Ahmad

ACKNOWLEDGEMENT

In preparing this thesis, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I would like to express my sincere gratitude to my supervisor Dr. Dayang Norulfairuz Binti Abang Zaidel for the continuous support of my Master study and related research, for her patience, motivation, and immense knowledge. I managed to complete this research and thesis writing with her guidance. I could not have imagined having a better advisor and mentor for my Master study. I am also very thankful to my co-supervisor, Associate Professor Dr. Liza Binti Md Salleh for her advices and motivation. Without their continued support and interest, this thesis would not have been the same as presented here.

My sincere thanks also goes to my fellow labmates for the motivating discussions, for the sleepless nights we were working together before deadlines, and for all the fun we have had throughout my Master study. I also want to thank lab assistances and staffs who helped with the research and gave access to the research facilities.

Last but not the least, I would like to thank my family: my parents and to my siblings for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

ABSTRACT

Swietenia macrophylla (*S.macrophylla*) or commonly known as *Tunjuk Langit* in Malaysia has been used as traditional remedy for diseases treatment as the seeds of *S. macrophylla* have been examined for its anti-inflammatory, anti-mutagenecity, and anti-tumour activities. The objectives of this research are to optimise the extraction of the *S. macrophylla* seed oil by using microwave assisted extraction (MAE) and to evaluate physicochemical and biological properties of the extracted *S. macrophylla* seed oil. MAE provides process acceleration and higher extraction yield compared to conventional extraction. The operating parameters were optimized by response surface methodology using design expert version 6 to obtain optimum yield of *S. macrophylla* seed oil. Properties of *S. macrophylla* seed oil were characterised by using total phenolic content (TPC), antioxidant properties via DPPH (2,2-diphenyl-1-picrilhydrazyl) and ABTS (2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulphonic acid)) free radical scavenging method, the anti-diabetic activity via α-glucosidase and α-amylase inhibition assays and the anti-microbial activity via agar disk-diffusion method. Gas chromatography-mass spectrometry (GC-MS) was used to analyse the fatty acid composition in the seed oil. The result showed that 43.69 ± 0.092 w/w % oil yield was obtained at optimal condition of 6 min irradiation time, solvent-to-solid ratio of 26 mL solvent/g solid and 460 W microwave power. The seed oil extracted by using MAE exhibited the highest TPC concentration, the best DPPH and ABTS inhibition compared to supercritical carbon dioxide extraction (SC-CO_2) and soxhlet extraction (SE) method. *S. macrophylla* seed oil demonstrated potent inhibition on α-amylase but weak inhibition towards α-glucosidase enzyme. *S. macrophylla* seed oil was found to have excellent inhibition zone towards *Escherichia coli* and *Bacillus subtilis*. Result from GC-MS analysis showed that the *S. macrophylla* seed oil was composed of fatty acids including linoleic (32.1%), oleic (57.3%) and palmitic (10.6%). These findings proved that *S. macrophylla* seed oil extracted using MAE could provide better quantity and quality of oil in shorter time compared to SC-CO_2 and SE methods.

ABSTRAK

Swietenia macrophylla (*S. macrophylla*) atau lazim dikenali sebagai *Tunjuk Langit* di Malaysia telah digunakan sebagai ubat tradisional untuk rawatan penyakit di mana biji *S. macrophylla* telah diperakui untuk aktiviti anti-radang, anti-mutagenisme, dan anti-tumor. Objektif penyelidikan ini adalah untuk mengoptimumkan pengekstrakan minyak biji *S. macrophylla* dengan menggunakan pengekstrak bantuan ketuhar gelombang mikro (MAE) dan untuk menilai sifat-sifat fizikokimia dan biologi daripada minyak biji *S. macrophylla* yang diekstrak. MAE menyediakan pecutan proses dan hasil ekstrak yang lebih tinggi berbanding dengan kaedah pengekstrakan konvensional. Parameter operasi dioptimumkan melalui kaedah permukaan tindak balas menggunakan *design expert* versi 6 untuk memperoleh hasil minyak biji *S. macrophylla* yang optimum. Sifat minyak biji *S. macrophylla* dikaji dengan menggunakan jumlah kandungan fenolik (TPC), sifat antioksidan menggunakan kaedah penyingkiran radikal bebas DPPH (2-2-dwifenil-1-pikrilhidrasil) dan ABTS (2,2-azino-bis (3-etilbenzothiazoline-6-asid sulfonik)), aktiviti anti-diabetes minyak biji dengan ujian perencatan enzim α-glucosidase dan α-amilase dan aktiviti anti-mikrob menggunakan kaedah resapan cakera agar. Kromatografi gas- spektrometri jisim (GC-MS) digunakan untuk menganalisa komposisi asid lemak bagi minyak biji tersebut. Keputusan menunjukkan sebanyak 43.69 ± 0.092 w/w% minyak telah dihasilkan pada keadaan optimum iaitu pada 6 minit masa penyinaran, nisbah pelarut kepada pepejal 26 mL pelarut/g pepejal dan 460 W kuasa gelombang mikro. Minyak biji yang diekstrak dengan menggunakan MAE menunjukkan kepekatan TPC tertinggi, perencatan DPPH dan ABTS terbaik berbanding pengekstrakan karbon dioksida superkritikal (SC-CO_2) dan pengekstrakan kaedah soxhlet (SE). Minyak biji *S. macrophylla* menunjukkan perencatan yang kuat terhadap enzim α-amylase tetapi lemah terhadap enzim α-glucosidase. Minyak biji *S. macrophylla* didapati menghasilkan zon perencatan yang baik terhadap *Escherichia coli* dan *Bacillus subtilis*. Hasil daripada analisis GC-MS mendapati bahawa minyak biji *S. macrophylla* terdiri daripada beberapa asid lemak termasuk linoleik (32.1%), oleik (57.3%) dan palmitik (10.6%). Penemuan ini membuktikan bahawa minyak biji *S. macrophylla* yang diekstrak menggunakan MAE dapat memberikan kuantiti dan kualiti minyak yang lebih baik dalam masa yang lebih singkat berbanding kaedah SC-CO_2 dan SE.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

S.macrophylla	-	*Swietenia macrophylla*
S. humilis	-	*Swietenia humilis*
S. condollie	-	*Swietenia condollie*
S. mahagoni	-	*Swietenia mahagoni*
PUFA	-	Polyunsaturated Fatty Acid
CVD	-	Cardiovascular Disease
SE	-	Soxhlet Extraction
SC-CO_2	-	Supercritical Carbon Dioxide Extraction
MAE	-	Microwave Assisted Extraction
RSM	-	Response Surface Methodology
TPC	-	Total Phenolic Content
DPPH	-	2,2-diphenyl-1-picrylhydrazyl
ABTS	-	2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulphonic acid)
GC-MS	-	Gas Chromatography Mass Spectrometry
GC	-	Gas Chromatography
STZ	-	Streptozotocin
SFE	-	Supercritical Carbon Dioxide Extraction
UAE	-	Ultrasound-Assisted Extraction
ASE	-	Accelerated Solvent Extraction
CO_2	-	Carbon dioxide
CHSE	-	Conventional Heating-Stirring Extraction
MAAEE	-	Microwave Assisted Enzymatic Extraction
UMAE	-	Ultrasonic-Microwave Assisted Extraction
NMAE	-	Negative Pressure Cavitation–Microwave Assisted
SWE	-	Subcritical Water Extraction
HPLC	-	High Performance Liquid Chromatography
H_2O	-	Water
DMSO	-	Dimethyl sulfoxide
WHO	-	World Health Organization
FRIM	-	Forest Research Institute Malaysia

LIST OF SYMBOLS

°C	-	Degree celcius
µm	-	Micrometer
h	-	Hour
mg	-	Milligram
g	-	Milligram
mL	-	Millilitre
min	-	Minute
W	-	Watt
a_{ij}	-	constant regression coefficients
MPa	-	Megapascal
mm	-	Millimetre
R^2	-	Determination coefficient
Adj R^2	-	Adjusted determination coefficient

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Swietenia macrophylla (Linn.) Jacq. (Meliaceae) grows and multiply mostly in tropical areas of Asia, including India, Malaysia, Indonesia and southern mainland China (Orwa et al., 2009) but the breed came from Bahamas, Cuba, Haiti, Jamaica, Netherlands Antilles, and United States of America. There are other species in the same group including *S. humilis*, *S. condollie* and *S. mahagoni.* The bark of *S. macrophylla* is known as astringent for the remedy for diarrhoea, as supplements, and as haemorrhage inducer. It also aids to clear blood, healthy appetite, and strength revival for disease such as tuberculosis by using rea liquid soaked bark (Orwa et al., 2009). Meanwhile, the seed has been used as anti-hyperglycaemic drug, body ointment to enhance the healing of skin cuts, itches and wound (Naveen et al., 2014) and has decent antioxidative effect (Kanti et al., 2013). It also has been investigated for its capability to serve as inflammatory prevention, tumour prevention activities and mutagenicity prevention (Guevara et al., 1996). *S. macrophylla* or commonly known as *Tunjuk Langit* in Malaysia has been used as traditional remedy for diseases treatment such as diabetes. Previous research by Hashim et al. (2013) has stated that fucosterol and β-sitosterol might be the responsible bioactive compounds to serve as antidiabetic agent while Koba & Yanagita (2013) has proved linoleic acid to exhibit the same potential.

Diabetes is a chronic condition when glucose remains circulating in the blood stream due to the lacking and ineffectiveness of the insulin in the body. The function of insulin is to transport glucose from blood stream into cell to be used as energy (McLaughlin et al., 2015). Diabetes mellitus occurs when there are defects either in insulin secretion, insulin action or both. There are 3 types of diabetes mellitus including Type 1, Type 2 and gestational diabetes. Type 1 diabetes is caused by the damage of β-cells of the pancreas which result in decreased insulin supply to the circulation. The patients need to fully depend on insulin injection on daily basis while Type 2 results in peripheral insulin resistance, thereby results in decreased insulin sensitivity to the skeletal muscles, adipose tissues and liver. There are a lot of other factors such as aging, obesity, physical inactivity, population growth and urbanization that can lead to steady increase diabetes sufferers (Choudhury et al., 2018). The last category of diabetes is gestational diabetes which commonly occur to pregnant woman and normally disappears after birth.

Statistically, the diabetes sufferer total number is expected to increase from 414.7 million in 2015 to 641.7 million in 2040. China is the first country with the greatest number of adults with diabetes followed by India and United States of America (USA) (McLaughlin et al., 2015). Meanwhile in Malaysia, there were over 3 million cases of diabetes in 2017 (World Health Organization, 2016). In USA, more than 90% of diabetes patients suffered from Type 2 diabetes and affected 9.3% of USA population. Adults diagnosed with diabetes treat the disease by oral medication (56.9 %), insulin (14 %), both (14.7 %), and 14.4 % use neither (Tran et al., 2015). Oral medicine was acknowledged as the major treatment for diabetes. However, commercial antidiabetic drugs such as sulfonylureas and rosiglitazone have been reported to have side effects such as increased risks of cardiovascular disease (CVD) and stroke (Castilla-guerra et al., 2018). Therefore, the search in natural sources for antidiabetic drugs should be taken seriously to provide an alternative to the patients.

Plants contain bioactive compounds, which are secondary plant metabolites responsible to provide pharmacological or toxicological benefits in human body (Bernhoft, 2010). Secondary metabolites derived from fatty acids such as omega-3 and omega-6 fatty acids are called essential fatty acids because cannot be made by the body in desired amounts, so they must be consumed in the diet. omega-3 polyunsaturated fatty acids (PUFA) was derived from original fatty acid α-linoleic acid while omega-6 PUFAs were derived from linoleic acid (Corte et al., 2018). Nutritional studies in animal models have shown loads of advantageous health effects by consuming conjugated linoleic acid including anti-obesity, anticarcinogenic and antidiabetic effects. Previous research has reported that

S.macrophylla contains linoleic acid as major composition of fatty acid with 33.87% and 49.08% for plant origin from India and Mexico respectively (Chakrabarty and Chowdhuri, 1956). This information supported that *S. macrophylla* seed oil can be a good source of PUFA for diabetes Type 2 treatment.

In order to prepare oral medication to treat diabetes, a good extraction method to produce optimum oil yield should be studied to extract optimum bioactive compound that can contribute to the treatment process (Tran et al., 2015). The extraction method is divided into two categories which are conventional method and modern method. Conventional extraction method such as Soxhlet extraction (SE) is widely used since 1879, however, it has many downsides compared to other extraction method because it uses long time for extraction process and huge amount of extractant which also leads to environmental problem as it is expensive to dispose. The thermolabile of targeted species might also be decomposed due to exposure to high temperature for long time. Soxhlet extraction method also limited by extractant and no automation process (Castro and Priego-Capote, 2010). Meanwhile, for supercritical carbon dioxide extraction (SC-CO_2), it is a rising modern method for extraction which provide shorter time and automated process. Nevertheless, it also has disadvantages such as not suitable for samples containing high amounts of water, low yield of polar compound and it is a high cost instrumentation (Khaw et al., 2017).

Another promising modern extraction method is microwave assisted extraction (MAE) which provides environmentally friendly automated process. In comparison with SC-CO_2, it provides higher extraction efficiency, reduction of solvent usage about 90%, shorter time, high sample amount, low cost and easier to handle (Calle & Costas-Rodríguez, 2017). Even though the biggest concern with MAE is the loss of bioactive compound due to the exposure to the irradiation, this problem can be overcome with intermittent microwave extraction process. Intermittent extraction prevents samples from overheating while balancing heat, mass transfer processes and improves the efficiency of bioactive compounds extraction (Swamy and Muthukumarappan, 2017).

S. macrophylla was chosen in this study because it has higher total phenolic content compared to seed oil of blueberry, red raspberry, marionberry and boysenberry which have much lower TPC which ranges from 0.9 to 2 mg GAE/mg. (Parry et al., 2005). According to Moghadamtousi et al. (2013), *S. macrophylla* has exceptional advantages in phytomedicine because of the diversity in biological activities including antimicrobial, anti-inflammatory, antioxidant effects, antimutagenic, anticancer, antitumor and antidiabetic activities. This study aims to optimise the extraction of *S. macrophylla* seed oil by using microwave-assisted extraction with three main parameters which were time, microwave power and solvent to solid ratio to give the best yield of oil. Characterisation of optimum extract from different methods including SE, SC-CO_2 and MAE were performed to compare the properties of the extract in order to evaluate advantages and disadvantages of each method. The oil extracted at optimum conditions was subjected to antioxidant, antimicrobial and antidiabetic test to prove the ability of the extract to serve as an alternative for diabetes treatment. *In vitro* diabetic model was used to analyse the antidiabetic activities. In addition, the correlation of linoleic acid and the inhibitory activities of α-glucosidase and α-amylase were also investigated.

1.2 Problem Statement

In 2011, there were approximately 366 million people suffered diabetes mellitus and the number is expected to increase to 439 million by 2030. Type 2 diabetes mellitus sufferers in low and middle income country has been increasing by 80% and caused 4.6 million deaths in 2011 (Olokoba et al., 2012). There were over 3 million cases of diabetes in Malaysia in 2017 (World Health Organization, 2016). The exploration for brand new drugs continues even with considerable development in treatment by using oral hypoglycaemic agents because the existing synthetic drugs have several limitations (Issa & Bule, 2015) and adverse effects (Patel et al., 2012) such as hypoglycaemia, liver damage, gastrointestinal symptoms, and weight gain (Eleazu et al., 2018). Hence, it is crucial to develop a safe and effective treatment for diabetes. Plants offer excellent option to cure diabetes by providing safe and effective medication because plants have been an exemplary source of medicine since ancient times. Herbal plants have been traditionally used for diabetes treatment worldwide. Plant drugs are frequently considered to be less toxic and free from side effects than synthetic drugs (Patel et al., 2012). In this case, *S. macrophylla* has been proven by previous studies to have the ability to serve as the cure for many diseases such as diabetes mellitus (Jemain et al., 2011), hypertension and malaria (Dewanjee and Maiti, 2011). There are a number of bioactive compounds that reckoned to contribute as antidiabetic agent such as fucosterol, β-sitosterol (Hashim et al., 2013), and linoleic acid (Hartati et al., 2018)

Appropriate and standardised extraction techniques with optimum oil yield recovery are needed in order to obtain bioactive compounds from plant materials for isolation, identification, characterisation and industrial production purposes (Reinoso et al., 2017). The growing attention in plant secondary metabolites is followed by a need to develop and modify the resource of plant extraction protocols. However, the conventional extraction process may require high cost and long extraction time such as Soxhlet method, which has the drawbacks of using huge volume of solvent and prolonged extraction time of compounds producing lower yield. The increasing demand of herbal products requires wider, safer and high quality production with low processing cost and higher yield in order to grow herbal and nutraceutical medicine based industries (Belwal et al., 2018). To achieve these expectations, an increased demand for alternative and modern extraction process have been introduced such as microwave assisted extraction (MAE) and supercritical carbon dioxide extraction (SC-CO_2). MAE has the ability to efficiently extract multiple samples simultaneously in short time (about 90% time reduction), low cost and minimal usage of solvent volume (Dean and Tyne, 2012). MAE also has promising advantages against SC-CO_2 which is easier to handle, lower cost equipment and provide higher extraction yield in shorter extraction time. It is also appropriate for thermolabile constituents and offers agitation during extraction to improve the mass transfer phenomenon (Mandal and Siva, 2006).

1.3 Objectives of the Study

This study aimed to achieve the following objectives:

a) To optimise the extraction of the *S. macrophylla* seed oil by using microwave-assisted extraction (MAE).

b) To evaluate physicochemical and biological poperties of the extracted *S. macrophylla* seed oil.

1.4 Scope of the Study

In order to achieve the objectives stated in section 1.3, the scopes of study were as follows:

i. Optimisation of *S. macrophylla* extraction using MAE was performed by using Response Surface Methodology (RSM) at three parameters, which were time (3, 5 and 7 min), solvent to solid ratio (10, 20 and 30 mL/g) and microwave power (300, 400 and 500 W) using seed oil yield as the response.

ii. Extraction of *S. macrophylla* seed oil was performed at optimum conditions according to previous research using SE with solvent to solid ratio 50:1, ethanol as solvent and 6 h extraction time (Mohan et al., 2016) and SC-CO_2 with 710 μm particle size, temperature 67.88ºC and pressure at 29.02 MPa (Hartati et al., 2018) .

iii. Characterisation of the oil extracted from SE, SC-CO_2 and MAE at optimum conditions using total phenolic content (TPC) and antioxidant assays including DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity and ABTS (2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulphonic acid)) radical cation decolorisation assay. Investigation on *in vitro* study of antimicrobial activity of *S. macrophylla* oil was conducted by using disk diffusion assay by using *Escherichia coli* as gram negative and *Bacillus subtilis* as gram positive and *in vitro* study of antidiabetic activity of *S. macrophylla* oil was analysed by α-amylase and α-glucosidase enzymes inhibition assays. Linoleic acid content was evaluated by using Gas Chromatography Mass Spectrometry (GC-MS) analysis.

1.5 Significance of the Study

i. The data obtained from the optimised extraction of *S. macrophylla* seed oil by using microwave assisted extraction would be very useful because there is no extraction of *S. macrophylla seed* oil by using microwave assisted method yet. It is important to always seek for new alternative method to enhance the extraction method and produce better yield quality.

ii. The study of antidiabetic property of *S. macrophylla* seeds using α-amylase and α-glucosidase enzymes inhibition assays can be contributed in the pharmaceutical and nutraceutical industries.

iii. The correlation between linoleic acid content in the oil extract and the antidiabetic activities is important to prove that linoleic acid is one of the major contributing bioactive compounds towards antidiabetic activities.

REFERENCES

Al-Hamamre, Z., Foerster, S., Hartmann, F., Kröger, M., & Kaltschmitt, M. (2012) ‘Oil extracted from spent coffee grounds as a renewable source for fatty acid methyl ester manufacturing’, *Fuel*, 96, pp. 70–76.

Alara, O. R., Abdurahman, N. H., Mudalip, S. K. A., & Olalere, O. A. (2018) ‘Microwave-assisted extraction of Vernonia amygdalina leaf for optimal recovery of total phenolic content’, *Journal of Applied Research on Medicinal and Aromatic Plants*, pp. 1-9.

Ali, H., Houghton, P. J., & Soumyanath, A. (2006) ‘α-Amylase inhibitory activity of some Malaysian plants used to treat diabetes; with particular reference to *Phyllanthus amarus', Journal of Ethnopharmacology*, 107(3), pp. 449–455.

Alqahtani, F. Y., Aleanizy, F. S., Mahmoud, A. Z., Farshori, N. N., Alfaraj, R., Al-sheddi, E. S., & Alsarra, I. A. (2018) ‘Chemical composition and antimicrobial, antioxidant, and anti-inflammatory activities of *Lepidium sativum* seed oil’, *Saudi Journal of Biological Sciences*, pp. 5–8.

Aris, N. A., Zaini, A. S., Nasir, H. M., Idham, Z., Vellasamy, Y., & Yunus, M. A. C. (2018) ‘Effect of particle size and co-extractant on Momordica charantia extract yield and diffusion coefficient using supercritical CO_2’, *Malaysian Journal of Fundamental and Applied Sciences*, 14(3), pp. 368–373.

Azmir, J., Zaidul, I. S. M., Rahman, M. M., Sharif, K. M., Mohamed, A., Sahena, F., Omar, A. K. M. (2013) ‘Techniques for extraction of bioactive compounds from plant materials : A review’, *Journal of Food Engineering,* 117, pp. 426–436.

Azwanida, N. N., (2015) ‘A Review on the Extraction Methods Use in Medicinal Plants, Principle, Strength and Limitation’ *Medicinal & Aromatic Plants,* 4(3), pp. 1-6.

Bacsal, K., Chavez, L., Diaz, I., Espina, S., Javillo, J., Manzanilla, H., Motalban, J., Panganiban, C., Rodriguez, A., Sumpaico, C., Talip, B. & Yap, S. (1997) ‘The Effect of Swietenia Mahogani (Mahogany) Seed Extract On Indomethacin-Induced Gastric Ulcers In Female Sprague- Dawley Rats’, *Acta Medica Philippina*, 3, pp. 127-139.

Belwal, T., Ezzat, S. M., Rastrelli, L., Bhatt, I. D., Daglia, M., Baldi, A., Devkota, H. P., Orhan, I. E., Patra, J. K., Das, G., Anandharamakrishnan, C., Gomez-Gomez, L., Nabavi, S. F., Nabavi, S. M., Atanasoz, A.G. (2018) 'A Critical Analysis of Extraction Techniques Used for Botanicals: Trends, Priorities, Industrial Uses and Optimization Strategies', *Trends in Analytical Chemistry*, 100, pp. 82–102.

Benmoussa, H., Elfalleh, W., He, S., Romdhane, M., Benhamou, A., & Chawech, R. (2018) 'Microwave hydrodiffusion and gravity for rapid extraction of essential oil from Tunisian cumin (*Cuminum cyminum L.*) seeds: Optimization by response surface methodology' *Industrial Crops and Products*, 124, pp. 633–642. doi.org/10.1016/j.indcrop.2018.08.036

Bera, T. K., Chatterjee, K., Jana, K. Ali, K. M., De, D., Maiti, S., Ghosh, D. (2012) 'Antihyperglycemic and antioxidative effect of hydro - methanolic (2:3) extract of the seed of Swietenia mahagoni (L.) Jacq. in streptozotocin-induced diabetic male albino rat: An approach through pancreas', *Genomic Medicine, Biomarkers, and Health Sciences*, 4(4), pp. 107-117.

Bernhoft, A. (2010) 'Bioactive Compounds in Plants: Benefits and Risks for Man and Animals' *Proceeding of Symposium The Norwegian Academy*, pp. 11–17.

Bhagour, K., Arya, D., Gupta, R. S. (2016) 'A Review: Antihyperglycemic Plant Medicines in Management of Diabetes', Acupunture and Related Therapies, pp. 8-15.

Bimakr, M., Rahman, R. A., Taip, F. S., Adzahan, N. M., Islam Sarker, M. Z., & Ganjloo, A. (2013) 'Supercritical carbon dioxide extraction of seed oil from winter melon (*Benincasa hispida*) and its antioxidant activity and fatty acid composition', *Molecules*, 18(1), pp. 997–1014.

Bothon, F. T., Debiton, E., Avlessi, F., Forestier, C., Teulade, J. C., & Sohounhloue, D. K. (2013) 'In vitro biological effects of two anti-diabetic medicinal plants used in Benin as folk medicine', *BMC Complementary and Alternative Medicine*, 13(51), pp. 1-8. doi.org/1472-6882-13-51.

Bourdy, G., DeWalt, S.J., Chávez de Michel, L.R., Roca, A., Deharo, E., Muñozd, V., Balderrama, L., Quenevof, C., Gimenezg, A. (1997) 'Medicinal plants uses of the Tacana, an Amazonian Bolivian ethnic group', *Journal of Ethnopharmacology,* 70 (2000), pp. 87- 109.

Calle, I. de la, & Costas-Rodríguez, M. (2017) 'Microwaves for Greener Extraction', *The Application of Green Solvents in Separation Processes*, pp. 253-300.

Calo, J. R., Crandall, P. G., O'Bryan, C. A., & Ricke, S. C. (2014) 'Essential Oils as Antimicrobials in Food Systems–A Review'; *Food Control*, 54, pp. 111-119.

Castilla-guerra, L., Fernandez-moreno, C., Leon-jimenez, D., & Carmona-nimo, E. (2018) 'Antidiabetic drugs and stroke risk . Current evidence', *European Journal of Internal Medicine*, 48, pp. 1–5.

Castro, M. D. L. de, & Priego-Capote, F. (2010) 'Soxhlet extraction: Past and present panacea', *Journal of Chromatography A*, 1217(16), pp. 2383–2389.

Chakrabarty, M. M., & Chowdhuri, D. K. (1956) 'The Fatty Acid Composition of the Seed Fat from *Swietenia Macrophylla*'. *The Journal of the American Oil Chemists' Society*, pp. 489–490.

Chan, C. H., Yusoff, R., Ngoh, G. C., & Kung, F. W. L. (2011) 'Microwave-assisted extractions of active ingredients from plants', *Journal of Chromatography A*, 1218(37), pp. 6213–6225. http://doi.org/10.1016/j.chroma.2011.07.040.

Chemat, S., Aït-Amar, H., Lagha, A., & Esveld, D. C. (2005) 'Microwave-assisted extraction kinetics of terpenes from caraway seeds', *Chemical Engineering and Processing: Process Intensification*, 44(12), pp. 1320–1326.

Choudhury, H., Pandey, M., Kui, C., Shi, C., Koh, J., Kong, L., Ern, L . Y., Ashraf, N. A., Soohg, W. K., Tan, S. Y., Pichika, M. R., Gorain, B., Kesharwani, P. (2018) 'An update on natural compounds in the remedy of diabetes mellitus : A systematic *review' Journal of Traditional Complementary Medicine*, 8(3), pp. 361–376. http://doi.org/10.1016/j.jtcme.2017.08.012.

Cömert, E. D., & Gökmen, V. (2018) 'Evolution of food antioxidants as a core topic of food science for a century', *Food Research International*, 105, pp. 76–93.

Corte, C. Della, Iasevoli, S., Strologo, A. Dello, Sanseviero, M., & Nobili, V. (2018) 'Omega-3 Fatty Acids and Fatty Liver Disease in Children' *Advances in Food and Nutrition Research*, 85(1), pp. 59-77.

Dahmoune, F., Nayak, B., Moussi, K., Remini, H., & Madani, K. (2015) 'Optimization of microwave-assisted extraction of polyphenols from *Myrtus communis L.* Leaves', *Food Chemistry*, 166, pp. 585–595.

Dahmoune, F., Spigno, G., Moussi, K., Remini, H., Cherbal, A., & Madani, K. (2014) '*Pistacia lentiscus* leaves as a source of phenolic compounds: Microwave-assisted extraction optimized and compared with ultrasound-assisted and conventional solvent extraction', *Industrial Crops and Products*, 61, pp. 31–40. http://doi.org/10.1016/j.indcrop.2014.06.035.

de Castro, M. D. L., & Castillo-Peinado, L. S. (2016) *Innovative Food Processing Technologies: Extraction, Separation, Component Modification and Process Intensification*. Woodhead Publishing. pp. 57-110. http://doi.org/10.1016/B978-0-08-100294-0.00003-1.

De, D., Chatterjee, K., Ali, K. M., Bera, T. K., & Ghosh, D. (2011) 'Antidiabetic Potentiality of the Aqueous-Methanolic Extract of Seed of Swietenia mahagoni (L .) Jacq . in Streptozotocin-Induced Diabetic Male Albino Rat : A Correlative and Evidence-Based Approach with Antioxidative and Antihyperlipidemic Activities', *Evidence-Based Complementary and Alternative Medicine*, pp. 1-12. http://doi.org/10.1155/2011/892807.

Dean, J. R., & Tyne, N. (2012) *Comprehensive Sampling and Sample Preparation, E-book library* [online]. Available at: http://doi.org/10.1016/B978-0-12-381373-2.10048-X.

Dewanjee, S., & Maiti, A. (2011) 'Swietenine, Big Leaf Mahogany (*Swietenia macrophylla*) Seed Extract as a Hypoglycemic Agent', *Nuts and Seeds in Health and Disease Prevention,* pp. 205–212.

Dharmalingam, K., Tan, B. K., Mahmud, M. Z., Sedek, S. A., Majid, M. I., Kuah, M. K., Sulaiman, S. F., Ooi, K. L., Khan, N. A., Muhammad, T. S., Tan, M. W., Shu-Chien, A. C. (2012) 'Swietenia macrophylla extract promotes the ability of Caenorhabditis elegans to survive Pseudomonas aeruginosa infection', *J Ethnopharmacol.*, 139(2), pp. 657-63

Divya, Khare., Pradeep, H.R., Kumar, K. K., Hari Venkatesh, K.R., Jyothi, T. (2012) 'Herbal Drug Swietenia Mahagoni Jacq. - A Review', *Global J Res. Med. Plants & Indigen. Med.*, 1(10), pp.557–567.

Efthymiopoulos, I., Hellier, P., Ladommatos, N., Kay, A., & Mills-Lamptey, B. (2017) 'Effect of Solvent Extraction Parameters on the Recovery of Oil from Spent Coffee Grounds for Biofuel Production', *Waste and Biomass Valorization*, pp. 1–12. http://doi.org/10.1007/s12649-017-0061-4.

Ekezie, F. G. C., Sun, D. W., & Cheng, J. H. (2017) 'Acceleration of microwave-assisted extraction processes of food components by integrating technologies and applying emerging solvents: A review of latest developments', *Trends in Food Science and Technology*, 67, pp. 160–172.

Eleazu, C., Charles, A., Eleazu, K., & Ngozi Achi. (2018) 'Free fatty acid receptor 1 as a novel therapeutic target for type 2 diabetes mellitus-current status', *Chemico-Biological Interactions*, 289, pp. 32–39.

Farhadpour, M., Hashempour, H., Talebpour, Z., A-Bagheri, N., Shushtarian, M. S., Gruber, C. W., & Ghassempour, A. (2016) 'Microwave-assisted extraction of cyclotides from *Viola ignobilis'*, *Analytical Biochemistry*, 497, pp. 83–89. http://doi.org/10.1016/j.ab.2015.12.001.

Favareto, R. et al. (2017) 'Study of the supercritical extraction of Pterodon fruits (*Fabaceae*)', *Journal of Supercritical Fluids*, 128, pp.159–165.

Ferreira, S. L. C., Bruns, R. E., Ferreira, H. S., Matos, G. D., David, J. M., Brandão, G. C., Ferreira, H. S. (2007). 'Box-Behnken design: An alternative for the optimization of analytical methods', *Analytica Chimica Acta*, 597(2), pp. 179–186. https://doi.org/10.1016/j.aca.2007.07.011

Figueiredo-González, M., Grosso, C., Valentão, P., & Andrade, P. B. (2016) 'α-Glucosidase and α-amylase inhibitors from *Myrcia* spp.: A stronger alternative to acarbose?', *Journal of Pharmaceutical and Biomedical Analysis*, 118, pp. 322–327.

Gaikwad, S. B., Krishna Mohan, G., & Sandhya Rani, M. (2014) 'Phytochemicals for Diabetes Management', *Pharmaceutical Crops*, *5*, pp. 11–28.

Ghafoor, K., Özcan, M. M., Al-juhaimi, F., & Babiker, E. E. (2018) 'Changes in quality, bioactive compounds, fatty acids, tocopherols, and 2 phenolic composition in oven- and microwave-roasted poppy seeds and oil', *LWT - Food Science and Technology*, pp. 1–21.

Guevara, A.P., Apilado, A., Sakurai, H., Kozuka, M. (1996) 'Anti-inflammatory, antimutagenicity, and antitumor-promoting activities of mahogany seeds, Swietenia macrophylla (Meliaceae)', *Philippine Journal of Science,* 125(4), pp. 271-277.

Gustinelli, G., Eliasson, L., Svelander, C., Alminger, M., & Ahrné, L. (2018) 'Supercritical CO_2 extraction of bilberry (*Vaccinium myrtillus L.*) seed oil: fatty acid composition and antioxidant activity', The Journal of Supercritical Fluids, 135, pp. 91–97. http://doi.org/10.1016/j.supflu.2018.01.002.

Hammer, K. A., Carson, C. F., & Riley, T. V. (1999) 'Antimicrobial activity of essential oils and other plant extracts', *Journal of Applied Microbiology*, 86(6), pp. 985–990.

Hammi, K. M., Jdey, A., Abdelly, C., Majdoub, H., Ksouri, R. (2015) 'Optimization of ultrasound-assisted extraction of antioxidant compounds from Tunisian Zizyphus lotus fruits using response surface methodology', *Food Chemistry*, 184, pp. 80-89.

Hartati, Salleh, L. M., Pagarra, H., & Rachmawaty. (2018) 'Response Surfaces of Linoleic Acid of Swietenia Mahagoni in Supercritical Carbon Dioxide', *Journal of Physics Conference Series,* 1028(1), pp. 1-6.

Hartati, Salleh, L. M., Yunus, M. A. C., & Aziz, A. A. (2014) 'Optimization of Supercritical CO_2 Extraction of Swietenia Mahagoni Seed by Response Surface Methodology', *Jurnal Teknologi,* 1, pp. 15–20.

Hashim, M. A., Yam, M. F., Hor, S. Y., Lim, C. P., Asmawi, M. Z., & Sadikun, A. (2013) 'Anti-hyperglycaemic activity of *swietenia macrophylla* king (meliaceae) seed extracts in normoglycaemic rats undergoing glucose tolerance tests', *Chinese Medicine*, 8(1), pp. 1–8. http://doi.org/10.1186/1749-8546-8-11.

Herrero, M., Cifuentes, A., Ibañez, E. (2006) 'Sub- and Supercritical Fluid Extraction of Functional Ingredients from Different Natural Sources: Plants, Food-Byproducts, Algae and Microalgae', *Food Chemistry*, pp. 136-148.

Hill, R. A., and Connolly, J. D. (2013) 'Triterpenoids', *Natural Product Reports*, 30(7), pp. 1028-1065.

Hu, B., Zhou, K., Liu, Y., Liu, A., Zhang, Q., Han, G., & Liu, S. (2018) 'Optimization of microwave-assisted extraction of oil from tiger nut (*Cyperus esculentus L* .) and its quality evaluation', *Industrial Crops & Products,* 115, pp. 290–297.

Ibrahim, N. A., Zaini, M. A. A., (2017) 'Solvent Selection in Microwave Assisted Extraction of Castor Oil', *Chemical Engineering Transactions*, 56, pp. 865–870.

Issa, I. A., & Bule, M. H. (2015) 'Hypoglycemic Effect of Aqueous and Methanolic Extract of Artemisia afra on Alloxan Induced Diabetic Swiss Albino Mice', *Evidence-Based Complementary and Alternative Medicine*, pp. 1-5.

Ivanovic, J., Ristic, M., & Skala, D. (2011) 'Supercritical Fluids Supercritical CO_2 extraction of Helichrysum italicum : Influence of CO_2 density and moisture content of plant material', *The Journal of Supercritical Fluids*, 57(2), pp. 129-136. doi.org/10.1016/j.supflu.2011.02.013.

Jahongir, H., Miansong, Z., Amankeldi, I., Yu, Z., & Changheng, L. (2018) 'The influence of particle size on supercritical extraction of dog rose (*Rosa canina*) seed oil', *Journal of King Saud University - Engineering Sciences*, 1-4.

Janssen, A., Scheffer, J., & Svendsen, A. (1987) 'Antimicrobial Activity of Essential Oils: A 1976-1986 Literature Review. Aspects of the Test Methods', *Planta Medica*, 53(5), pp. 395–398. http://doi.org/10.1055/s-2006-962755.

Jemain, M., Musa, M. N., Rohaya, A., Rashid, L. A., & Hadiani, I. N. (2011) 'In vitro antihyperglycaemic effects of some Malaysian plants', *Journal of Tropical Forest Science*, 23(4), pp. 467–472.

Jiao, J., Li, Z. G., Gai, Q. Y., Li, X. J., Wei, F. Y., Fu, Y. J., & Ma, W. (2014) 'Microwave-assisted aqueous enzymatic extraction of oil from pumpkin seeds and evaluation of its physicochemical properties, fatty acid compositions and antioxidant activities', *Food Chemistry*, 147, pp. 17–24.

Juhaimi, F. A. L., Musa Özcan, M., Ghafoor, K., & Babiker, E. E. (2018). 'The effect of microwave roasting on bioactive compounds, antioxidant activity and fatty acid composition of apricot kernel and oils', *Food Chemistry*, 243, pp. 414–419.

Kala, H., Mehta, R., Sen, K., Tandey, R., & Mandal, V. (2016) 'Trends in Analytical Chemistry Critical analysis of research trends and issues in microwave assisted extraction of phenolics : Have we really done enough', *Trends in Analytical Chemistry*, 85, pp. 140–152. http://doi.org/10.1016/j.trac.2016.09.007.

Kamel, F. O., Magadmi, R. M., Hagras, M. M., Magadmi, B., & AlAhmad, R. A. (2017) 'Knowledge, attitude, and beliefs toward traditional herbal medicine use among diabetics in Jeddah Saudi Arabia', *Complementary Therapies in Clinical Practice*, 29, pp. 207–212. http://doi.org/10.1016/j.ctcp.2017.10.007.

Kanti, T., Chatterjee, K., Jana, K., Monjur, K., De, D., Maiti, S., & Ghosh, D. (2013) 'Antihyperglycemic and antioxidative effect of hydro - methanolic (2: 3) extract of the seed of *Swietenia mahagoni* (L.) Jacq. in streptozotocin-induced diabetic male albino rat: An approach through pancreas', *Genomic Medicine, Biomarkers, and Health Sciences*, 4(4), pp. 107–117.

Kandhro, A., Shezari, S. T. H., Mahesar, S. A., Bhanger, M. I. (2008) 'GC-MS quantification of fatty acid profile including trans FA in the locally manufactured margarines of Pakistan', *Food Chemistry*, 109, pp. 207-211.

Keisandokht, S., Haddad, N., Gariepy, Y., & Orsat, V. (2018) 'Screening the microwave-assisted extraction of hydrocolloids from *Ocimum basilicum L.* seeds as a novel extraction technique compared with conventional heating-stirring extraction', *Food Hydrocolloids*, 74, pp. 11–22.

Khare Divya, Pradeep H.R., Kumar K. K., Hari Venkatesh K.R, J. T. (2012). Herbal Drug Swietenia Mahagoni Jacq. - A Review, 1(10), *Global Journal of Research on Medicinal Plants & Indigenous Medicine*, pp. 557–567.

Khaw, K.-Y., Parat, M.-O., Shaw, P. N., & Falconer, J. R. (2017) 'Solvent Supercritical Fluid Technologies to Extract Bioactive Compounds from Natural Sources: A Review', *Molecules*, 22(7), pp. 1186.

Koba, K., & Yanagita, T. (2013) 'Health benefits of conjugated linoleic acid (CLA)', *Obesity Research & Clinical Practice*, pp. 1–8.

Kondamudi, N., Mohapatra, S. K., & Misra, M. (2008) 'Spent Coffee Grounds as a Versatile Source of Green Energy', *Journal of Agricultural and Food Chemistry*, 56(24), pp. 11757–11760. http://doi.org/10.1021/jf802487s.

Koyu, H., Kazan, A., Demir, S., Haznedaroglu, M. Z., & Yesil-Celiktas, O. (2018) 'Optimization of microwave assisted extraction of *Morus nigra L.* fruits maximizing tyrosinase inhibitory activity with isolation of bioactive constituents', *Food Chemistry*, 248, pp. 183–191.

Li. D. D., Chena, J. H., Chen, Q., Li, G. W. (2005) 'Swietenia mahagony extract shows agonistic activity to PPAR gamma and gives ameliorative effects on diabetic db/db mice' *Acta Pharmacologica Sinica*, 26(2), pp. 220-222.

Lopez-avila, V. (2000). *Techniques and Instrumentation in Analytical Chemistry*, 21, pp. 115-153. *E-book library* [online]. Available at: https://doi.org/10.1016/S0167-9244(00)80009-8.

Lu, X., Zheng, Z., Li, H., Cao, R., Zheng, Y., Yu, H., Zheng, B. (2017) 'Optimization of ultrasonic-microwave assisted extraction of oligosaccharides from lotus (*Nelumbo nucıfera Gaertn.*) seeds', *Industrial Crops and Products*, 107, pp. 546–557.

Luque de Castro, M. D., & García-Ayuso, L. E. (1998). Soxhlet extraction of solid materials: An outdated technique with a promising innovative future', *Analytica Chimica Acta*, 369(1–2), pp. 1–10.

Maiti, A., Dewanjee, S., Mandal, S. C., & Annadurai. (2007) 'Exploration of Antimicrobial Potential of Methanol and Water Extract of Seeds of *Swietenia Macrophylla* (Family: Meliaceae), to Substantiate Folklore Claim', *Iranian Journal of Pharmacology and Therapeutics*, 6, pp. 99–102.

Maiti, A., Dewanjee, S. Jana, G., Mandal, S. C. (2008) 'Hypoglycemic effect of Swietenia macrophylla seeds against type II diabetes'*, International Journal of Green Pharmacy*, pp. 224-227.

Mandal, V., & Siva, H. (2006) 'Microwave Assisted Extraction - An Innovative and Promising Extraction Tool for Medicinal Plant Research, *Pharmacognosy Reviews,* 1(1), pp. 7–18.

Mandana, B., Russly, A. R., Farah, S. T., Noranizan, M. A., Zaidul, I. S., & Ali, G. (2012) 'Antioxidant activity of winter melon (benincasa hispida) seeds using conventional soxhlet extraction technique', *International Food Research Journal*, 19(1), pp. 229–234.

Maran, J. P., & Priya, B. (2015) 'Supercritical fluid extraction of oil from muskmelon (*Cucumis melo*) seeds', *Journal of the Taiwan Institute of Chemical Engineers*, 47, pp. 71–78.

McLaughlin, S., Chaney, D., Belton, A., & Garst, J. (2015) 'International Standards for Education of Diabetes Health Professionals', *International Diabetes Federation*, pp. 15–27. Retrieved from www.idf.org.

Miller, G. L. (1959) 'Use of Dinitrosalicylic Acid Reagent for Determination of Reducing Sugar', *Analytical Chemistry*, 31(3), pp. 426–428.

Moghadamtousi, S. Z., Goh, B. H., Chan, C. K., Shabab, T., & Kadir, H. A. (2013) 'Biological activities and phytochemicals of *Swietenia macrophylla* king', *Molecules*, 18(9), pp 10465–10483.

Mohan, M. R., Jala, R. C. R., Kaki, S. S., Prasad, R. B. N., & Rao, B. V. S. K. (2016) '*Swietenia mahagoni* seed oil: A new source for biodiesel production', *Industrial Crops and Products*, 90, pp. 28–31.

Morais, S. (2013) *Functional Ingredients from Algae for Foods and Nutraceuticals.* Woodhead Publishing. pp. 586–601.

Moreira, M. M., Barroso, M. F., Boeykens, A., Withouck, H., Morais, S., & Delerue-Matos, C. (2017) 'Valorization of apple tree wood residues by polyphenols extraction: Comparison between conventional and microwave-assisted extraction', *Industrial Crops and Products*, 104, 210–220.

Nagy, B., & Simándi, B. (2008) 'Effects of particle size distribution, moisture content, and initial oil content on the supercritical fluid extraction of paprika', *The Journal of Supercritical Fluids*, 46(3), pp. 293–298.

Naveen, Y. P. uttaswamy, Divya Rupini, G., Ahmed, F., & Urooj, A. (2014) 'Pharmacological effects and active phytoconstituents of Swietenia mahagoni: a review', *Journal of Integrative Medicine*, 12(2), pp. 86–93.

Nde, D. B., Boldor, D., & Astete, C. (2015) 'Optimization of microwave assisted extraction parameters of neem (*Azadirachta indica A. Ju*ss) oil using the Doehlert 's experimental design. *Industrial Crops & Products*, 65(7), pp. 233–240.

Olalere, O. A., Abdurahman, N. H., Yunus, R. bin M., Alara, O. R., & Akbari, S. (2018) 'Evaluation of optimization parameters in microwave reflux extraction of piperine-oleoresin from black pepper (*Piper nigrum*). *Beni-Suef University Journal of Basic and Applied Sciences*, pp. 1-6.

Olokoba, A. B., Obateru, O. A., & Olokoba, L. B. (2012) 'Type 2 diabetes mellitus: a review of current trends', *Oman Medical Journal*, 27(4), pp. 269–273.

Orsat, V., & Routray, W. (2017) *Water Extraction of Bioactive Compounds from Plants to Drug Development*, Elsevier. pp. 221–244.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., Anthony, S. (2009) '*Agroforestree Database:a tree reference and selection guide version 4.0*', pp. 1-5.

Palconite, C. L., Edrolin, A. C., Lustre, S. N. B., Manto, A. A., Caballero, J. R. L., Tizo, M. S., Ido, A. L., Arazo, R. O. (2018) 'Optimization and characterization of bio-oil produced from Ricinus communis seeds via ultrasonic-assisted solvent extraction through response surface methodology', *Sustainable Environment Research.* 28(6), pp. 444-453.

Pandey, R., & Shrivastava, S. L. (2018) ‘Comparative evaluation of rice bran oil obtained with two-step microwave assisted extraction and conventional solvent extraction’ *Journal of Food Engineering*, 218, pp. 106–114.

Parry, J., Su, L., Luther, M., Zhou, K., Peter Yurawecz, M., Whittaker, P., & Yu, L. (2005) ‘Fatty acid composition and antioxidant properties of cold-pressed marionberry, boysenberry, red raspberry, and blueberry seed oils’, *Journal of Agricultural and Food Chemistry*, 53(3), pp. 566–573.

Patel, D. K., Kumar, R., Laloo, D., & Hemalatha, S. (2012) ‘Natural medicines from plant source used for therapy of diabetes mellitus: An overview of its pharmacological aspects’, *Asian Pacific Journal of Tropical Disease*, 2(3), pp. 239–250. http://doi.org/10.1016/S2222-1808(12)60054-1.

Pereañez, J. A., Núñez, V., Rojano, B., Lobo-Echeverri, T. (2013) ‘Inhibitory effects of *Swietenia macrophylla* on myotoxic phospholipases A_2’, *Revista Brasileira de Farmacognosia,* 23(6), pp. 885-894.

Piñeiro, Z., Marrufo-Curtido, A., Vela, C., & Palma, M. (2017) ‘Microwave-assisted extraction of stilbenes from woody vine material’, *Food and Bioproducts Processing*, 103, pp. 18–26. http://doi.org/10.1016/j.fbp.2017.02.006.

Putri, L. S. E., Dasumiati, Kristiyanto, Mardiansyah, Malik, C., Leuvinadrie, L. P., & Mulyono, E. A. (2016) ‘Ethnobotanical study of herbal medicine in Ranggawulung Urban Forest, Subang District, West Java, Indonesia’, *Biodiversitas*, 17(1), pp. 172–176.

Rahman, A. K. M. S., Chowdhury, A. K. A., Ali, H. A., Raihan, S. Z., Ali, M. S., Nahar, L., & Sarker, S. D. (2009) ‘Antibacterial activity of two limonoids from Swietenia mahagoni against multiple-drug-resistant (MDR) bacterial strains’, *Journal of Natural Medicines*, 63(1), pp. 41–45. http://doi.org/10.1007/s11418-008-0287-3.

Redfern, J., Kinninmonth, M., Burdass, D., & Verran, J. (2014) ‘Using Soxhlet Ethanol Extraction to Produce and Test Plant Material (Essentian Oils) for Their Antimicrobial Properties’, *Journal of Microbiology & Biology Education*, 15(1), pp. 45–46.

Reinoso, B. D., Munoz, M. J. G., & Gonzalez, H. D. (2017). *Water Extraction of Bioactive Compound*. Elsevier. *E-book library* [online]. Available at: https://doi.org/10.1016/B978-0-12-809380-1.00001-2.

Ren, B., Chen, C., Li, C., Fu, X., You, L., & Liu, R. H. (2017) 'Optimization of microwave-assisted extraction of Sargassum thunbergii polysaccharides and its antioxidant and hypoglycemic activities', *Carbohydrate Polymers*, 173, pp. 192–201. doi.org/10.1016/j.carbpol.2017.05.094

Rivera-Chávez, J., González-Andrade, M., Del Carmen González, M., Glenn, A. E., & Mata, R. (2013) 'A-Glucosidase inhibitors from MEXU 27095, an endophytic fungus from *Hintonia latiflora*', *Phytochemistry*, 94, pp. 198–205. http://doi.org/10.1016/j.phytochem.2013.05.021.

Roy, A., & Saraf, S. (2006) 'Limonoids: Overview of Significant Bioactive Triterpenes Distributed in Plants Kingdom', *Biological & Pharmaceutical Bulletin*, 29(2), pp. 191—201.

Sahgal, G., Ramanathan, S., Sasidharan, S., Mordi, M. N., Ismail, S., & Mansor, S. M. (2009a) 'In Vitro Antioxidant and Xanthine Oxidase Inhibitory Activities of Methanolic *Swietenia mahagoni* Seed Extracts', *Molecules,* 14, pp. 4476–4485.

Sahgal, G., Ramanathan, S., Sasidharan, S., Mordi, M. N., Ismail, S., & Mansor, S. M. (2009b) 'Phytochemical and antimicrobial activity of *Swietenia mahagoni* crude methanolic seed extract', *Tropical Biomedicine*, 26(3), pp. 274–279.

Sapkale, G. N., Patil, S. M., Surwase, U. S., & Bhatbhage, P. K. (2010). Supercritical Fluid Extraction-A Review, *Int. J. Chem. Sci*, 8(2), pp. 729–743.

Sarkar, M. S., Datta, P. C., (1986) 'Pharmacognosy of *Swietenia Mahagoni* Bark Drug', *Ancient Science of Lıfe*, 5(3), pp. 172–181.

Sasidharan, S., Chen, Y., Saravanan, D., Sundram, K. M., & Latha, L. Y. (2011) 'Extraction, Isolation nd Characterization of Bioactive Compounds from Plants' Extracts', *Afr J Tradit Complement Altern Med,* 8(1), pp. 1–10.

Schmidt, L., Joker, D., (2000) 'Seed Leaflet (Swietenia Mahagoni L. Jacq,)', Denmark*: Danida Forest Seed Centre*, pp. 1.

Shreve, B., Thiex, N., & Wolf, M. (2006) '*National Forage Testing Association Reference Method: Dry Matter by Oven Drying for 3 hr at 105 °C*, pp. 1-4.

Simić, V. M., Rajković, K. M., Stojičević, S. S., Veličković, D. T., Nikolić, N., Lazić, M. L., & Karabegović, I. T. (2016) 'Optimization of microwave-assisted extraction of total polyphenolic compounds from chokeberries by response surface methodology and artificial neural network', *Separation and Purification Technology*, 160, pp. 89–97. http://doi.org/10.1016/j.seppur.2016.01.019.

Sin, H. N., Yusof, S., Hamid, N. S. A., & Rahman, R. A. (2006) ‘Optimization of enzymatic clarification of sapodilla juice using response surface methodology’, *Journal of Food Engineering,* 73(4), pp. 313–319.

Singleton, V. L., Orthofer, R., & Lamuela-Raventos, R. M. (1999) ‘Analysis of Total Phenols and Other Oxidation Substrates and Antioxidants by Means of Folin-Ciocalteu Reagent’, *Methods In Enzymology*, 299(1974), pp. 152–178.

Subhadip, H., Archana, M., Pinkee, P., Jinu, J., Pradeep, M., & Suresh, V. P. (2013) ‘Free Radical Scavenging and A-Amylase Inhibitory Activity of Swietenia Mahagoni Seeds Oil’, *International Journal of Pharmacognosy and Phytochemical Research*, 5(1), pp. 51–56.

Surya, S., Salam, A. D., Tomy, D. V., Carla, B., Kumar, R. A., & Sunil, C. (2014) ‘Diabetes mellitus and medicinal plants-a review’, *Asian Pacific Journal of Tropical Disease*, 4(5), pp. 337–347.

Suryawanshi, B., & Mohanty, B. (2018) ‘Modeling and optimization: Supercritical CO2 extraction of Pongamia pinnata (L.) seed oil’, *Journal of Environmental Chemical Engineering,* 6(2), pp. 2660–2673.

Swamy, G. J., & Muthukumarappan, K. (2017) ‘Optimization of continuous and intermittent microwave extraction of pectin from banana peels’, *Food Chemistry*, 220, pp. 108–114. http://doi.org/10.1016/j.foodchem.2016.09.197.

Tian, Y., Xu, Z., Zheng, B., & Lo, Y. M. (2013) ‘Optimization of ultrasonic-assisted extraction of pomegranate (*Punica granatum L*) seed oil’, *Ultrasonics Sonochemistry* ,20, pp. 202–208.

Tran, L., Zielinski, A., Roach, A. H., Jende, J. A., Householder, A. M., Cole, E. E., Thompson, E. E. (2015) ‘Pharmacologic Treatment of Type 2 Diabetes : Oral Medications’, *Annals of Pharmacotherapy*, 49(5), pp. 540-556.

Veggi, P. C., Martinez, J., & Meireles, M. A. A. (2013) *‘Microwave-assisted Extraction for Bioactive Compounds: Theory and Practice*, Food Engineering Series 4, http://doi.org/10.1007/978-1-4614-4830-3.

Vinatoru, M., Mason, T. J., & Calinescu, I. (2017) ‘Ultrasonically assisted extraction (UAE) and microwave assisted extraction (MAE) of functional compounds from plant materials’, *Trends in Analytical Chemistry*, 97, pp. 159–178. http://doi.org/10.1016/j.trac.2017.09.002

World Health Organization (2016) ‘Diabetes country profiles’, pp. 1. 2016

Wresdiyati, T., Sa'diah, S., Winarto, A., & Febriyani, V. (2015) 'Alpha-Glucosidase Inhibition and Hypoglycemic Activities of *Sweitenia mahagoni* Seed Extract', *HAYATI Journal of Biosciences*, 22(2), 73–78.

Wu, H., Li, C., Li, Z., Liu, R., Zhang, A., Xiao, Z., Deng, S. (2018) 'Simultaneous extraction of oil and tea saponin from *Camellia oleifera Abel.* seeds under subcritical water conditions', *Fuel Processing Technology*, 174, pp. 88–94. http://doi.org/10.1016/j.fuproc.2018.02.014.

Yanık, D. K. (2017) 'Alternative to traditional olive pomace oil extraction systems: Microwave-assisted solvent extraction of oil from wet olive pomace', *LWT - Food Science and Technology*, 77, pp. 45–51.

Yu, H., Wang, C., Deng, S., & Bi, Y. (2017) 'Optimization of ultrasonic-assisted extraction and UPLC-TOF/MS analysis of limonoids from lemon seed', *LWT - Food Science and Technology*, 84, pp. 135–142.

Yuan, X. H., Fu, L. N., Gu, C. B., Zhang, Y. D., & Fu, Y. J. (2014) 'Microwave-assisted extraction and antioxidant activity of vaccarin from the seeds of Vaccaria segetalis', *Separation and Purification Technology*, 133, pp. 91–98. http://doi.org/10.1016/j.seppur.2014.06.002.

Zhang, D. Y., Yao, X. H., Luo, M., Zhao, C. J., & Fu, Y. J. (2016) 'Optimization of negative pressure cavitation-microwave assisted extraction of yellow horn seed oil and its application on the biodiesel production', *Fuel,* 166, pp. 67–72. http://doi.org/10.1016/j.fuel.2015.10.022.

Zhang, L., Wu, H. T., Yang, F. X., & Zhang, J. H. (2015) 'Evaluation of Soxhlet extractor for one-step biodiesel production from *Zanthoxylum bungeanum* seeds', *Fuel Processing Technology*, 131, pp. 452–457.

Zhang, D. Y., Yao, X. H., Luo, M. (2016) 'Supercritical carbon dioxide extraction of seed oil from yellow horn (*Xanthoceras sorbifolia Bunge.*) and its anti-oxidant activity', *Fuel*, 166, pp. 67-72.