OPTIMIZATION OF ULTRASONIC-ASSISTED EXTRACTION PARAMETERS OF *GARCINIA CAMBOGIA* AND THE BIOLOGICAL ACTIVITIES OF THE EXTRACT

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DEDICATION

This thesis is dedicated to my family; supportive husband, Mohd Mokhtar bin Kassim and my lovely children; Khalisya Husna, Anas Hamza, Eiman Hadi and Annur Hasana. Thank you to my beloved father, Musa Md Yusof.

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ABSTRACT

Garcinia cambogia (G.cambogia) which is known locally as asam gelugur has been recognized in many Asian countries for its benefits to treat constipation piles, rheumatism, irregular menstruation, and intestinal parasites. The previous study reported that the main extract of *G.cambogia*,(-)-hydroxycitric acid ((-)-HCA), an organic acid component of the fruit, exhibited anti-obesity activity. Most of the products available in the market nowadays contain a low percentage of this active ingredient, (-)-HCA while and some of the products contain a combination of different active ingredients. Thus, optimization of ultrasonic-assisted extraction (UAE) of *G.cambogia* and the biological activities; antioxidant activity, antimicrobial and *in vitro* inhibitory activity of a *G.cambogia* extract on pancreatic lipase activity was studied. Response surface methodology (RSM) involving central composite design was employed to study the effect of ultrasound-assisted extraction parameters namely sonication amplitude (10–70 %), solid-liquid ratio (4–12 %w/v) and extraction time (10-40 min) on the yield of (-)-hyrdroxycitric acid and total organic acid. The significant ($p < 0.05$) response surface models with high coefficients of determination values (R^2) of 0.9297 and 0.9438 for the yield of (-)-HCA and total organic acid, respectively were obtained. The high R^2 values indicated that these polynomial response models are well fitted for describing the extraction efficiencies of the responses. Based on the RSM result, the optimal condition for obtaining higher extraction was at extraction time of 21 min, percentage amplitude of 22 %, and solid-liquid ratio of 6 % w/v. Under this optimal condition, the *G.cambogia* extract obtained contain 36.916 g/100 g dry weight of (-)-HCA and 69.251 g/100 g dry weight of total organic acid. Meanwhile, *G.cambogia* extract shows that it exhibited antioxidant activity of 2,2-diphenyl-1-picrylhydrazyl (DPPH) with IC_{50} value 46.57 ± 0.93 μg/ml. For antimicrobial activity, maximum inhibition zone was recorded against *S. aureus* (19.3 ± 2.3 mm) and *E.coli* (15.3 ± 2.3 mm) at concentration 0.5 g/ml crude extract of *G.cambogia*. The result from *in vitro* inhibitory pancreatic lipase study indicated the inhibitory effect of optimized *G.cambogia* which the lipolysis on tributyrin was reduced by 11.81 %. The study showed that the extraction using UAE of *G.cambogia* with controlled parameters produce a high yield of *G.cambogia* extracts with high biological activities. Thus, *G.cambogia* extracted using this process has the potential to enhance the quality of herbal products in the market.

ABSTRAK

Garcinia cambogia (G.cambogia) yang juga dikenali sebagai asam gelugor telah diiktiraf dikebanyakan negara Asia dengan faedah untuk merawat sembelit, buasir, penyakit sendi, haid tidak teratur, dan parasit usus. Kajian terdahulu melaporkan bahawa ekstrak utama *G.cambogia*, (-)-asid hidroksisitrik ((-)-HCA) yang merupakan komponen asid organik buah ini, mempunyai aktiviti anti obesiti. Kebanyakan produk yang terdapat di pasaran pada masa kini mengandungi bahan aktif, (-)-HCA yang rendah, dan beberapa produk mengandungi kombinasi bahan aktif yang berbeza. Oleh itu, pengoptimuman pengekstrakan berbantukan ultrasonik (UAE) *G.cambogia* dan aktiviti biologi iaitu aktiviti antioksidan, antimikrobial dan aktiviti perencatan ekstrak *G.cambogia in vitro* pada aktiviti lipase pankreas telah dikaji. Kaedah sambutan permukaan (RSM) yang melibatkan reka bentuk komposit berpusat digunakan untuk mengkaji kesan parameter pengekstrakan berbantukan ultrasonik iaitu amplitud sonikasi (10-70 %), nisbah pepejal cecair (4-12 %w/v) dan masa pengekstrakan (10- 40 min) ke atas hasil (-)-asid hidrosisitrik dan jumlah asid organik. Model permukaan sambutan yang signifikan ($p < 0.05$) dengan nilai pekali penentuan (R^2) yang tinggi iaitu 0.9297 dan 0.9438 diperolehi bagi (-)-HCA dan jumlah asid organik. Nilai R^2 yang tinggi menunjukkan bahawa model polinomial sesuai untuk menerangkan kecekapan pengekstrakan sambutan. Berdasarkan keputusan RSM, keadaan optimum untuk mendapatkan hasil pengekstrakan yang tinggi adalah pada masa pengekstrakan 21 minit, peratusan amplitude 22 %, dan nisbah pepejal-cecair 6 %w/v. Pada keadaan optimum ini, *G.cambogia* yang diekstrak mengandungi hasil ekstrak (-)-HCA 36.916 g/100 g berat kering dan jumlah asid organik 69.251 g/100 g berat kering. Sementara itu, ekstrak *G.cambogia* menunjukkan aktiviti antioksidan 2,2-diphenyl-1-picrylhydrazyl (DPPH) dengan nilai IC_{50} 46.57 ± 0.93 μg/ml. Bagi aktiviti antimikrobial, zon perencatan maksimum direkodkan terhadap *S. aureus* (19.3 ± 2.3 mm) dan *E.coli* (15.3 ± 2.3 mm) pada kepekatan 0.5 g/ml ekstrak mentah *G.cambogia*. Hasil daripada aktiviti perencatan pankreas lipase *in vitro* menunjukkan kesan perencatan terhadap ekstrak optimum *G.cambogia* pada pencernaan lipase di mana lipolisis pada tributyrin berkurangan sehingga 11.81 %. Kajian ini menunjukkan bahawa pengekstrakan menggunakn UAE *G.cambogia* dengan parameter terkawal menghasilkan ekstrak *G.cambogia* dengan aktiviti biologi yang tinggi. Oleh itu, *G.cambogia* yang diekstrak dengan menggunakan kaedah ini berpotensi meningkatkan kualiti produk herba di pasaran.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATION

LIST OF ABBREVIATIONS

(-)-HCA	-	(-)-Hydroxycitric Acid
ANOVA	-	Analysis of Variance
BBD	-	Box-Behnken Design
$CaCl_2$	-	Calcium chloride
CCD	-	Central Composite Design
dF	-	Dilution Factor
DPPH	-	2,2-diphenyl-1-picrylhydrazine
FFA	-	Free Fatty Acid
G.cambogia	-	*Garcinia cambogia*
GAE	-	Gallic Acid
GC	-	*Garcinia cambogia*
HAE	-	Heat-assisted extraction
HIV	-	Human Immunodeficiency Virus
HPLC-PDA	-	High Performance Liquid Chromatography-Photodiode Array
IC_{50}	-	The half maximal inhibitory concentration
IR	-	Infra-Red
LOF	-	Lack of Fit
MeOH	-	Methanol
MHA	-	Mueller-Hinton Agar
NaCl	-	Sodium Chloride
NaOH	-	Sodium Hydroxide
OFAT	-	One factor at a time
ROS	-	Reactive Oxygen Species
RSM	-	Response Surface Methodology
TOA	-	Total Organic Acid
UAE	-	Ultrasonic-assisted Extraction
UV	-	Ultra Violet
V	-	Volume
w	-	Weight
WEGC	-	Water extract of *Garcinia cambogia*

LIST OF SYMBOLS

%	-	Percentage
μg	-	Microgram
μl	-	Microliter
μm	-	Micrometre
μmole	-	Micromole
$[\alpha]^{20}{}_{D}$	-	Measurement rotation in degrees
CFU/ml	-	colony-forming units per millilitre
g	-	Gram
g/100g	-	Gram per 100 gram
h	-	hour
H_a	-	Alternative Hypothesis
H_o	-	Null Hypothesis
IU	-	International unit
kHz	-	Kilohertz
L	-	Litre
M	-	Molarity
mg	-	Milligram
min	-	Minute
ml	-	millilitre
mm	-	Millimetre
nm	-	nanometre
ºC	-	Degree Celsius
ppm	-	Part per million
R^2	-	Coefficient of multiple determination
Rf	-	The ratio of the distance moved by the solute
W	-	Watt

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 General Background

Garcinia cambogia (Asam Gelugur) has been recognized in many Asian countries for its benefits to treat traditionally constipation, intestinal parasites, piles, rheumatism, and irregular menstruation (Tharachand and Avadhani, 2013). (-)-Hydroxycitric acid ((-)-HCA) is the major organic acid that exhibited anti-obesity activity including reducing appetite and play an essential role as a weight reduction agent in body mass (Blaszczak-Boxe, 2014). Various *in vivo* and *in vitro* studies have contributed to the understanding of the anti-obesity effect of (-)-HCA in Garcinia species via regulation of serotonin level and glucose uptake. Besides that, it also helps to enhance fat oxidation (Ishihara *et al*., 2000) while inhibition *de novo* lipogenesis activity (Spencer *et al*., 1964). In lipogenesis activity, (-)-HCA inhibits extramitochondrial enzyme adenosine triphosphate-citrate (pro-3S)-lyase to cleavage citrate into oxaloacetate and acetyl-coenzyme A (Acetyl-CoA). These enzymes play important roles in fatty acid, triglycerides and cholesterol synthesis.

Nowadays, many supplements available commercially in the market that promotes weight loss which contains (-)-HCA, the active ingredient in Garcinia species. Most of the supplement available claim for high contains with (-)-HCA. However, according to Chuah *et al.* (2013), some of Garcinia supplements contain only 20% to 60% of (-)-HCA. The products might contain combinations of different active ingredients rather than (-)-HCA alone or other artificial ingredients, fillers and binder. Klein Junior *et al.* (2010) also had reported that there are many dietary supplements with lower content of (-)-HCA as an active ingredient than the specified value. This should be considered when assessing the quality, safety and efficacy of this product.

Optimization of *Garcinia cambogia* (*G.cambogia*) is crucial in scaling up the industry to avoid wastage of capital investment. Thus, the optimum condition in water extraction of *G.cambogia* by using ultrasonic-assisted extraction is the main objective of this study. The principal interest in the extraction process is to maximize the target compound yield, whilst minimizing the extraction of undesirable compounds species. Conventional extraction techniques, such as Soxhlet extraction, maceration, infusion, solid-liquid extraction (SLE) require longer processing time and may employ a large volume of toxic solvents. The safety concerns associated with the usage of organic solvent and the presence of toxic solvent residues in the final extract are considered to be some of the serious concerns following conventional extraction. Moreover, the high-temperature operation during the conventional extraction process may damage the quality of heat sensitive active compounds in the extract. With proper isolation, numerous cellular components of microorganisms and plants can fulfil the human nutritional and functional need (Huie, 2002).

Ultrasound-assisted extraction (UAE) is one of the environmental friendly techniques for extraction (Tiwari, 2015) and has been proven by many researchers as an effective extraction method in the extraction of phytochemicals in plants (Palma and Barroso, 2002; Hossain *et al.*, 2012; Tian *et al.*, 2013; XS *et al.*, 2014). The increment in extraction obtained by using ultrasound is mainly attributed to the effect of acoustic cavitation produced in the solvent as a result of ultrasound wave passage (Rezaie *et al*., 2015). Ultrasound also exerts a mechanical effect, allowing greater penetration of solvent into the tissue, increasing the contact surface area between the solid and liquid phase. As a result, the solute quickly diffuses from the solid phase to the solvent (Rostagno *et al*., 2003). However, the effects of ultrasonic on extraction yield and kinetics may be linked to the nature of the plant matrix. The presence of a dispersed phase contributes to the ultrasonic wave attenuation and the active part of ultrasound inside the extractor is restricted to a zone located in the vicinity of the ultrasonic emitter (Wang and Weller, 2006).

Extracts of the *G.cambogia* have been reported to exhibit diverse biological activities such as anti-HIV (Narayan *et al.*, 2011), antimicrobial (Mackeen *et al*. 2000; Dubey, 2013), anticholinesterase and antioxidant activities (Subhashini, Nagarajan, & Kavimani, 2011), but these studies did not involve water extract of *G.cambogia*. In this study, the influence of several experimental parameters; extraction time, sonication amplitude, solid-liquid ratio, on the ultrasonic extraction of *G.cambogia* were investigated while the optimum percentage of yield with a high amount of (-)-HCA and total organic acid as a response were recorded. A central composite design (CCD) and response surface methodology (RSM) were used to optimize experimental conditions for extraction of *G.cambogia*. The optimized extract was tested for biological activities such as antioxidant activity assay, antimicrobial activity and *in vitro* inhibitory activity of a *G.cambogia* extract on pancreatic lipase activity.

1.2 Problem Statement

The growth of nutraceutical, pharmaceutical and cosmeceutical products in Malaysia's herbal market is due to the increasing awareness in consuming natural product among consumers. Many supplements or herbal products claim to have lots of advantages such as slimming effect and high in antioxidant. The increasing consumption of natural products leads to high demand for herbal and natural products. However, for manufacturers, high demand means massive production. The massive production of an active compound involves a large volume of raw materials and solvents. Some active compounds are heat sensitive, light-sensitive, pH-sensitive and others. These factors make them unstable and most likely to denature due to the unfavourable condition during the extraction process. In the extraction process, the type of extraction methods and parameters are the key components in contributing to the quantity and quality of the crude extract of herbs.

Several scholars agreed that conventional methods of extraction are no longer suitable to be used in the extraction process in term of yield, environment-friendly and even production cost to meet the market demand (Pico, 2013; Tiwari, 2015; Panda and Manickam, 2019). The conventional extraction techniques such as soxhlet, maceration, infusion extraction have several drawbacks; time-consuming, laborious, low selectivity and low extraction yields. Moreover, these conventional techniques employ large amounts of toxic solvents. At present, the extraction methods that are able to overcome the above-mentioned drawbacks are being studied. Among them are supercritical fluid extraction (SFE), accelerated solvent extraction (ASE), ultrasonic-assisted extraction (UAE) and microwave-assisted extraction (MAE).

UAE is an inexpensive, simple and efficient alternative to conventional extraction techniques. The main benefits of the use of ultrasound in solid-liquid extraction include the increase of extraction yield and faster kinetics. Ultrasound can also reduce the operating temperature allowing the extraction of thermolabile compounds. Compared with other novel extraction techniques such as microwave-assisted extraction, the ultrasound apparatus is cheaper and its operation is easier. Furthermore, the UAE, like Soxhlet extraction, can be used with any solvent for extracting a wide variety of natural compounds.

Therefore, this research studied on ultrasonic-assisted extraction (UAE) method by controlling the condition of extraction to optimize the efficiency of the yield of (-)-HCA and total organic acid which is chosen as the product of interest in *G.cambogia*. Optimization of extraction (-)-HCA and total organic acid in *G.cambogia* by using UAE are not adequately researched in order to determine the optimal operating conditions for the highest possible extraction yield. Hence, the screening by using OFAT method followed by the optimization of the extraction of *G.cambogia* was carried out so that the concentrations of those compounds at optimum operating conditions can be measured and determined by using response surface methodology (RSM) and involving central composite design (CCD).

1.3 Research Objectives

The objectives of this study are:

(i) To optimize the ultrasonic-assisted extraction processing parameter of *G.cambogia* with regards to (-)-HCA and total organic acid as the responses.

(ii) To determine the biological activity of *G.cambogia* extract for antioxidant activity, antimicrobial activity and *in vitro* inhibitory activity of a *G.cambogia* extract on pancreatic lipase activity

1.4 The Scope of the Research

(i) Screening of parameter conditions; type of solvent (H_2O, Methanol, Ethanol and Acetone), amplitude (10 % to 90 %), solid-liquid ratio (2 % to 100 %) and sonication time (10 min to 50 min) of extraction process using ultrasonic-assisted extraction (UAE) method.

(ii) Optimization of UAE processing parameters; amplitude (10 % to 70 %), solid-liquid ratio (2 % to 12 %) and sonication time (10 min to 40 min) of *G.cambogia* with regards to (-)-HCA and total organic acid as the responses.

(iii) Biological activity evaluation of *G.cambogia* extract for antioxidant activity using 2,2-diphenyl-1-picrylhydrazine scavenging activity (DPPH), antimicrobial activity against *E.coli* and *S.aureus* and in vitro inhibitory activity of *G.cambogia* extract on pancreatic lipase activity by using auto titrator

1.5 Significant of Study

The increasing awareness among consumers on healthy living and obesity problem had led to a rapid increase in the development of slimming product lately. *G.cambogia* extract can be capitalized as a source of weight reduction agent and further commercialized as a value-added ingredient into nutraceutical based product. Thus, the optimization of the ultrasonic-assisted extraction process is very crucial in order to increase the extraction yield of the active compound of *G.cambogia*. At the end of this study, the optimized parameter of UAE can guide herbal related manufacturers to boost their production. The quality and quantity of extract can be increased with the employment of the best extraction method.

REFERENCES

Abd Rahman, R. N. Z. R. (2017). Anti-obesity Potential of Selected Tropical Plants via Pancreatic Lipase Inhibition. *Advances in Obesity, Weight Management & Control*, *6*(4).

Aboutabl, E. A., Saleh, I. A., Mason, T. J., Hammouda, F. M., Abdel-Azim, N. S., & Vinatoru, M. (2016). A possible general mechanism for ultrasound-assisted extraction (UAE) suggested from the results of UAE of chlorogenic acid from *Cynara scolymus* L. (artichoke) leaves. *Ultrasonics Sonochemistry*, *31*, 330–336.

Ahmadi, M., Vahabzadeh, F., Bonakdarpour, B., Mofarrah, E., & Mehranian, M. (2005). Application of the central composite design and response surface methodology to the advanced treatment of olive oil processing wastewater using Fenton's peroxidation. *Journal of Hazardous Materials*, *123*(1), 187–195.

Akram, M., Chowdhury, A., & Chakrabarti, S. (2016). Removal of Rhodamine B dye from wastewater by ultrasound-assisted Fenton process: a comparison between bath and probe type sonicators. *Environmental Science: An Indian Journal*, *12*, 1–13.

Ali, H., Siddiqui, A., & Nazzal, S. (2010). The Effect of Media Composition, pH, and Formulation Excipients on the In Vitro Lipolysis of Self-Emulsifying Drug Delivery Systems (SEDDS). *Journal of Dispersion Science and Technology*, *31*(2), 226–232.

Altiner, A., Ates, A., Gursel, E., & Bilal, T. (2012). Effect of the antiobesity agent *Garcinia cambogia* extract on serum lipoprotein (a), Apolipoproteins A1 and B, and total Cholesterol levels in female rats fed atherogenic diet. *J Anim Plant Sci*, *22*(4), 872–877.

Asghar, M., Monjok, E., Kouamou, G., Ohia, S. E., Bagchi, D., & Lokhandwala, M. F. (2007). Super CitriMax (HCA-SX) attenuates increases in oxidative stress, inflammation, insulin resistance, and body weight in developing obese Zucker rats. *Molecular and Cellular Biochemistry*, *304*(1–2), 93–99.

Asish, G. R., Parthasarathy, U., Zachariah, T. J., Gobinath, P., Mathew, P. A., George, J. K., & Saji, K. V. (2008). A Comparative Estimation of (-) Hydroxycitric acid in Different Species of Garcinia. *The Hort. J.*, *21*(1), 26–29.

Awad, T. S., Moharram, H. A., Shaltout, O. E., Asker, D., & Youssef, M. M. (2012). Applications of ultrasound in analysis, processing and quality control of food: A review. *Food Research International*, *48*(2), 410–427.

Baldi, A., Pandit, M. K., & Ranka, P. (2012). Amelioration of in-vivo Antioxidant Activity by Banana Extracts. *International Journal of Pharmaceutical & Biological Archives*, *3*(1), 157–161.

Bauer, E., Jakob, S., & Mosenthin, R. (2004). Physiology of Lipid Digestion. *Asian-Australasian Journal of Animal Sciences*, *18*(2), 282–295. Retrieved from https://www.ajas.info/upload/pdf/18_44.pdf

Boligon, A. A., Machado, M. M., & Athayde, M. L. (2014). Technical Evaluation of Antioxidant Activity. *Medicinal Chemistry*, *4*(7), 517–522.

Boonkird, S., Phisalaphong, C., & Phisalaphong, M. (2008). Ultrasound-assisted extraction of capsaicinoids from *Capsicum frutescens* on a lab- and pilot-plant scale. *Ultrasonics Sonochemistry*, *15*(6), 1075–1079.

Bucić-Kojić, A., Planinić, M., Tomas, S., Bilić, M., & Velić, D. (2007). Study of solid–liquid extraction kinetics of total polyphenols from grape seeds. *Journal of Food Engineering*, *81*(1), 236–242.

Cacace, J. E., & Mazza, G. (2003). Mass transfer process during extraction of phenolic compounds from milled berries. *Journal of Food Engineering*, *59*(4), 379–389.

Carratù, B., Boniglia, C., Giammarioli, S., Mosca, M., & Sanzini, E. (2008). Free amino acids in botanicals and botanical preparations. *Journal of Food Science, 73*(5), C323–C328.

Carrera, C., Ruiz-Rodríguez, A., Palma, M., & Barroso, C. G. (2012). Ultrasound assisted extraction of phenolic compounds from grapes. *Analytica Chimica Acta, 732*, 100–104.

Chae, H. S., Kim, E. Y., Han, L., Kim, N. R., Lam, B., Paik, J. H., … Chin, Y. W. (2016). Xanthones with pancreatic lipase inhibitory activity from the pericarps of *Garcinia mangostana* L. (Guttiferae). *European Journal of Lipid Science and Technology*, *118*(9), 1416–1421.

Chan, Y. Y., Lim, K. K., Lim, K. H., Teh, C. H., Kee, C. C., Cheong, S. M., … Ahmad, N. A. (2017). Physical activity and overweight/obesity among Malaysian adults: Findings from the 2015 National Health and morbidity survey (NHMS). *BMC Public Health*, *17*(1), 1–12.

Cheema- Dhadli, S., Halperin, M. L., & Leznoff, C. C. (1973). Inhibition of Enzymes which Interact with Citrate by (—) Hydroxycitrate and 1, 2, 3,-Tricarboxybenzene. *European Journal of Biochemistry*, *38*(1), 98–102.

Chen, Q., Fung, K. Y., Lau, Y. T., Ng, K. M., & Lau, D. T. W. (2016). Relationship between maceration and extraction yield in the production of Chinese herbal medicine. *Food and Bioproducts Processing*, *98*, 236–243.

Chen, Y., Xie, M.-Y., & Gong, X.-F. (2007). Microwave-assisted extraction used for the isolation of total triterpenoid saponins from *Ganoderma atrum*. *Journal of Food Engineering*, *81*(1), 162–170.

Cheng, I.-S., Huang, S.-W., Lu, H.-C., Wu, C.-L., Chu, Y.-C., Lee, S.-D., … Kuo, C.-H. (2012). Oral hydroxycitrate supplementation enhances glycogen synthesis in exercised human skeletal muscle. *British Journal of Nutrition*, *107*(07), 1048–1055.

Cheok, C. Y., Chin, N. L., Yusof, Y. A., Talib, R. A., & Law, C. L. (2012). Optimization of total phenolic content extracted from *Garcinia mangostana* Linn. hull using response surface methodology versus artificial neural network. *Industrial Crops and Products*, *40*(1), 247–253.

Choppa, T., Selvaraj, C. I., & Zachariah, A. (2015). Evaluation and Characterization of Malabar Tamarind Seed Oil. *Journal of Food Science and Technology*, *52*(9), 5906–5913.

Chuah, L. O., Ho, W. Y., Beh, B. K., & Yeap, S. K. (2013). Updates on antiobesity effect of garcinia origin (−)-HCA. *Evidence-Based Complementary and Alternative Medicine*, *2013*.

Clark, P. (2008). An updates on ultrasonics. *Food Technology*, 75–77.

Czitrom, V. (1999). One-factor-at-a-time versus designed experiments. *American Statistician*, *53*(2), 126–131.

Deng, J., Xu, Z., Xiang, C., Liu, J., Zhou, L., Li, T., … Ding, C. (2017). Comparative evaluation of maceration and ultrasonic-assisted extraction of phenolic compounds from fresh olives. *Ultrasonics Sonochemistry*, *37*, 328–334.

dos Reis, S. B., de Oliveira, C. C., Acedo, S. C., da Conceição Miranda, D. D., Ribeiro, M. L., Pedrazzoli, J., & Gambero, A. (2009). Attenuation of colitis injury in rats using *Garcinia cambogia extract*. *Phytotherapy Research*, *23*(3), 324–329.

Dubey, G. P. (2013). In Vitro Assessment of Antibacterial and Antioxidant Activities of Fruit Rind Extracts of *Garcinia Cambogia*. L. *International Journal of Pharmacy and Pharmaceutical Sciences*, *5*(2), 2–5.

Easmina, M. S., Sarkera, M. Z. I., * S. F., Shamsudina, S. H., Yunusb, Kamaruzzaman BinUDdina, M. S., Sarkerc, M. M. R., … Khalil, H. A. (2014). Bioactive compounds and advanced processing technology: *J Chem Technol Biotechnol.*, 1–11.

Edelin C, B.R. Ramesh, Bouakhaykhone Svengsuksa, P. J. E. K. (n.d.). Biodiversity Informatics and Co-operation in Taxonomy for Interactive shared Knowledge Base. Retrieved from December 2008 website: http://biotik.org/india/species/g/garcgumm/garcgumm_en.html

Fang Xinsheng, Jianhua Wang, Yingzi Wang, Xueke Li, Hongying Zhou, L. Z. (2014). Optimization of ultrasonic-assisted extraction of wedelolactone and antioxidant polyphenols from *Eclipta prostrate* L using response surface methodology. *Separation and Purification Technology*, *138*, 55–64.

Farid Chemat, Natacha Rombaut, Anne-Gaëlle Sicaire, Alice Meullemiestre, Anne-Sylvie Fabiano-Tixier, M. A.-V. (2017). Ultrasound assisted extraction of food and natural products. Mechanisms, techniques, combinations, protocols and applications. A review. *Ultrasonics Sonochemistry*, *34*, 540–560.

Ferreira, S. L. C., Bruns, R. E., Ferreira, H. S., Matos, G. D., David, J. M., Brandão, G. C., … dos Santos, W. N. L. (2007). Box-Behnken design: An alternative for the optimization of analytical methods. *Analytica Chimica Acta*, *597*(2), 179–186.

Frost, J. (2019). How To Interpret R-squared in Regression Analysis. Retrieved from https://statisticsbyjim.com/regression/interpret-r-squared-regression/

Gertenbach, D. D. (2002). Solid–liquid extraction technologies for manufacturing nutraceuticals from botanicals. In and M. L. M. J. Shi, G. Mazza (Ed.), *Functional Foods: Bioachemical and Processing Aspects* (pp. 332–365). USA: CRC Press.

Ghafoor, K. (2009). Optimization of Ultrasound Assisted Extraction of Phenolic Compounds and Antioxidants from Grape Peel through Response Surface Methodology. *Journal of the Korean Society for Applied Biological Chemistry*, *52*(3), 295–300.

Gogoi, A., Gogoi, N., & Neog, B. (2014). Estimation of (-)-hydroxycitric acid (HCA) in *Garcinia lanceaefolia* Roxb. using novel HPLC methodology. *International Journal of Pharmaceutical Sciences and Research*, *5*(11), 4993.

Gordillo, B., Baca-Bocanegra, B., Rodriguez-Pulído, F. J., González-Miret, M. L., García Estévez, I., Quijada-Morín, N., … Escribano-Bailón, M. T. (2016). Optimisation of an oak chips-grape mix maceration process. Influence of chip dose and maceration time. *Food Chemistry*, *206*, 249–259.

Grundy, M. M. L., Wilde, P. J., Butterworth, P. J., Gray, R., & Ellis, P. R. (2015). Impact of cell wall encapsulation of almonds on in vitro duodenal lipolysis. *Food Chemistry*, *185*(4), 405–412.

Haraguchi, H., Inoue, J., Tamura, Y., & Mizutani, K. (2002). Antioxidative components of *Psoralea corylifolia* (Leguminosae). *Phytotherapy Research*, *16*(6), 539–544.

Hasegawa, N. (2001). Garcinia extract inhibits lipid droplet accumulation without affecting adipose conversion in 3T3-L1 cells. *Phytotherapy Research*, *15*(2), 172–173.

Hashemi, S. M. B., Michiels, J., Asadi Yousefabad, S. H., & Hosseini, M. (2015). Kolkhoung (*Pistacia khinjuk*) kernel oil quality is affected by different parameters in pulsed ultrasound-assisted solvent extraction. *Industrial Crops and Products*, *70*, 28–33.

Hayamizu, K., Hirakawa, H., Oikawa, D., Nakanishi, T., Takagi, T., Tachibana, T., & Furuse, M. (2003). Effect of *Garcinia cambogia* extract on serum leptin and insulin in mice. *Fitoterapia*, *74*(3), 267–273.

Heidari, O., Reza, A., & Nafchi, M. (2015). Optimization of Lycopene Extraction from Tomato Waste with the Integration of Ultrasonic - Enzymatic Processes by Response Surface Methodology. *Journal of Industrial Engineering Research*, *1*(3), 29–34.

Ho, C. H. L., Cacace, J. E., & Mazza, G. (2008). Mass transfer during pressurized low polarity water extraction of lignans from flaxseed meal. *Journal of Food Engineering*, *89*(1), 64–71.

Hong, J., Sang, S., Park, H.-J., Kwon, S. J., Suh, N., Huang, M.-T., … Yang, C. S. (2006). Modulation of arachidonic acid metabolism and nitric oxide synthesis by garcinol and its derivatives. *Carcinogenesis*, *27*(2), 278–286.

Hossain, M. B., Brunton, N. P., Patras, A., Tiwari, B., O'Donnell, C. P., Martin-Diana, A. B., & Barry-Ryan, C. (2012). Optimization of ultrasound assisted extraction of antioxidant compounds from marjoram (*Origanum majorana* L.) using response surface methodology. *Ultrasonics Sonochemistry*, *19*(3), 582–590.

Huie, C. W. (2002). A review of modern sample-preparation techniques for the extraction and analysis of medicinal plants. *Analytical and Bioanalytical Chemistry*, *373*(1–2), 23–30.

Hundy, G. F., & AR, T. (2008). Welch TC. In *Refrigeration and Air-Conditioning. 4th ed. Oxford: Butterworth Heinemann*.

Iinuma, M., Ito, T., Miyake, R., Tosa, H., Tanaka, T., & Chelladurai, V. (1998). A xanthone from *Garcinia cambogia*. *Phytochemistry*, *47*(6), 1169–1170.

Ishihara, K., Oyaizu, S., Onuki, K., Lim, K., & Fushiki, T. (2000). Chronic (-)-hydroxycitrate administration spares carbohydrate utilization and promotes lipid oxidation during exercise in mice. *The Journal of Nutrition*, *130*(12), 2990–2995.

J Mason, T., Chemat, F., & Vinatoru, M. (2011). The extraction of natural products using ultrasound or microwaves. *Current Organic Chemistry*, *15*(2), 237–247.

Jadhav, D., B.N., R., Gogate, P. R., & Rathod, V. K. (2009). Extraction of vanillin from vanilla pods: A comparison study of conventional soxhlet and ultrasound assisted extraction. *Journal of Food Engineering*, *93*(4), 421–426.

Jagtap, P., Bhise, K., & Prakya, V. (2015). A Phytopharmacological Review on *Garcinia indica*. *International Journal of Herbal Medicine*, *3*(4), 2–7.

Jayaprakasha, G. K., & Sakariah, K. K. (2000a). Determination of (-) hydroxycitric acid in commercial samples of *Garcinia cambogia* extract by liquid chromatography with ultraviolet detection. *Journal of Liquid Chromatography and Related Technologies*, *23*(6), 915–923.

Jayaprakasha, G. K., & Sakariah, K. K. (2000b). Determination Of (−) Hydroxycitric Acid In Commercial Samples of *Garcinia Cambogia* Extract By Liquid Chromatography With Ultraviolet Detection. *Journal of Liquid Chromatography & Related Technologies*, *23*(6), 915–923.

Jayaprakasha, G. K., & Sakariah, K. K. (2002). Determination of organic acids in leaves and rinds of *Garcinia indica* (Desr.) by LC. *Journal of Pharmaceutical and Biomedical Analysis*, *28*(2), 379–384.

Jayaprakasha, G K, & Sakariah, K. K. (1998). Determination of organic acids in *Garcinia cambogia* (Desr.) by high-performance liquid chromatography. *Journal of Chromatography A*, *806*(2), 337–339.

Jayaprakasha, Guddadarangavvanahally K., Jena, B. S., & Sakariah, K. K. (2003). Improved liquid chromatographic method for determination of organic acids in leaves, pulp, fruits, and rinds of Garcinia. *Journal of AOAC International*, *86*(5), 1063–1068.

Jena, B. S., Jayaprakasha, G. K., Singh, R. P., & Sakariah, K. K. (2002). Chemistry and biochemistry of (-)-hydroxycitric acid from Garcinia. *Journal of Agricultural and Food Chemistry*, *50*(1), 10–22.

Jena, Bhabani S., Jayaprakasha, G. K., & Sakariah, K. K. (2002). Organic acids from leaves, fruits, and rinds of *Garcinia cowa*. *Journal of Agricultural and Food Chemistry*, *50*(12), 3431–3434.

Joana Gil-Chávez, G., Villa, J. A., Fernando Ayala-Zavala, J., Basilio Heredia, J., Sepulveda, D., Yahia, E. M., & González-Aguilar, G. A. (2013). Technologies for Extraction and Production of Bioactive Compounds to be Used as Nutraceuticals and Food Ingredients: An Overview. *Comprehensive Reviews in Food Science and Food Safety*, *12*(1), 5–23.

Juhel, C., Armand, M., Pafumi, Y., Rosier, C., Vandermander, J., & Lairon, D. (2000). Green tea extract (AR25®) inhibits lipolysis of triglycerides in gastric and duodenal medium in vitro. *Journal of Nutritional Biochemistry*, *11*(1), 45–51.

Kaikai Shen, Jianling Xie, Hua Wang, Hong Zhang, Mengyuan Yu, Fangfang Lu, Hongsheng Tan, and H. X. (2015). Cambogin induces caspase-independent apoptosis through the ROS/JNK pathway and epigenetic regulation in breast cancer cells. *Molecular Cancer Therapeutics*, *14*(7), 1738–1749.

Kim, M., Kim, J., Kwon, D., & Park, R. (2004). Anti-adipogenic effects of Garcinia extract on the lipid droplet accumulation and the expression of transcription factor. *Biofactors*, *22*(1–4), 193–196.

Kimura, M., & Rodriguez-Amaya, D. B. (1999). Sources of errors in the quantitative analysis of food carotenoids by HPLC. *Archivos Latinoamericanos de Nutricion*, *49*(3 Suppl 1), 58S-66S.

Kiyose, C., Kubo, K., & Saito, M. (2006). Effect of Garcinia cambogia administration on female reproductive organs in rats. *Journal of Clinical Biochemistry and Nutrition*, *38*(3), 188–194.

Klein Junior, L. C., Antunes, M. V, Linden, R., & Vasques, C. A. R. (2010). Quantification of (-) Hydroxycitric Acid in Marketed Extracts of *Garcinia cambogia* by High Performance Liquid Chromatography. *Latin American Journal of Pharmacy*, *29*(5), 835–838.

Kolodziejczyk, J., Masullo, M., Olas, B., Piacente, S., Wachowicz, B., Ponte, V., … Farmaceutiche, S. (2009). Effects of garcinol and guttiferone K isolated from *Garcinia cambogia* on oxidative / nitrative modifications in blood platelets and plasma. *Platelets*, *20*(7), 487–492.

Koshy, A. S., & Vijayalakshmi, N. R. (2001). Impact of certain flavonoids on lipid profiles-potential action of *Garcinia cambogia* flavonoids. *Phytotherapy Research*, *15*(5), 395–400.

Kovacs, E. M. R., & Westerterp-Plantenga, M. S. (2006). Effects of (-)-hydroxycitrate on net fat synthesis as *de novo* lipogenesis. *Physiology and Behavior*, *88*(4–5), 371–381.

Kumar, S., Sharma, S., & Chattopadhyay, S. K. (2009). High-performance liquid chromatography and LC- ESI- MS method for identification and quantification of two isomeric polyisoprenylated benzophenones isoxanthochymol and camboginol in different extracts of Garcinia species. *Biomedical Chromatography*, *23*(8), 888–907.

Kuriyan, K. I., & Pandya, K. C. (1931). A note on the main constituents of the dried rind of the fruit of *Garcinia cambogia*. *J Indian Chem Soc*, *8*, 469.

Lewis, Y. S., & Neelakantan, S. (1965). (-)-Hydroxycitric acid-the principal acid in the fruits of *Garcinia cambogia* desr. *Phytochemistry*, *4*(4), 619–625.

Li, H., Pordesimo, L., & Weiss, J. (2004). High intensity ultrasound-assisted extraction of oil from soybeans. *Food Research International*, *37*(7), 731–738.

Liang, N., & Kitts, D. D. (2014). Antioxidant property of coffee components: Assessment of methods that define mechanism of action. *Molecules*, *19*(11), 19180–19208.

Liao, C., Sang, S., Liang, Y., Ho, C., & Lin, J. (2004). Suppression of inducible nitric oxide synthase and cyclooxygenase-2 in downregulating nuclear factor-kappa B pathway by Garcinol. *Molecular Carcinogenesis*, *41*(3), 140–149.

Lim, S., Choi, A., Kwon, M., Joung, E., Shin, T., Gil, S., … Kim, H. (2019). Evaluation of antioxidant activities of various solvent extract from Sargassum serratifolium and its major antioxidant components. *Food Chemistry*, *278*, 178–184.

Lowenstein, J. (1973). *Method of treating obesity*. Google Patents.

Lowenstein, J. M., & Brunengraber, H. (1981). Hydroxycitrate [Garcinia and Hibiscus species]. *Methods in Enzymology*, *72*, 486–497.

Ma, W., Lu, Y., Dai, X., Liu, R., Hu, R., & Pan, Y. (2009). Determination of Anti-Tumor Constitute Mollugin from Traditional Chinese Medicine *Rubia cordifolia*: Comparative Study of Classical and Microwave Extraction Techniques. *Separation Science and Technology*, *44*(4), 995–1006.

MacGregor, K. J., Embleton, J. K., Lacy, J. E., Perry, E. A., Solomon, L. J., Seager, H., & Pouton, C. W. (1997). Influence of lipolysis on drug absorption from the gastro-intestinal tract. *Advanced Drug Delivery Reviews*, *25*(1), 33–46.

Mackeen, M. M., Ali, A. M., Lajis, N. H., Kawazu, K., Hassan, Z., Amran, M., … Mohamed, S. M. (2000). Antimicrobial, antioxidant, antitumour-promoting and cytotoxic activities of different plant part extracts of Garcinia atroviridis Griff. ex T. Anders. *72*, 395–402.

Magaldi, S., Mata-Essayag, S., De Capriles, C. H., Perez, C., Colella, M. T., Olaizola, C., & Ontiveros, Y. (2004). Well diffusion for antifungal susceptibility testing. *International Journal of Infectious Diseases*, *8*(1), 39–45.

Mahapatra, S., Mallik, S. B., Rao, G. V., Reddy, G. C., & Guru Row, T. N. (2007). Garcinia lactone. *Acta Crystallographica Section E: Structure Reports Online*, *63*(9), 3869–3869.

Mahendran, P., & Devi, C. S. S. (2001). The modulating effect of *Garcinia cambogia* extract on ethanol induced peroxidative damage in rats. *Indian Journal of Pharmacology*, *33*(2), 87–91.

Mahendran, P., Sabitha, K. E., & Devi, C. S. S. (2002). Prevention of HCl-ethanol induced gastric mucosal injury in rats by *Garcinia cambogia* extract and its possible mechanism of action. *Indian Journal of Experimental Biology*, *40*(1), 58–62.

Maheshwari, R. K., Mohan, L., & Upadhyay, B. (2014). *Garcinia Cambogia* : An Awesome Superfruit for Healthcare. *Journal of Pharmaceutical and Biomedical*, *2*(1), 80–84.

Majeed, M., Badmaev, V., & Rajendran, R. (1997). *Patent No. 5783603*. Washington DC: US Patent and Trademark office.

Malani, K. (2017). Garcinia Cambogia Dosage: How To Take & Best Time To Take. Retrieved from https://www.myfitfuel.in/mffblog/garcinia-cambogia-dosage/

Mani-López, E., García, H. S., & López-Malo, A. (2012). Organic acids as antimicrobials to control Salmonella in meat and poultry products. *Food Research International*, *45*(2), 713–721.

Martin, F. W., Campbell, C. W., & Ruberté, R. M. (1987). Perennial edible fruits of the tropics: An inventory. In *Agriculture Handbook, USDA*.

Mason, T. J., Paniwnyk, L., & Lorimer, J. (1996). The uses of ultrasound in food processing. *Ultrasonics Sonochemistry*, *3*(3), S253–S260.

Masullo, M., Bassarello, C., Bifulco, G., & Piacente, S. (2010). Polyisoprenylated benzophenone derivatives from the fruits of Garcinia cambogia and their absolute configuration by quantum chemical circular dichroism calculations. *Tetrahedron*, *66*(1), 139–145.

Masullo, M., Bassarello, C., Suzuki, H., Pizza, C., & Piacente, S. (2008). Polyisoprenylated benzophenones and an unusual polyisoprenylated tetracyclic xanthone from the fruits of *Garcinia cambogia*. *Journal of Agricultural and Food Chemistry*, *56*(13), 5205–5210.

Mathew, G E, Mathew, B., Sheneeb, M. M., Nyanthara, H. Y., & Haribabu, Y. (2011). Anthelmintic activity of leaves of *Garcinia cambogia*. *Int J Res Pharm Sci*, *2*(1), 63–65.

Mathew, Githa E, Mathew, B., Shaneeb, M. M., & Nyanthara, B. (2011). Diuretic activity of leaves of *Garcinia cambogia* in rats. *Indian Journal of Pharmaceutical Sciences*, *73*(2), 228.

Mazzio, E. A., & Soliman, K. F. A. (2009). In vitro screening for the tumoricidal properties of international medicinal herbs. *Phytotherapy Research: PTR*, *23*(3), 385.

Medina-torres, N., Ayora-talavera, T., & Espinosa-andrews, H. (2017). Ultrasound Assisted Extraction for the Recovery of Phenolic Compounds from Vegetable Sources. *Agronomy*, *7*, 47.

Michael E Carpenter. (2018). Errors in Titration Experiments. Retrieved from https://sciencing.com/reasons-error-chemistry-experiment-8641378.html

Moffett, S. A., Bhandari, A. K., & Ravindranath, B. (1997). *Patent No. 5,656,314*. Washington DC: US Patent and Trademark Office.

Mohamad, M., Ali, M. W., Ripin, A., & Ahmad, A. (2013). Effect of Extraction Process Parameters on the Yield of Bioactive Compounds from the Roots of *Eurycoma Longifolia*. *Journal Teknologi*, *60*, 21–57.

Mohan, A., & Pohlman, F. W. (2016). Role of organic acids and peroxyacetic acid as antimicrobial intervention for controlling *Escherichia coli* O157: H7 on beef trimmings. *LWT - Food Science and Technology*, *65*, 868–873.

Mohd Azizi Che Yunus, Ching Yaw Lee, Z. I. (2011). Effects Of Variables On The Production Of Red-Fleshed Pitaya Powder Using Response Surface Methodology. *Jurnal Teknologi*, *56*, 15–29.

Montes, I., Lai, C., & Sanabria, D. (2003). Like Dissolves Like: A Guided Inquiry Experiment for Organic Chemistry. *Journal of Chemical Education*, *80*(4), 447.

Mopuri, R., & Meriga, B. (2014). Anti-Lipase and Anti-Obesity Activities of *Terminalia paniculata* Bark in High Calorie Diet-Induced Obese Rats. *Global J. Pharmacol*, *8*(1), 114–119.

Moulton, K. J., & Wang, L. C. (1982). A Pilot- Plant Study of Continuous Ultrasonic Extraction of Soybean Protein. *Journal of Food Science*, *47*(4), 1127–1129.

Nagalingam, A. P., & Yeo, S. H. (2018). Effects of ambient pressure and fluid temperature in ultrasonic cavitation machining. *International Journal of Advanced Manufacturing Technology*, *98*(9–12), 2883–2894.

Narayan, C., Rai, R. V., & Tewtrakul, S. (2011). A Screening strategy for selection of Anti-HIV-1 Integrase and anti-HIV-1 Protease Inhibitors from extracts of Indian Medicinal plants. *International Journal of Phytomedicine*, *3*(3), 312.

Nascimento, G. G. F., Locatelli, J., Freitas, P. C., Silva, G. L., & Piracicaba, U. M. De. (2000). Antibacterial Activity of Plant Extracts and Phytochemicals on Antibiotic-Resistant Bacteria. *Brazilian Journal of Microbiology*, *31*, 247–256.

Nayak, C. A., & Rastogi, N. K. (2013). Optimization of solid-liquid extraction of phytochemicals from *Garcinia indica* Choisy by response surface methodology. *Food Research International*, *50*(2), 550–556.

Niazi, S., Hashemabadi, S. H., & Noroozi, S. (2014). Numerical Simulation of Operational Parameters And Sonoreactor Configurations For The Highest Possibility Of Acoustic Cavitation In Crude Oil. *Chemical Engineering Communications*, *201*(10), 1340–1359.

Oluyemi, K. A., Jimoh, O. R., Adesanya, O. A., Omotuyi, I. O., Josiah, S. J., & Oyesola, T. O. (2007). Effects of crude ethanolic extract of *Garcinia cambogia* on the reproductive system of male wistar rats (*Rattus novergicus*). *African Journal of Biotechnology*, *6*(10), 1236–1238.

Onakpoya, I., Hung, S. K., Perry, R., Wider, B., & Ernst, E. (2010). The use of garcinia extract (hydroxycitric acid) as a weight loss supplement: A systematic review and meta-analysis of randomised clinical trials. *Journal of Obesity*, *2011*.

Opalić, M., Domitran, Z., Komes, D., & KarlOVIć, D. (2009). The Effect of Ultrasound Pre-Treatment and Air-Drying on the Quality of Dried Apples. *Czech Journal of Food Sciences*, *27*(SI), S297–S300.

Palma, M., & Barroso, C. G. (2002). Ultrasound-assisted extraction and determination of tartaric and malic acids from grapes and winemaking by-products. *Analytica Chimica Acta*, *458*(1), 119–130.

Panda, D., & Manickam, S. (2019). Cavitation Technology-The Future of Greener Extraction Method : A Review on the Extraction of Natural Products and Process Intensification Mechanism and Perspectives. *Applied Sciences*, *9,* 766.

Patil, M. N., Kagathara, V. G., Harle, U. N., Pujari, R. R., & Ingawale, D. K. (2010). Effect of polyherbal formulation in obesity associated diabetes. *International Journal of Pharmacy and Pharmaceutical Sciences*, *2*(3), 180–186.

Pico, Y. (2013). Ultrasound-assisted extraction for food and environmental samples. *Trends in Analytical Chemistry*, *43*, 84–99.

Pifferi, P. G., & Vaccari, A. (1983). The anthocyanins of sunflower: II. A study of the extraction process. *International Journal of Food Science & Technology*, *18*(5), 629–638.

Pingret, D., Fabiano-Tixier, A.-S., Ginies, C., Durand, G., Chemat, F., & Rockenbauer, A. (2012). Degradation of Edible Oil during Food Processing by Ultrasound: Electron Paramagnetic Resonance, Physicochemical, and Sensory Appreciation. *Journal of Agricultural and Food Chemistry*, *60*(31), 7761–7768.

Pisoschi, A. M., & Negulescu, G. P. (2012). Methods for Total Antioxidant Activity Determination: A Review. *Biochem Anal Biochem*, *1*(1), 106.

Purohit, A. P., & Kushwaha, R. (2013). Antiulcer activity of polyherbal formulation. *Int J Pharm Bio Sci*, *4*(1), 604–611.

Qu, W., Pan, Z., & Ma, H. (2010). Extraction modeling and activities of antioxidants from pomegranate marc. *Journal of Food Engineering*, *99*(1), 16–23.

Rezaie, M., Farhoosh, R., Iranshahi, M., Sharif, A., & Golmohamadzadeh, S. (2015). Ultrasonic-assisted extraction of antioxidative compounds from Bene (*Pistacia atlantica* subsp. mutica) hull using various solvents of different physicochemical properties. *Food Chemistry*, *173*, 577–583.

Roh, C., & Jung, U. (2012). Screening of crude plant extracts with anti-obesity activity. *International Journal of Molecular Sciences*, *13*(2), 1710–1719.

Rostagno, M. A., Palma, M., & Barroso, C. G. (2003). Ultrasound-assisted extraction of soy isoflavones. *Journal of Chromatography A*, *1012*(2), 119–128.

Roy, S., Rink, C., Khanna, S., Phillips, C., Bagchi, D., Bagchi, M., & Sen, C. K. (2003). Body weight and abdominal fat gene expression profile in response to a novel hydroxycitric acid-based dietary supplement. *Gene Expression*, *11*(5–6), 251–262.

S.S Patel. (2017). *Engineering Physics Group 1 DP Semester 1*. Atul Prakashan.

Saadat, N., & Gupta, S. V. (2012). Potential role of garcinol as an anticancer agent. *Journal of Oncology*, *2012*.

Saddozai, A. A., Ahad, K., Safdar, M. N., Kausar, T., Mumtaz, A., & Jabbar, S. (2016). Extraction and quantification of polyphenols from kinnow (*Citrus reticulate* L.) peel using ultrasound and maceration techniques. *Journal of Food and Drug Analysis*, *25*(3), 488–500.

Saito, M., Ueno, M., Ogino, S., Kubo, K., Nagata, J., & Takeuchi, M. (2005). High dose of *Garcinia cambogia* is effective in suppressing fat accumulation in developing male Zucker obese rats, but highly toxic to the testis. *Food and Chemical Toxicology*, *43*(3), 411–419.

Samani, M. (2016). *Optimization of Extraction Process and Antioxidant Activity of Phaleria Macrocarpa*. Universiti Teknologi Malaysia.

Samlı, S. S. and R. (2013). Ultrasonics Sonochemistry Optimization of olive leaf extract obtained by ultrasound-assisted extraction with response surface methodology. *Ultrasonics Sonochemistry*, *20*, 595–602.

Šavikin, K. P., Zdunić, G. M., Đorđević, V. B., Bugarski, B. M., Gođevac, D. M., Jovanović, A. A., & Pljevljakušić, D. S. (2017). Optimization of the extraction process of polyphenols from Thymus serpyllum L. herb using maceration, heat and ultrasound assisted techniques. *Separation and Purification Technology*, *179*, 369–380.

Semwal, D. K., & Semwal, R. B. (2015). Efficacy and safety of *Stephania glabra*: an alkaloid-rich traditional medicinal plant. *Natural Product Research*, *29*(5), 396–410.

Semwal, R. B., Semwal, D. K., Vermaak, I., & Viljoen, A. (2015). A comprehensive scientific overview of *Garcinia cambogia*. *Fitoterapia*, *102*, 134–148.

Seyedan, A., Alshawsh, M. A., Alshagga, M. A., Koosha, S., & Mohamed, Z. (2015). Medicinal Plants and Their Inhibitory Activities against Pancreatic Lipase: A Review. *Evidence-Based Complementary and Alternative Medicine*, *2015*, 1–13.

Sheela, K., Nath, K. G., Vijayalakshmi, D., Yankanchi, G. M., & Patil, R. B. (2004). Proximate Composition of Underutilized Green Leafy Vegetables in Southern Karnataka. *Journal of Human Ecology*, *15*(3), 227–229.

Shivakumar, S., Sandhiya, S., Subhasree, N., Agrawal, A., & Dubey, G. P. (2013). In vitro assessment of antibacterial and antioxidant activities of fruit rind extracts of *Garcinia cambogia* L. *International Journal of Pharmacy and Pharmaceutical Sciences*, *5*(2), 254–257.

Silva, E. M., Rogez, H., & Larondelle, Y. (2007). Optimization of extraction of phenolics from *Inga edulis* leaves using response surface methodology. *Separation and Purification Technology*, *55*(3), 381–387.

Song, J. Z., Yip, Y. K., Han, Q. Bin, Qiao, C. F., & Xu, H. X. (2007). Rapid determination of polyprenylated xanthones in gamboge resin of *Garcinia hanburyi* by HPLC. *Journal of Separation Science*, *30*(3), 304–309.

Soni, M. G., Burdock, G. A., Preuss, H. G., Stohs, S. J., Ohia, S. E., & Bagchi, D. (2004). Safety assessment of (-)-hydroxycitric acid and Super CitriMax®, a novel calcium/potassium salt. *Food and Chemical Toxicology*, *42*(9), 1513–1529.

Spencer, A., Corman, L., & Lowenstein, J. M. (1964). Citrate and the conversion of carbohydrate into fat. A comparison of citrate and acetate incorporation into fatty acids. *Biochemical Journal*, *93*(2), 378.

Sreenivasan, A., & Venkataraman, R. (1959). Chromatographic detection of the organic constituents of Gorikapuli (*Garcinia cambogia* Desr.) used in pickling fish. *Current Science*, *28*, 151–152.

Subhashini, N., Nagarajan, G., & Kavimani, S. (2011). In vitro antioxidant and anticholinesterase activities of *Garcinia combogia*. *Int J Pharm Pharm Sci*, *3*(3), 129–132.

Tao, Y., Wu, D., Zhang, Q. A., & Sun, D. W. (2014). Ultrasound-assisted extraction of phenolics from wine lees: Modeling, optimization and stability of extracts during storage. *Ultrasonics Sonochemistry*, *21*(2), 706–715.

Taylor, P., Nayak, C. A., Rastogi, N. K., & Raghavarao, K. S. M. S. (2010). Bioactive Constituents Present in *Garcinia Indica* Choisy and its Potential Food Applications : A Review. *International Journal of Food Properties*, *13*(3), 441–453.

Tharachand, S. I., & Avadhani, M. (2013). Medicinal properties of Malabar tamarind [*Garcinia cambogia* (Gaertn) DESR.]. *Int J Pharm Sci Rev Res*, *19*(2), 101–107.

Tian, Y., Xu, Z., Zheng, B., & Martin Lo, Y. (2013). Optimization of ultrasonic-assisted extraction of pomegranate (*Punica granatum* L.) seed oil. *Ultrasonics Sonochemistry*, *20*(1), 202–208.

Tiwari, B. K. (2015). Ultrasound: A clean, green extraction technology. *TrAC - Trends in Analytical Chemistry*, *71*, 100–109.

Tobias, P., & Trutna, L. (2013). *e-Handbook of Statistical Methods* (C. Carroll & T. Paul, Eds.). NIST/SEMATECH.

Toma, M., Vinatoru, M., Paniwnyk, L., & Mason, T. J. (2001). Investigation of the effects of ultrasound on vegetal tissues during solvent extraction. *Ultrasonics Sonochemistry*, *8*(2), 137–142.

Valgas, C., Souza, S. M. de, Smânia, E. F. A., & Smânia Jr, A. (2007). Screening methods to determine antibacterial activity of natural products. *Brazilian Journal of Microbiology*, *38*(2), 369–380.

Vasques, C. A. R., Schneider, R., Klein- Júnior, L. C., Falavigna, A., Piazza, I., & Rossetto, S. (2014). Hypolipemic effect of *Garcinia cambogia* in obese women. *Phytotherapy Research*, *28*(6), 887–891.

Vinatoru, M., & Nenitzescu, D. (2001). An Overview of the Ultrasonically Assisted Extraction of Bioactive. *Ultrasonics Sonochemistry*, *8*, 303–313.

Vinatoru, M., Toma, M., & Mason, T. J. (1999). Ultrasonically assisted extraction of bioactive principles from plants and their constituents. *Advances in Sonochemistry*, *5*, 209–247.

Vinh, D. Q., Cuong, D. H., & Thuong, N. (2011). Extracting (-)-hydroxycitric acid from dried rinds of *Garcinia oblongifolia* champ. ex Benth by using microwave. *Journal of the Korean Chemical Society*, *55*(6), 983–987.

Vo, H. D., & Le, V. V. M. (2014). Optimization of ultrasonic treatment of rose myrtle mash in the extraction of juice with high antioxidant level. *International Food Research Journal*, *21*(6), 2331–2335.

Wang, L., & Weller, C. L. (2006). Recent advances in extraction of nutraceuticals from plants. *Trends in Food Science and Technology*, *17*(6), 300–312.

Watson, J. A., & Lowenste., J. (1970). Citrate And Conversion of Carbohydrate Into Fat-Fatty Acid Synthesis From Pyruvate By A Combination of Mitochondria And Cytoplasm Prepared From Rat Liver. *Federation Proceedings*, *29*(2), A676.

Wielinga, P. Y., Wachters-Hagedoorn, R. E., Bouter, B., van Dijk, T. H., Stellaard, F., Nieuwenhuizen, A. G., … Scheurink, A. J. W. (2005). Hydroxycitric acid delays intestinal glucose absorption in rats. *American Journal of Physiology-Gastrointestinal and Liver Physiology*, *288*(6), G1144–G1149.

Writer, C. (2014). How to calculate titratable acidity. Retrieved from http://www.ehow.com/how_5185931_calculate-titratable-acidity.html

YS Lewis, S Neelakantan, C. A. (1964). Acids in *Garcinia cambogia*. *Current Science*, *33*, 82–83.

Zeynep Akar, M. K. and H. D. (2017). A new colorimetric DPPH scavenging activity method with no need for a spectrophotometer applied on synthetic and natural antioxidants and medicinal herbs. *Journal of Enzyme Inhibition and Medicinal Chemistry*, *32*(1), 640–647.

Zhang, S., Bi, H., & Liu, C. (2007). Extraction of bio-active components from Rhodiola sachalinensis under ultrahigh hydrostatic pressure. *Separation and Purification Technology*, *57*(2), 277–282.

Zhao, L. C., He, Y., Deng, X., Yang, G. L., Li, W., Liang, J., & Tang, Q. L. (2012). Response surface modeling and optimization of accelerated solvent extraction of four lignans from fructus schisandrae. *Molecules*, *17*(4), 3618–3629.

Zheng, X., Xu, X., Liu, C., Sun, Y., Lin, Z., & Liu, H. (2013). Extraction characteristics and optimal parameters of anthocyanin from blueberry powder under microwave-assisted extraction conditions. *Separation and Purification Technology*, *104*, 17–25.