UNIVERSITI PUTRA MALAYSIA

EFFECT OF PROCESS VARIABLES IN SUPERCRITICAL CARBON DIOXIDE EXTRACTION OF TOCOTRIENOLS FROM PALM FATTY ACID DISTILLATE

NAJWA BINTI OTHMAN

FSTM 2022 7

EFFECT OF PROCESS VARIABLES IN SUPERCRITICAL CARBON DIOXIDE EXTRACTION OF TOCOTRIENOLS FROM PALM FATTY ACID DISTILLATE

By

NAJWA BINTI OTHMAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the degree of Master of Science

December 2021

DEDICATION

This thesis is dedicated to

My supportive parents,

My husband, family, and not to forget

To all my friends.

For their unconditional love, prayers and support through this journey.

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

EFFECT OF PROCESS VARIABLES IN SUPERCRITICAL CARBON DIOXIDE EXTRACTION OF TOCOTRIENOLS FROM PALM FATTY ACID DISTILLATE

By

NAJWA BINTI OTHMAN

December 2021

Chair : Norhidayah Binti Suleiman, PhD
Faculty : Food Science and Technology

Palm fatty acid distillate (PFAD) is a by-product of palm oil refineries that have high valuable active compounds, specifically tocotrienols. It is commonly extracted using the conventional method, but, argued for its sustainability with the huge hazardous solvent residues, time consumption, and not suitable for thermo-labile compounds. Alternatively, the green sustainable technology, supercritical carbon dioxide ($scCO_2$) extraction was employed in this work. Hence, the objectives of this study were to evaluate the effect of main process variables, namely pressure and temperature on the tocotrienols extraction and to determine optimal conditions for the recovery of tocotrienols using $scCO_2$ extraction. In addition, investigation on the static mode (90and 180 min) and solvent polarity modification by using single and pair mixtures co-solvent at optimum condition were also carried out to enhance the extraction of tocotrienols. The research began with the optimization process of tocotrienols extraction from pre-treated PFAD using $scCO_2$ at a temperature range of 40-60 °C and pressure range of 20-40 MPa for a fixed CO_2 mass flow rate of 32 ± 2 g/min anddynamic extraction time of 5 h through the Central Composite Design (CCD) with five replications of the central point. It was found that temperature had the most positive effect on the extraction of tocotrienols. The tocotrienols extraction was proportionally increased to a temperature from 40 up to 50 °C. Further increased temperature to 60 °C lowered the density of $scCO_2$ hence, reduce the solubility of the interest compound to be extracted. Pressure is also a prominent factor in the extraction of tocotrienols. The predicted best condition (20 MPa and 53 °C) by response surface methodology (RSM) produced 16.45 mg/g of tocotrienols content. Static mode for 180 minutes does significantly improve the recovery of tocotrienols (23.62 ± 0.37 mg/g). The static mode was seen to promote the interest solute transfer through the enhancement of the permeability of cell walls by rupturing the sample. Besides, solvent polarity modification with aided of co-solvents significantly increased the tocotrienols content in the extracts. The content of tocotrienols was approximately double up (30.03 ± 0.03 mg/g) with the addition of 0.075 ml/g ethanol. Following that, the

presence of 0.075 ml/g hydrogen bond donor (HBD)-hydrogen bond acceptor (HBA) pair mixtures co-solvent (isopropanol:acetone) resulted in the highest tocotrienols concentration (33.47 ± 0.29 mg/g). This indicated the chemical and physical interaction between the co-solvent and the interest solute molecule, thus, improved the solubility of tocotrienols in the $scCO_2$ system. In summary, tocotrienols could be extracted from PFAD using $scCO_2$ and further improved with slight modifications to the techniques. The solvent polarity modification of the $scCO_2$ exhibited the best technique to improved the tocotrienols content, which may be related to the wide range of polarities. Herein, ethanol (0.075 ml/g) was chosen to improve the tocotrienols extraction since there were no significantly differences between single co-solvent of ethanol and pair mixtures co-solvent of isopropanol-acetone.

Keywords**:** Palm fatty acid distillate; Supercritical carbon dioxide extraction; Tocotrienols; Polarity modification; Static-mode extraction

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

KESAN PEMBOLEH UBAH SUPERKRITIKAL KARBON DIOKSIDA TERHADAP EKSTRAK TOKOTRIENOL DARIPADA SULINGAN ASID LEMAK SAWIT

Oleh

NAJWA BINTI OTHMAN

Disember 2021

Pengerusi : Norhidayah Binti Suleiman, PhD
Fakulti : Sains dan Teknologi Makanan

Sulingan asid lemak sawit (PFAD) adalah produk sampingan dari kilang minyak sawit yang mempunyai komponen aktif yang bernilai tinggi, khususnya tokotrienol. Tokotrienol biasanya diekstrak menggunakan kaedah konvensional, tetapi ia bertentangan dengan kelestarian alam seperti penghasilan sisa pelarut bahaya yang banyak, penggunaan masa yang terlalu lama, dan ia tidak sesuai untuk komponen yang termolabil. Sebagai alternatif, teknologi lestari hijau seperti pengekstrakan superkritikal karbon dioksida ($scCO_2$) digunakan dalam penyelidikan ini. Oleh itu, objektif kajian ini adalah untuk menilai kesan pemboleh ubah proses, iaitu tekanan dan suhu pada pengekstrakan tokotrienol dan untuk menentukan keadaan optimal untuk pengekstrakan tokotrienol dengan teknik $scCO_2$. Selain itu, ujikaji terhadap mod statik (90 dan 180 minit) dan pengubahsuaian polariti karbon dioksida dengan menggunakan pelarut tunggal dan pelarut campuran pada keadaan optimal juga dilakukan untuk meningkatkan pengekstrakan tokotrienol. Penyelidikan dimulakan dengan mencari keadaan optimal untuk pengekstrakan tokotrienol daripada PFAD yang telah dihidrolisis menggunakan $scCO_2$ pada julat suhu 40-60 °C dan tekanan 20- 40 MPa serta pada aliran jisim tetap CO_2 32 ± 2 g/min dan masa pengekstrakan dinamik selama 5 jam melalui Reka Bentuk Komposit Pusat (CCD) dengan lima ulangan pada titik pusat. Ia didapati bahawa suhu mempunyai kesan yang paling positif terhadap pengekstrakan tokotrienol. Tokotrienol meningkat secara berkadar dari suhu 40 °C hingga 50 °C. Pada suhu tinggi iaitu 60 °C, ketumpatan $scCO_2$ adalah lebih rendah dan ini mengurangkan kelarutan komponen yang akan diekstrak. Tekanan juga merupakan faktor utama dalam pengekstrakan tokotrienol. Dengan menggunakan kaedah permukaan tindak balas (RSM), keadaan optimal telah diramalkan (20 MPa dan 53 °C) dengan menghasilkan 16.45 mg/g kandungan tokotrienol. Mod statik selama 180 minit meningkatkan tokotrienol secara signifikan (23.62 ± 0.37 mg/g). Mod statik dilihat dapat menaikkan pemindahan zat terlarut melalui peningkatan keboleh telapan dinding sel melalui pemecahan pada sampel. Selain itu, pengubahsuaian polariti pelarut dengan bantuan pelarut dapat meningkatkan kandungan tokotrienol dalam ekstrak. Kandungan tokotrienol meningkat dua kali ganda (30.03 ± 0.03 mg/g) dengan penambahan 0.075 ml/g etanol. Selain itu, 0.075 ml/g pelarut

campuran HBD-HBA seperti isopropanol: aseton menghasilkan tokotrienol yang tinggi (33.47 ± 0.29 mg/g). Ini menunjukkan interaksi kimia dan fizikal antara pelarut dengan molekul zat terlarut, oleh itu kelarutan tokotrienol dalam sistem $scCO_2$ dapat ditingkatkan. Secara ringkasnya, tokotrienol dapat diekstrak daripada PFAD dengan menggunakan $scCO_2$ dan sedikit pengubahsuaian dalam teknik $scCO_2$. Pengubahsuaian polariti pelarut $scCO_2$ merupakan teknik terbaik untuk meningkatkan kandungan tokotrienol yang mungkin berkaitan dengan pelbagai julat polariti. Di sini, etanol (0.075 ml/g) telah dipilih untuk meningkatkan pengekstrakan tokotrienol kerana terdapat perbezaan yang tidak signifikan antara etanol dan pelarut campuran, isopropanol-aseton.

Kata kunci**:** Sulingan asid lemak sawit; Superkritikal karbon dioksida; Tokotrienol; Pengubahsuaian polariti; Pengekstrakan mod-statik

ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious, the Most Merciful. All praise is only for Allah. With His mercy and guidance, I am so grateful that being so blessed with strength, patience and faith along completing this research journey. No word can describe this feeling when this thesis is successfully materialized. Indeed, with every hardship, there is ease. I would like to express my sincere gratitude and appreciation to my great and kind supervisor, Dr Norhidayah Binti Suleiman, for her patience, motivation, inspiration, and encouragement throughout my challenges in completing this study. I would like to express my appreciation to my co-supervisors, Associate Professor Dr Chong Gun Hean and Dr Ezzat Binti Mohamad Azman for their contributions towards the success of completing this research. May Allah bless them and repay their kindness. I want to thank all the lecturers, officers, and staff for the technical support and facilities provided especially at Faculty of Food Science and Technology, Universiti Putra Malaysia. I owe a special thanks to my beloved parents, Mr Othman Md Lazim and Mrs Khalijah Mohamad, my husband, Mr Ahmad Aizuddin Faiz and my family, for their endless support, prayers, and encouragement. Not forgotten, sincere thanks to all those who indirectly contribute to this research. Finally, acknowledgements credited to Universiti Putra Malaysia for financial support.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the Master of Science. The members of the Supervisory Committee were as follows:

Norhidayah Binti Suleiman, PhD
Senior Lecturer
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Chairman)

Chong Gun Hean, PhD
Associate Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Member)

Ezzat Binti Mohamad Azman, PhD
Senior Lecturer
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Member)

_____
ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 19 May 2022

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

PFAD	Palm fatty acid distillate
FFA	Free fatty acid
$scCO_2$	Supercritical carbon dioxide
SFE	Supercritical fluid extraction
SCF	Supercritical fluid
CPO	Crude palm oil
T3	Tocotrienols
T	Tocopherols
GDP	Gross domestic product
PKO	Palm kernel oil
MPOC	Malaysia
MPOB	Malaysia Palm Oil Board
IV	Iodine value
PV	Peroxide value
SV	Saponifiable value
RBD	Refined, bleached, and deodorized
AV	Acid value
FAD	Fatty acid distillate
RSM	Response surface methodology
CCD	Central composite design
KT	Kamlet-Taft
HBA	Hydrogen bond acceptor
HBD	Hydrogen bond donor
HPLC	High-performance liquid chromatography
RP-LC	Reverse phase liquid chromatography
PFP	Pentafluorophenyl

CHAPTER 1

INTRODUCTION

1.1 Overview

By-product is a secondary product or waste that is derived from the manufacture or production of a primary product. It can be categorized as agricultural or forestry waste, sewage, manure, sawdust or food scarps (Jablonský et al., 2018). Approximately, in a year, 998 million tons of agriculture waste was produced globally and Malaysia recorded about 1.2 million tons per year that disposed into landfills (Ali, 2020). About 77% of agriculture waste is from oil palm industries and the remaining are from rice residues, forestry residues, rubber, cocoa, and coconut (Hamzah et al., 2019). It has been reported, 75% of palm oil waste are from plantation sites which are oil palm fronds (OPF) and oil palm trunks (OPT) and the remaining 25% from mill sites in form of empty fruit bunch (EFB), mesocarp fibre (MF), palm kernel shell (PKS), and palm oil mill effluent (POME) that produced during the extraction of palm oil from fruit bunch (Hamzah et al., 2019).

Proper management of the by-product from industries will help to initiate the entire life cycle of the circular economy concept through reuse/ recycle medium to support zero waste while generating advantages on both environment and economy at the same time (European Commission, 2020). Improper waste management may cause environmental risk specifically high amounts of gases such as N_2O, SO_2, CH_4 and smoke are generated which can pollute the air, besides, improper waste management may cause water and soil deterioration which can risk human health (Hsu, 2021; He et al., 2019). Proper waste management via reuse or recycle can be beneficial to environmental protection (He et al., 2019). Waste from the palm oil industry can be transformed into a useful product such as biogas, animal feed, soil fertilizer, fermentation media, and yeast production (Zuber et al., 2019). According to Zuber et al. (2019) and Estiasih et al. (2013), the oil residue from palm oil refining of main treatment of POME known as palm fatty acid distillate (PFAD), contains high free fatty acid (FFA) and other valuable bioactive compounds such as vitamin E, phytosterols and squalene.

Interestingly, retaining the availability of bioactive compounds until the manufacturing of the final product is important. Extraction is one of the critical stages in the recovery or valorization of bioactive compounds for any processing or manufacturing plant, irrespective of the product category. Recently, various extraction techniques have been introduced for the recovery of interesting compounds. Extraction techniques include liquid-liquid extraction, solid-phase extraction, solid-liquid extraction, and supercritical extraction. According to Patel et al. (2019), in the extraction process, the sample mixture is separated by dissolving each component with solvents which result in a two-phase-raffinate phase and extract phase. The extraction process was set based on operations (batch or continuous process) and type of phase. Furthermore, the condition of the extraction can have a significant, negative impact on its operating efficiency or quantity and quality of the interest compounds.

Significant research into the extraction or valorization of bioactive compounds from by-products has been conducted over the past century however in recent times this has increased. A Web of Science survey of articles published between 2000 and 2020 showed that of the 207 containing the word 'extraction' in the title, abstract or author- specific keywords, 202 related to food by-product. Similarly, 104 containing the word 'bioactive compounds', 371 related to the food by-product. This gives a proportion of interest in the extraction of bioactive compounds from a by-product.

In this Thesis, there are two studies of tocotrienols extraction. The first part of this thesis is to determine the favourable extraction condition. In particular, the main focus is on the study of main operating conditions (pressure and temperature) relevant to the extraction of tocotrienols using supercritical carbon dioxide ($scCO_2$). The second part of this Thesis is enhancing the efficiency of tocotrienols extraction using $scCO_2$ by modifying the $scCO_2$ system and altering the polarity of CO_2 at optimal conditions. Specifically, the work focuses on the static-dynamic mode extraction and addition of single or pair mixtures of co-solvents. A more detailed explanation of this optimization of $scCO_2$ process conditions for tocotrienols extraction and modification on $scCO_2$ for the enhancement tocotrienols extraction is explained in Chapter 4. In summary, this thesis describes the application of $scCO_2$ for the extraction of tocotrienols from a by- product of palm oil.

1.2 Problem statement

An increasing number of global issues on industrial waste management is alarming. Hence, transforming the industrial by-product into valuable products is necessary to generate zero waste using green sustainable technology. Widely used conventional methods are nevertheless somewhat controversial, as major drawbacks have been reported. The main challenge of these conventional extractions is required longer extraction time, conducted at high temperature, low selectivity of the interest compounds, and non-environmentally friendly. Steam- or hydro- distillation is a traditional extraction technique that has been commonly used to extract essential oils or bioactive compounds from many sources. Technically, this technique does not involve any organic solvents. Nevertheless, this technique is required to be conducted at high temperatures whereas temperature is a major factor that influences the extraction condition of bioactive compounds in this technique. Therefore, the main limitation of this technique is not suitable for thermolabile compound extraction as most volatile components will be degraded and lost by heat at high temperatures. In regards, the high temperature employed is another limitation affecting the quality of the final product since tocotrienols can easily degrade at high temperatures.

Soxhlet extraction has widely been used to extract bioactive compounds from various sources for the past century (Weggler et al., 2020; Rakhee et al., 2018). The Soxhlet extraction method is time-consuming, as it takes from several hours up to several days. The prolonged extraction time can cause the degradation of unsaturated or ester compounds and volatilization of the bioactive compounds through thermal or hydrolytic effects, hence, reduce the quality of the extracts. In addition, the low selectivity of the

interest compounds is another limitation of this conventional method. High selectivity of interest compounds can be achieved by choosing the right solvent based on the polarity of targeted compounds (Tzanova et al., 2020). Per law, the similarity and intermiscibility, a solvent with a polarity value close to the polarity solute are expected to deliver better results and vice versa. Besides, organic solvents are categorized as conventional extraction methods is widely used in many industries for tocotrienols production. The use of hazardous solvents such as hexane and chloroform are harmful to health, products, and the environment. The high consumption of harmful solvents and the management of the industrial waste contributes to the environment, hence, increase the production costs resulting in the production viable conventional method is no longer sustainable.

Recently, several technologies pairing green technology with a green chemistry solvent were developed for the recovery of one or a few target compounds from samples using a single process. Particularly for the recovery of the vitamin E family, researchers have focused on alternative extraction techniques. This study will focus primarily on supercritical fluid extraction (SFE) with the use of carbon dioxide as a solvent is a greener alternative to the conventional extraction method. Due to its superior properties, it can be applied to food and pharmaceutical applications. However, the capability of $scCO_2$ to extract moderate polar compounds is limited since CO_2 is a non-polar solvent. The efficiency of the extraction can be improved through the solubility of polar compounds in the separation process by a slight modification of the technique and altering the polarity of the system.

1.3 Objectives

The primary objective of this thesis is to assess the efficiency of $scCO_2$ with possible available techniques in the extraction of tocotrienols in PFAD. The specific aims to achieve the main objective were to:

1. Evaluate the impact of pressure and temperature of $scCO_2$ on the yield of tocotrienols extraction from PFAD.
2. Determine the optimal condition for the recovery of tocotrienols from PFAD by using central composite design (CCD).
3. Utilize and extend available techniques in $scCO_2$ to monitor the impact and effectiveness of the recovery of tocotrienols in a range of conditions.

REFERENCES

Ahmad, T., Masoodi, F. A., A. Rather, S., Wani, S. M., & Gull, A. (2019). Supercritical Fluid Extraction: A Review. *Journal of Biological and Chemical Chronicles*. https://doi.org/10.33980/jbcc.2019.v05i01.019

Ahsan, H., Ahad, A., & Siddiqui, W. A. (2015). A review of characterization of tocotrienols from plant oils and foods. *Journal of Chemical Biology*, *8*(2), 45–59. https://doi.org/10.1007/s12154-014-0127-8

Al-Asheh, S., Allawzi, M., Al-Otoom, A., Allaboun, H., & Al-Zoubi, A. (2012). Supercritical fluid extraction of useful compounds from sage. *Natural Science*. https://doi.org/10.4236/ns.2012.48072

Al Jitan, S., Alkhoori, S. A., & Yousef, L. F. (2018). Phenolic Acids From Plants: Extraction and Application to Human Health. In *Studies in Natural Products Chemistry*. https://doi.org/10.1016/B978-0-444-64056-7.00013-1

Alexander, D. L. J., Tropsha, A., & Winkler, D. A. (2015). Beware of R2: Simple, Unambiguous Assessment of the Prediction Accuracy of QSAR and QSPR Models. *Journal of Chemical Information and Modeling*. https://doi.org/10.1021/acs.jcim.5b00206

Ali, nor eeda. (2020). Agricultural Waste Management System [AWMS] in Malaysian. *Open Access Journal of Waste Management & Xenobiotics*, *3*(2), 1–2. https://doi.org/10.23880/oajwx-16000140

Anikeev, V. I. (2014). Synthesis of Biodiesel Fuel in Supercritical Lower Alcohols with and without Heterogeneous Catalysts (Thermodynamics, Phase and Chemical Equilibriums, Experimental Studies). In *Supercritical Fluid Technology for Energy and Environmental Applications*. https://doi.org/10.1016/B978-0-444-62696-7.00001-0

Aris, N. A., Faadila, N., Idrus, M., Yian, L. N., Idham, Z., Syafiq, M., Ruslan, H., Azizi, M., & Yunus, C. (2019). The Effect of Fluid Flow Rate and Extraction Time in Supercritical Carbon Dioxide. *Journal of Advanced Research in Applied Sciences and Engineering Technology Journal Homepage*, *16*(1), 26–34. www.akademiabaru.com/araset.html

Asep, E. K., Jinap, S., Russly, A. R., Jahurul, M. H. A., Ghafoor, K., & Zaidul, I. S. M. (2016). The effect of flow rate at different pressures and temperatures on cocoa butter extracted from cocoa nib using supercritical carbon dioxide. *Journal of Food Science and Technology*. https://doi.org/10.1007/s13197-016-2191-2

Azeman, N. H., Yusof, N. A., Abdullah, J., Yunus, R., Hamidon, M. N., & Hajian, R. (2015). Study on the spectrophotometric detection of free fatty acids in palm oil utilizing enzymatic reactions. *Molecules*, *20*(7), 12328–12340. https://doi.org/10.3390/molecules200712328

Belayneh, H. D., Wehling, R. L., Cahoon, E., & Ciftci, O. N. (2015). Extraction of omega-3-rich oil from Camelina sativa seed using supercritical carbon dioxide. *Journal of Supercritical Fluids*, *104*. https://doi.org/10.1016/j.supflu.2015.06.002

Bellafiore, louis, & Henretta, K. (2002). *method for producing purified tocotrienols and tocopherols using liquid chromatography*.

Brunner, G. (2005). Supercritical fluids: Technology and application to food processing. *Journal of Food Engineering*, *67*(1–2), 21–33. https://doi.org/10.1016/j.jfoodeng.2004.05.060

Capuzzo, A., Maffei, M. E., & Occhipinti, A. (2013). *Supercritical Fluid Extraction of Plant Flavors and Fragrances*. 7194–7238. https://doi.org/10.3390/molecules18067194

Casas, L., Mantell, C., Rodríguez, M., Torres, A., Macías, F. A., & Martínez de la Ossa, E. (2007). Effect of the addition of cosolvent on the supercritical fluid extraction of bioactive compounds from Helianthus annuus L. *Journal of Supercritical Fluids*, *41*(1), 43–49. https://doi.org/10.1016/j.supflu.2006.09.001

Chai, Y. H., Yusup, S., Nadiah, W., Kadir, A., Wong, C. Y., & Rosli, S. S. (2021). *Valorization of Tropical Biomass Waste by Supercritical Fluid Extraction Technology*.

Chandrasekaram, K., Ng, M. H., Choo, Y. M., & Chuah, C. H. (2009). Effect of storage temperature on the stability of phytonutrients in palm concentrates. *American Journal of Applied Sciences*, *6*(3), 529–533. https://doi.org/10.3844/ajassp.2009.529.533

Chang, A. S., Sherazi, S. T. H., Kandhro, A. A., Mahesar, S. A., Chang, F., Shah, S. N., Laghari, Z. H., & Panhwar, T. (2016). Characterization of palm fatty acid distillate of different oil processing industries of Pakistan. *Journal of Oleo Science*. https://doi.org/10.5650/jos.ess16073

Chernyak, Y. (2006). Dielectric constant, dipole moment, and solubility parameters of some cyclic acid esters. *Journal of Chemical and Engineering Data*, *51*(2), 416–418. https://doi.org/10.1021/je050341y

Chu, B. S., Baharin, B. S., & Quek, S. Y. (2002). Factors affecting pre-concentration of tocopherols and tocotrienols from palm fatty acid distillate by lipase-catalysed hydrolysis. *Food Chemistry*, *79*(1), 55–59. https://doi.org/10.1016/S0308-8146(02)00177-2

Chu, B. S., Baharin, B. S., Quek, S. Y., & Che Man, Y. B. (2003). *Separation of Tocopherols and Tocotrienols from palm fatty acid distillate using hydrolysis-neutralization-adsorption chromatograpgy method*. 141–152.

Chu, B. S., Quek, S. Y., & Baharin, B. S. (2003). Optimisation of enzymatic hydrolysis for concentration of vitamin E in palm fatty acid distillate. *Food Chemistry*. https://doi.org/10.1016/S0308-8146(02)00178-4

Coelho, J. P., Filipe, R. M., Paula Robalo, M., Boyadzhieva, S., Cholakov, G. S., & Stateva, R. P. (2020). Supercritical CO_2 extraction of spent coffee grounds. Influence of co-solvents and characterization of the extracts. *Journal of Supercritical Fluids*, *161*. https://doi.org/10.1016/j.supflu.2020.104825

Cruz, M., Costa, E., Almeida, M. F., Alvim-Ferraz, M. da C., & Dias, J. M. (2018). Recovery of by-products from the olive oil production and the vegetable oil

refining for biodiesel production. *Detritus*. https://doi.org/10.31025/2611-4135/2018.13728

Da Porto, C., Decorti, D., & Natolino, A. (2014). Water and ethanol as co-solvent in supercritical fluid extraction of proanthocyanidins from grape marc: A comparison and a proposal. *Journal of Supercritical Fluids*, *87*, 1–8. https://doi.org/10.1016/j.supflu.2013.12.019

Dąbrowski, G., Konopka, I., & Czaplicki, S. (2018). Supercritical CO_2 extraction in chia oils production: impact of process duration and co-solvent addition. *Food Science and Biotechnology*, *27*(3), 677–686. https://doi.org/10.1007/s10068-018-0316-2

Damrongwattanakool, N., & Raviyan, P. (2018). Enrichment of vitamin e in palm fatty acid distillate using sequential-cooling urea–Fatty acid complexation. *Songklanakarin Journal of Science and Technology*. https://doi.org/10.14456/sjst-psu.2018.145

Danlami, J. M., Arsad, A., Zaini, M. A. A., & Sulaiman, H. (2014). A comparative study of various oil extraction techniques from plants. *Reviews in Chemical Engineering*, *30*(6), 605–626. https://doi.org/10.1515/revce-2013-0038

de O. Silva, L., Ranquine, L. G., Monteiro, M., & Torres, A. G. (2019). Pomegranate (Punica granatum L.) seed oil enriched with conjugated linolenic acid (cLnA), phenolic compounds and tocopherols: Improved extraction of a specialty oil by supercritical CO_2. *Journal of Supercritical Fluids*. https://doi.org/10.1016/j.supflu.2019.02.019

Dean, john a. (1968). lange's handbook of chemistry. In R. Esposito (Ed.), *McGraw-Hill, INC* (15th ed.).

Díaz-Reinoso, B., Moure, A., & Domínguez, H. (2020). Ethanol-Modified Supercritical CO_2 Extraction of Chestnut Burs Antioxidants. *Chemical Engineering and Processing - Process Intensification*, *156*(August), 108092. https://doi.org/10.1016/j.cep.2020.108092

Duereh, A., Guo, H., Sato, Y., & Inomata, H. (2020). Local composition models for predicting Kamlet-Taft dipolarity/polarizability of nonaqueous binary and ternary mixtures. *Journal of Molecular Liquids*, *304*, 112691. https://doi.org/10.1016/j.molliq.2020.112691

Duereh, A., & Smith, R. L. (2018). Strategies for using hydrogen-bond donor/acceptor solvent pairs in developing green chemical processes with supercritical fluids. *Journal of Supercritical Fluids*. https://doi.org/10.1016/j.supflu.2017.11.004

Duereh, A., Sugimoto, Y., Ota, M., Sato, Y., & Inomata, H. (2020). Kamlet-Taft Dipolarity/Polarizability of Binary Mixtures of Supercritical Carbon Dioxide with Cosolvents: Measurement, Prediction, and Applications in Separation Processes. *Industrial and Engineering Chemistry Research*, *59*(27), 12319–12330. https://doi.org/10.1021/acs.iecr.0c01251

Estiasih, T., & Ahmadi, K. (2018). Bioactive compounds from palm fatty acid distillate and crude palm oil. *IOP Conference Series: Earth and Environmental Science*, *131*(1), 0–6. https://doi.org/10.1088/1755-1315/131/1/012016

Estiasih, Teti, Ahmadi, K., Widyaningsih, T. D., Maligan, J. M., Mubarok, A. Z., Zubaidah, E., Mukhlisiyyah, J., & Puspitasari, R. (2013). Bioactive compounds of Palm Fatty Acid Distillate (PFAD) from several palm oil refineries. *Advance Journal of Food Science and Technology*, *5*(9), 1153–1159. https://doi.org/10.19026/ajfst.5.3074

European Commission. (2020). *Circular Economy Strategy*.

FAO. (2020). *Crops and livestock products*. http://www.fao.org/faostat/en/?#data/QCL

Ferdosh, S., Islam Sarker, M. Z., Abd Rahman, N. N. N., Selamat, J., Karim, M. R., Razak, T. A., & Abd Kadir, M. O. (2012). Fish oil recovery from viscera of indian mackerel (rastrelliger kanagurta) by supercritical fluid: An optimization approach. *Journal of the Chinese Chemical Society*, *59*(11), 1421–1429. https://doi.org/10.1002/jccs.201100235

Fizet, C. (1996). *process for tocopherols and sterols from natural sources*.

Gan, H. L., Tan, C. P., Che Man, Y. B., Noraini, I., & Nazimah, S. A. H. (2005). Monitoring the storage stability of RBD palm olein using the electronic nose. *Food Chemistry*, *89*(2), 271–282. https://doi.org/10.1016/J.FOODCHEM.2004.02.034

Gapor Md Top, A. (2010). Production and utilization of palm fatty acid distillate (PFAD). *Lipid Technol.*, *22*, 11–13.

Gast, K., Jungfer, M., Saure, C., & Brunner, G. (2005). *Purification of tocochromanols from edible oil*. *34*, 17–25. https://doi.org/10.1016/j.supflu.2004.09.003

Ghoreishi, S. M., Hedayati, A., & Mohammadi, S. (2016). Optimization of periodic static-dynamic supercritical CO_2 extraction of taxifolin from pinus nigra bark with ethanol as entrainer. In *Journal of Supercritical Fluids* (Vol. 113). Elsevier B.V. https://doi.org/10.1016/j.supflu.2016.03.015

Ghosh, S., & Bhattacharyya, D. K. (1996). Isolation of tocopherol and sterol concentrate sunflower oil deodorizer distillate. *JAOCS, Journal of the American Oil Chemists' Society*, *73*(10), 1271–1274. https://doi.org/10.1007/BF02525456

Gibon, V., De Greyt, W., & Kellens, M. (2007). Palm oil refining. *European Journal of Lipid Science and Technology*. https://doi.org/10.1002/ejlt.200600307

Gopaliya, P., Kambel, priyadarshani r, Kambel, R., & Chauhan, chetan singh. (2014). A Review on Supercritical Fluid Chromatography. *International Journal of Pharma Reasearch & Review*, *3*(5), 59–66. https://doi.org/10.33786/jcpr.2013.v03i02.005

Grebenstein, N., & Frank, J. (2012). Rapid baseline-separation of all eight tocopherols and tocotrienols by reversed-phase liquid-chromatography with a solid-core pentafluorophenyl column and their sensitive quantification in plasma and liver. *Journal of Chromatography A*, *1243*, 39–46. https://doi.org/10.1016/j.chroma.2012.04.042

Guclu-Ustundag, O., & Temelli, F. (2007). Column Fractionation of Canola Oil Deodorizer Distillate Using Supercritical Carbon Dioxide. *J. Am OIl Chem. Soc.*, *84*, 953–961. https://doi.org/10.1007/s11746-007-1117-6

Hamzah, N., Tokimatsu, K., & Yoshikawa, K. (2019). Solid fuel from oil palm biomass residues and municipal solid waste by hydrothermal treatment for electrical power generation in Malaysia: A review. *Sustainability (Switzerland)*, *11*(4), 1–23. https://doi.org/10.3390/su11041060

He, K., Zhang, J., & Zeng, Y. (2019). Knowledge domain and emerging trends of agricultural waste management in the field of social science: A scientometric review. *Science of the Total Environment*, *670*, 236–244. https://doi.org/10.1016/j.scitotenv.2019.03.184

Hidayat, A., Rochmadi, Wijaya, K., Nurdiawati, A., Kurniawan, W., Hinode, H., Yoshikawa, K., & Budiman, A. (2015). Esterification of Palm Fatty Acid Distillate with High Amount of Free Fatty Acids Using Coconut Shell Char Based Catalyst. *Energy Procedia*, *75*, 969–974. https://doi.org/10.1016/J.EGYPRO.2015.07.301

Hirschmann, R. (2021). *Gross domestic product (GDP) from the palm oil industry in Malaysia from 2011 to 2019*. https://www.statista.com/statistics/952715/malaysia-gdp-from-palm-oil-industry/

Hsu, E. (2021). Cost-benefit analysis for recycling of agricultural wastes in Taiwan. *Waste Management*, *120*, 424–432. https://doi.org/10.1016/j.wasman.2020.09.051

Ibragimov, A., Sidique, S. F., & Tey, Y. S. (2019). Productivity for sustainable growth in Malaysian oil palm production: A system dynamics modeling approach. *Journal of Cleaner Production*, *213*, 1051–1062. https://doi.org/10.1016/j.jclepro.2018.12.113

Idris, N. A., Lau, H. L. N., Wafti, N. S. A., Mustaffa, N. K., & Loh, S. K. (2020). Glycerolysis of Palm Fatty Acid Distillate (PFAD) as Biodiesel Feedstock Using Heterogeneous Catalyst. *Waste and Biomass Valorization*, *12*(2), 735–744. https://doi.org/10.1007/s12649-020-00995-6

Imsanguan, P., Roaysubtawee, A., Borirak, R., Pongamphai, S., Douglas, S., & Douglas, P. L. (2008). *Extraction of a -tocopherol and g -oryzanol from rice bran*. *41*, 1417–1424. https://doi.org/10.1016/j.lwt.2007.08.028

Irakli, M. N., Samanidou, V. F., & Papadoyannis, I. N. (2011). Development and validation of an HPLC method for the simultaneous determination of tocopherols, tocotrienols and carotenoids in cereals after solid-phase extraction. *Journal of Separation Science*, *34*(12), 1375–1382. https://doi.org/10.1002/jssc.201100077

Islam, T., Sarker, Z. I., Uddin, A. B. M. H., Yunus, B., M, R. P. D., Mia, A. R., & Ferdosh, S. (2020). *Kamlet Taft Parameters : A Tool to Alternate the Usage of Hazardous Solvent in Pharmaceutical and Chemical Manufacturing / Synthesis - A Gateway towards Green Technology*. https://doi.org/10.1080/22297928.2020.1860124

Jablonský, M., Škulcová, A., Malvis, A., & Šima, J. (2018). Extraction of value-added components from food industry based and agro-forest biowastes by deep eutectic solvents. *Journal of Biotechnology*, *282*, 46–66. https://doi.org/10.1016/j.jbiotec.2018.06.349

Jafarian Asl, P., Niazmand, R., & Yahyavi, F. (2020). Extraction of phytosterols and tocopherols from rapeseed oil waste by supercritical CO_2 plus co-solvent: A comparison with conventional solvent extraction. *Heliyon*, *6*(3), e03592. https://doi.org/10.1016/j.heliyon.2020.e03592

Jiang, S. T., Shao, P., Pan, L. J., & Zhao, Y. Y. (2006). Molecular Distillation for recovering Tocopherol and Fatty Acid Methyl Esters from Rapeseed Oil Deodoriser Distillate. *Biosystems Engineering*, *93*(4), 383–391. https://doi.org/10.1016/j.biosystemseng.2006.01.008

Kamali, H., Aminimoghadamfarouj, N., Golmakani, E., & Nematollahi, A. (2015). The optimization of essential oils supercritical CO_2 extraction from Lavandula hybrida through static-dynamic steps procedure and semi-continuous technique using response surface method. *Pharmacognosy Research*. https://doi.org/10.4103/0974-8490.147209

Kasim, N. S., Gunawan, S., Yuliana, M., & Ju, Y. H. (2010). A simple two-step method for simultaneous isolation of tocopherols and free phytosterols from soybean oil deodorizer distillate with high purity and recovery. *Separation Science and Technology*, *45*(16), 2437–2446. https://doi.org/10.1080/01496391003789171

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). https://doi.org/10.3390/molecules22071186

King, J. W., & List, G. R. (1996). *Supercritical Fluid Technology in Oil and Lipid Chemistry*. The American Oil Chemists Society. https://books.google.com.my/books?id=W65QMeQPOB4C&printsec=frontcover#v=onepage&q&f=false

Klein-Júnior, L. C., Vander Heyden, Y., & Henriques, A. T. (2016). Enlarging the bottleneck in the analysis of alkaloids: A review on sample preparation in herbal matrices. In *TrAC - Trends in Analytical Chemistry*. https://doi.org/10.1016/j.trac.2016.02.021

Klein, E. J., Santos, K. A., Palú, F., Vieira, M. G. A., & Silva, E. A. da. (2018). Use of supercritical CO_2 and ultrasound-assisted extractions to obtain α / β - amyrin-rich extracts from uvaia leaves (Eugenia pyriformis Cambess .). *The Journal of Supercritical Fluids*, *137*(January), 1–8. https://doi.org/10.1016/j.supflu.2018.02.019

Kraujalis, P., & Venskutonis, P. R. (2013). Supercritical carbon dioxide extraction of squalene and tocopherols from amaranth and assessment of extracts antioxidant activity. *Journal of Supercritical Fluids*. https://doi.org/10.1016/j.supflu.2013.04.005

Kuppithayanant, N., Hosap, P., & Nuchtida, C. (2014). The Effect of Heating on Vitamin E Decomposition in Edible Palm Oil. *IJERD-International Journal of Environmental and Rural Development*, 5–7.

Laboureur, L., Ollero, M., & Touboul, D. (2015). Lipidomics by supercritical fluid chromatography. *International Journal of Molecular Sciences*, *16*(6), 13868–13884. https://doi.org/10.3390/ijms160613868

Lee, J., Ye, L., Landen, W. O., & Eitenmiller, R. R. (2000). Optimization of an Extraction Procedure for the Quantification of Vitamin E in Tomato and Broccoli using Response Surface Methodology. *Journal of Food Composition and Analysis*, *13*(1), 45–57. https://doi.org/10.1006/jfca.1999.0845

Lee, W. J., Ng, C. C., Ng, J. S., Smith, R. L., Kok, S. L., Hee, Y. Y., Lee, S. Y., Tan, W. K., Zainal Abidin, N. H., Halim Lim, S. A., & Chong, G. H. (2019). Supercritical carbon dioxide extraction of α-mangostin from mangosteen pericarp with virgin coconut oil as co-extractant and in-vitro bio-accessibility measurement. *Process Biochemistry*. https://doi.org/10.1016/j.procbio.2019.09.009

Lee, Y. Y., Park, H. M., Lee, C. K., Kim, S. L., Hwang, T. Y., Choi, M. S., Kwon, Y. U., Kim, W. H., Kim, S. J., Lee, S. C., & Kim, Y. H. (2012). Comparing extraction methods for the determination of tocopherols and tocotrienols in seeds and germinating seeds of soybean transformed with OsHGGT. *Journal of Food Composition and Analysis*, *27*(1), 70–80. https://doi.org/10.1016/j.jfca.2012.03.010

Lima, R. N., Ribeiro, A. S., Cardozo-Filho, L., Vedoy, D., & Alves, P. B. (2019). Extraction from Leaves of Piper klotzschianum using Supercritical Carbon Dioxide and Co-Solvents. *Journal of Supercritical Fluids*. https://doi.org/10.1016/j.supflu.2018.11.006

Liong, K. H., Wells, P. A., & Foster, N. R. (1992). *Diffusion of Fatty Acid Esters in Supercritical Carbon Dioxide*. 390–399. https://doi.org/10.1021/ie00001a053

Lokman, I. M., Rashid, U., Zainal, Z., Yunus, R., Taufiq-Yap, & Hin, Y. (2014). Microwave-assisted Biodiesel Production by Esterification of Palm Fatty Acid Distillate. *Journal of Oleo Science*, *63*(9), 849–855. https://doi.org/10.1016/j.biombioe.2007.03.001

Lucas, A. De, De, E. M., & Rinco, J. (2002). *Supercritical fluid extraction of tocopherol concentrates from olive tree leaves*. *22*, 221–228.

Ma, Q., Xu, X., Gao, Y., Wang, Q., & Zhao, J. (2008). Optimisation of supercritical carbon dioxide extraction of lutein esters from marigold (Tagetes erect L .) with soybean oil as a co-solvent. *International Journal of Food Science and Technology*, 1763–1769. https://doi.org/10.1111/j.1365-2621.2007.01694.x

Maarasyid, C., Muhamad, I. I., & Supriyanto, E. (2014a). *Potential Source and Extraction of Vitamin E From Palm-Based Oils : A Review Jurnal Teknologi Full paper Potential Source and Extraction of Vitamin E From Palm-Based Oils : A Review*. *January 2015*. https://doi.org/10.11113/jt.v69.3172

Maarasyid, C., Muhamad, I. I., & Supriyanto, E. (2014b). Potential source and extraction of Vitamin E from palm-based oils: A review. *Jurnal Teknologi (Sciences and Engineering)*. https://doi.org/10.11113/jt.v69.3172

Machado, B. A. S., De Abreu Barreto, G., Costa, A. S., Costa, S. S., Silva, R. P. D., Da Silva, D. F., Brandao, H. N., Da Rocha, J. L. C., Nunes, S. B., Umsza-Guez, M.

A., & Padilha, F. F. (2015). Determination of parameters for the supercritical extraction of antioxidant compounds from green propolis using carbon dioxide and ethanol as co-solvent. *PLoS ONE*, *10*(8), 1–26. https://doi.org/10.1371/journal.pone.0134489

Malekbala, M. R., Soltani, S. M., Hosseini, S., Eghbali Babadi, F., & Malekbala, R. (2017). Current technologies in the extraction, enrichment and analytical detection of tocopherols and tocotrienols: A review. *Critical Reviews in Food Science and Nutrition*. https://doi.org/10.1080/10408398.2015.1020532

Marcus, Y. (2005). Solvatochromic probes in supercritical fluids. *Journal of Physical Organic Chemistry*, *18*(5), 373–384. https://doi.org/10.1002/poc.882

McHugh, M. A., & Krukonis, V. J. (1994). *Supercritical Fluid Extraction: Principles and Practice* (2nd ed.). Elsevier. https://doi.org/10.1016/C2009-0-26919-4

Mendes, M. F., Pessoa, F. L. P., Coelho, G. V, & Uller, A. M. C. (2005). *Recovery of the high aggregated compounds present in the deodorizer distillate of the vegetable oils using supercritical fluids*. *34*, 157–162. https://doi.org/10.1016/j.supflu.2004.11.009

Mesomo, M. C., Corazza, M. L., Ndiaye, P. M., Dalla, O. R., Cardozo, L., & Paula, A. De. (2013). Supercritical CO_2 extracts and essential oil of ginger (Zingiber officinale R .): Chemical composition and antibacterial activity. *The Journal of Supercritical Fluids*, *80*, 44–49. https://doi.org/10.1016/j.supflu.2013.03.031

Mesomo, M. C., Scheer, A. D. P., Perez, E., Ndiaye, P. M., & Corazza, M. L. (2012). Ginger (Zingiber officinale R.) extracts obtained using supercritical CO 2 and compressed propane: Kinetics and antioxidant activity evaluation. *Journal of Supercritical Fluids*, *71*, 102–109. https://doi.org/10.1016/j.supflu.2012.08.001

Miękus, N., Iqbal, A., Marszałek, K., Puchalski, C., & Świergiel, A. (2019). Green chemistry extractions of carotenoids from daucus carota L.-Supercritical carbon dioxide and enzyme-assisted methods. *Molecules*, *24*(23), 1–20. https://doi.org/10.3390/molecules24234339

Monroy, Y. M., Rodrigues, R. A. F., Sartoratto, A., & Cabral, F. A. (2016). The Journal of Supercritical Fluids Influence of ethanol , water , and their mixtures as co-solvents of the supercritical carbon dioxide in the extraction of phenolics from purple corn cob (Zea mays L .). *The Journal of Supercritical Fluids*, *118*, 11–18. https://doi.org/10.1016/j.supflu.2016.07.019

MPOB. (2020). *Overview of the Malaysian Oil Palm Industry*. Malaysian Palm Oil Board. www.mpob.gov

MPOC. (2020). *Malaysian Palm Oil Industry – MPOC*. http://mpoc.org.my/malaysian-palm-oil-industry/

Muhamad, I. I., Hassan, N. D., Mamat, S. N. H., Nawi, N. M., Rashid, W. A., & Tan, N. A. (2017). Extraction Technologies and Solvents of Phytocompounds From Plant Materials : Physicochemical Characterization and Identification of Ingredients and Bioactive Compounds From Plant Extract Using Various Instrumentations. In *Ingredients Extraction by Physicochemical Methods in Food*. https://doi.org/10.1016/b978-0-12-811521-3.00014-4

Nagesha, G. K., Manohar, B., & Udaya Sankar, K. (2003). Enrichment of tocopherols in modified soy deodorizer distillate using supercritical carbon dioxide extraction. *European Food Research and Technology*, *217*(5), 427–433. https://doi.org/10.1007/s00217-003-0781-5

Norhidayah, S., Baharin, B. S., Hamed, M., & Zaidul, I. S. M. (2012). Squalene recovery from palm fatty acid distillate using supercritical fluid extraction. *International Food Research Journal*.

Ozkal, S. G., Yener, M. E., & Bayındırlı, L. (2005). Mass transfer modeling of apricot kernel oil extraction with supercritical carbon dioxide. *Journal of Supercritical Fluids*, *35*, 119–127. https://doi.org/10.1016/j.supflu.2004.12.011

Patel, K., Panchal, N., & Ingle, P. (2019). Review of Extraction Techniques Extraction Methods: Microwave, Ultrasonic, Pressurized Fluid, Soxhlet Extraction, Etc. *International Journal of Advanced Research in Chemical Science*, *6*(3), 6–21. https://doi.org/10.20431/2349-0403.0603002

Peach, J., & Eastoe, J. (2014). Supercritical carbon dioxide: A solvent like no other. *Beilstein Journal of Organic Chemistry*, *10*, 1878–1895. https://doi.org/10.3762/bjoc.10.196

Peng, W. L., Mohd-Nasir, H., Setapar, S. H. M., Ahmad, A., & Lokhat, D. (2020). Optimization of process variables using response surface methodology for tocopherol extraction from Roselle seed oil by supercritical carbon dioxide. *Industrial Crops and Products*. https://doi.org/10.1016/j.indcrop.2019.111886

Poodi, Y., Bimakr, M., Ganjloo, A., & Zarringhalami, S. (2018). Intensification of bioactive compounds extraction from Feijoa (Feijoa sellowiana Berg.) leaves using ultrasonic waves. *Food and Bioproducts Processing*. https://doi.org/10.1016/j.fbp.2017.12.004

Putra, N. R., Yian, L. N., Nasir, H. M., Binti Idham, Z., & Yunus, M. A. C. (2018). Effects of process parameters on peanut skins extract and CO_2 diffusivity by supercritical fluid extraction. *IOP Conference Series: Materials Science and Engineering*. https://doi.org/10.1088/1757-899X/334/1/012057

Quek, S. Y., Baharin, badlishah sham, & Chu, B. (2007). *Commercial extraction of vitamin E from food sources*. *January*.

Rad, H. B., Sabet, J. K., & Varaminian, F. (2019). *Study of Solubility in Supercritical Fluids : Thermodynamic Concepts and Measurement Methods - A Review*. *36*(04), 1367–1392.

Raja, P. M. V, & Barron, A. R. (2021). Physical methods in chemistry. *Nature*, *134*(3384), 366–367. https://doi.org/10.1002/jctb.5000533702

Rajo, M. H. A., Zin, A. F. M., & Asmuin, N. (2020). Palm Fatty Acid Distillate (PFAD) as Source of Biofuel: Availability and Suitability Analysis. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *76*(1), 156–163. https://doi.org/10.37934/arfmts.76.1.156163

Rakhee, Mishra, J., Sharma, R. K., & Misra, K. (2018). Characterization Techniques for Herbal Products. *Management of High Altitude Pathophysiology*, 171–202. https://doi.org/10.1016/B978-0-12-813999-8.00009-4

Ramamurthi, S., & McCurdy, A. R. (1993). Enzymatic pretreatment of deodorizer distillate for concentration of sterols and tocopherols. *Journal of the American Oil Chemists' Society*, *70*(3), 287–295. https://doi.org/10.1007/BF02545310

Raventós, M., Duarte, S., & Alarcón, R. (2002). Application and Possibilities of Supercritical CO_2 Extraction in Food Processing Industry: An Overview. *Food Science and Technology International*, *8*(5), 269–284. https://doi.org/10.1106/108201302029451

Reichardt, C., & Welton, T. (2010). solvents and solvent effect in organic chemistry, fourth edition. In *Solvents and Solvent Effects in Organic Chemistry*. https://doi.org/10.1002/9783527632220.ch7

Rezaei, K. A., & Temelli, F. (2000). *Using supercritical fluid chromatography to determine di ff usion coe ffi cients of lipids in supercritical CO*. *17*, 35–44.

Ribeiro, P. P. C., E Silva, D. M. de L., Dantas, M. M., Ribeiro, K. D. da S., Dimenstein, R., & Damasceno, K. S. F. da S. C. (2019). Determination of tocopherols and physicochemical properties of faveleira (Cnidoscolus quercifolius) seed oil extracted using different methods. *Food Science and Technology*. https://doi.org/10.1590/fst.24017

Ricciarelli, R., Zingg, J., & Azzi, A. (2002). *The 80th Anniversary of Vitamin E: Beyond Its Antioxidant*. *383*(April), 457–465.

Rovetto, L. J., & Aieta, N. V. (2017). Supercritical carbon dioxide extraction of cannabinoids from Cannabis sativa L. *Journal of Supercritical Fluids*. https://doi.org/10.1016/j.supflu.2017.03.014

Saad, B., Ling, C. W., Jab, M. S., Lim, B. P., Mohamad Ali, A. S., Wai, W. T., & Saleh, M. I. (2007). Determination of free fatty acids in palm oil samples using non-aqueous flow injection titrimetric method. *Food Chemistry*, *102*(4), 1407–1414. https://doi.org/10.1016/j.foodchem.2006.05.051

Sabiha Hanim, S., Norsyabilah, R., Nor Suhaila, M. H., Noraishah, A., & Siti Kartina, A. K. (2012). Effects of temperature, time and pressure on the hemicelluloses yield extracted using subcritical water extraction. *Procedia Engineering*, *42*(August), 562–565. https://doi.org/10.1016/j.proeng.2012.07.448

Sahena, F., Zaidul, I. S. M., Jinap, S., Jahurul, M. H. A., Khatib, A., & Norulaini, N. A. N. (2010). Extraction of fish oil from the skin of Indian mackerel using supercritical fluids. *Journal of Food Engineering*. https://doi.org/10.1016/j.jfoodeng.2010.01.038

Sahena, F., Zaidul, I. S. M., Jinap, S., Karim, A. A., Abbas, K. A., Norulaini, N. A. N., & Omar, A. K. M. (2009). Application of supercritical CO_2 in lipid extraction - A review. *Journal of Food Engineering*, *95*(2), 240–253. https://doi.org/10.1016/j.jfoodeng.2009.06.026

Saini, R. K., & Keum, Y. S. (2016). Tocopherols and tocotrienols in plants and their products: A review on methods of extraction, chromatographic separation, and detection. *Food Research International*, *82*, 59–70. https://doi.org/10.1016/j.foodres.2016.01.025

Salleh, L. M., Mohd Nasir, H., Yaakob, H., & Che Yunus, M. A. (2014). Determination of supercritical carbon dioxide extraction parameters for quercus infectoria galls and the effects on extraction yield and antioxidant activity. *Jurnal Teknologi (Sciences and Engineering)*, *67*(2), 1–4. https://doi.org/10.11113/jt.v67.2725

Sato, T., Fukuda, F., Nihei, K. ichi, & Itoh, N. (2017). Effect of temperature and pressure on the extraction of strawberry receptacles with a mixture of supercritical carbon dioxide and entrainers. *Journal of Supercritical Fluids*, *130*(June), 23–29. https://doi.org/10.1016/j.supflu.2017.07.011

Sen, C. K., Khanna, S., & Roy, S. (2006). Tocotrienols : Vitamin E beyond tocopherols. *Life Sciences*, *78*(18), 2088–2098. https://doi.org/10.1016/j.lfs.2005.12.001

Shan, B., Xie, J. H., Zhu, J. H., & Peng, Y. (2012). Ethanol modified supercritical carbon dioxide extraction of flavonoids from Momordica charantia L. and its antioxidant activity. *Food and Bioproducts Processing*, *90*(3), 579–587. https://doi.org/10.1016/j.fbp.2011.09.004

Siew, wai lin, Tang, thin sue, & Tan, yew ai. (1995). *PORIM: test methods*. Palm oil researh institute of Malaysia.

Smith, R. M., & Townshend, A. (1988). Supercritical fluid chromatography : The Royal Society of Chemistry, London, 1988 (ISBN 0-85186-577-1). xii + 238 pp. Price $27.50/US$59.00. *Analytica Chimica Acta*, *215*, 363. https://doi.org/10.1016/S0003-2670(00)85306-4

Song, Z., Lin, Y., Du, F., Yin, Y., & Wang, Z. (2017). Statistical optimisation of process variables and large-scale production of Metarhizium rileyi (Ascomycetes: Hypocreales) microsclerotia in submerged fermentation. *Mycology*, *8*(1), 39–47. https://doi.org/10.1080/21501203.2017.1279688

Sookwong, P., Suttiarporn, P., Boontakham, P., Seekhow, P., Wangtueai, S., & Mahatheeranont, S. (2016). Simultaneous quantification of Vitamin E, γ-oryzanols and xanthophylls from rice bran essences extracted by supercritical CO_2. *Food Chemistry*, *211*, 140–147. https://doi.org/10.1016/j.foodchem.2016.05.001

Su, W. (2010). *Electrochemistry in supercritical fluids*. University of Nottingham, United Kingdom.

Tai, H. P., & Brunner, G. (2019). Extraction of Oil and Minor compounds from oil palm fruit with supercritical carbon dioxide. *Processes*. https://doi.org/10.3390/pr7020107

Tay, B., Ping, Y., & Yusof, M. (2009). Characteristics and Properties of Fatty Acid Distillates from Palm Oil. *Oil Palm Bulletin*, *59*(November), 5–11.

Temelli, F., Saldana, M., & Comin, L. (2012). Application of Supercritical Fluid Extraction in Food Processing. In *Comprehensive Sampling and Sample*

Preparation: Analytical Techniques for Scientists (Vol. 4). Elsevier. https://doi.org/10.1016/B978-0-12-381373-2.10142-5

Tom, J. W., & Debenedetti, P. G. (1991). Particle formation with supercritical fluids-a review. *Journal of Aerosol Science*, *22*(5), 555–584. https://doi.org/10.1016/0021-8502(91)90013-8

Trevisani Juchen, P., Nolasco Araujo, M., Hamerski, F., Corazza, M. L., & Pedersen Voll, F. A. (2019). Extraction of parboiled rice bran oil with supercritical CO_2 and ethanol as co-solvent: Kinetics and characterization. *Industrial Crops and Products*. https://doi.org/10.1016/j.indcrop.2019.111506

Työppönen, J. T., & Hakkarainen, R. V. J. (1985). Thermal Stability of Vitamin E in Barley. *Acta Agriculturae Scandinavica*, *35*(2), 136–138. https://doi.org/10.1080/00015128509435767

Týskiewicz, K., Konkol, M., & Rój, E. (2018). The application of supercritical fluid extraction in phenolic compounds isolation from natural plant materials. *Molecules*, *23*(10). https://doi.org/10.3390/molecules23102625

Tzanova, M., Atanasov, V., Yaneva, Z., Ivanova, D., & Dinev, T. (2020). Selectivity of current extraction techniques for flavonoids from plant materials. *Processes*, *8*(10), 1–30. https://doi.org/10.3390/pr8101222

Uwineza, P. A., & Waśkiewicz, A. (2020). Recent advances in supercritical fluid extraction of natural bioactive compounds from natural plant materials. In *Molecules*. https://doi.org/10.3390/molecules25173847

Varkkey, H., Tyson, A., & Choiruzzad, S. A. B. (2018). Palm oil intensification and expansion in Indonesia and Malaysia: Environmental and socio-political factors influencing policy. *Forest Policy and Economics*, *92*(May), 148–159. https://doi.org/10.1016/j.forpol.2018.05.002

Veningtia Sari, A., Harimawan, A., & Lestari, D. (2021). Purification of vitamin E from palm fatty acid distillate through neutralization, extraction, and adsorption methods. *IOP Conference Series: Materials Science and Engineering*. https://doi.org/10.1088/1757-899x/1143/1/012062

Verhé, R., Verleyen, T., Van Hoed, V., & De Greyt, W. (2008). Influence of refining of vegetable oils on minor components. *Proceedings - 2008 Joint Central European Congress: 4th Central European Congress on Food, CEFood 2008 and 6th Croatian Congress of Food Technologists, Biotechnologists and Nutritionists*.

Watanabe, Y., Nagao, T., Nishida, Y., Takagi, Y., & Shimada, Y. (2007). Enzymatic production of fatty acid methyl esters by hydrolysis of acid oil followed by esterification. *JAOCS, Journal of the American Oil Chemists' Society*, *84*(11), 1015–1021. https://doi.org/10.1007/s11746-007-1143-4

Weerachanchai, P., Lim, K. H., & Lee, J. M. (2014). Influence of organic solvent on the separation of an ionic liquid from a lignin-ionic liquid mixture. *Bioresource Technology*. https://doi.org/10.1016/j.biortech.2014.01.077

Weggler, B. A., Gruber, B., Teehan, P., Jaramillo, R., & Dorman, F. L. (2020). Inlets and sampling. *Separation Science and Technology (New York)*, *12*, 141–203. https://doi.org/10.1016/B978-0-12-813745-1.00005-2

Yunus, M. A. C., Zhari, S., Haron, S., Arsad, N. H., Idham, Z., & Ruslan, M. S. H. (2015). Extraction and identification of vitamin e from Pithecellobium jiringan seeds using supercritical carbon dioxide. *Jurnal Teknologi*. https://doi.org/10.11113/jt.v74.4692

Zaidul, I. S. M., Norulaini, N., Omar, a. k. mohd, & Jr., r. l. smith. (2007). *Supercritical carbon dioxide (SC-CO 2) extraction of palm kernel oil from palm kernel*. *79*, 1007–1014. https://doi.org/10.1016/j.jfoodeng.2006.03.021

Zaidul, M., Sarker, I., Selamat, J., Sayem, A., & Habib, A. (2012). *Optimization of Supercritical CO 2 Extraction of Fish Oil from Viscera of African Catfish (Clarias gariepinus)*. 11312–11322. https://doi.org/10.3390/ijms130911312

Zhou, J., Gullón, B., Wang, M., Gullón, P., Lorenzo, J. M., & Barba, F. J. (2021). The application of supercritical fluids technology to recover healthy valuable compounds from marine and agricultural food processing by-products: A review. *Processes*, *9*(2), 1–23. https://doi.org/10.3390/pr9020357

Zuber, M. ahmar, Yahya, wira jazair, Ithnin, ahmad muhsin, Sugeng, dhani avianto, abd kadir, H., & Ahmad, mohamad azrin. (2019). *A Brief Review on Palm Oil Liquid Waste Conversion*.