INFLUENCE OF CHURNING AND THAWING TEMPERATURES ON YIELD AND QUALITY OF VIRGIN COCONUT OIL

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INFLUENCE OF CHURNING AND THAWING TEMPERATURES ON YIELD AND QUALITY OF VIRGIN COCONUT OIL

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Dedicated to my beloved family, my husband, Sulaiman Ngadiran, and my children, Muhammad Aiman and Zara Aisyah

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ABSTRACT

The churning and thawing temperatures affect the yield and quality of coconut oil in integrated wet process. The thesis reports on the selection of *Cocos nucifera* species that contributed the highest oil content, followed by the optimization of integrated wet process. The highest oil content from coconut varieties was rendered by Soxhlet extraction. The response surface methodology (RSM) was used to determine the effects of churning (T_c) and thawing (T_t) temperatures by using the central composite design (CCD). The experimental design was limited to T_c (0.5-17.5 $^oC \pm 1.0$) and T_t (25.0 - 67.2 $^oC \pm 1.0$). The chemical constituent of ferulic acid was used to represent the total phenolic content in virgin coconut oil. The ferulic acid was determined by using high performance liquid chromatography (HPLC) and its colour was analysed by colorimeter. The free fatty acid (FFA) was determined by Association of Analytical Communities (AOAC) 940.28 method. The highest oil content ($p \leq 0.05$) was obtained from West African Tall (WAT), contributed 69.07 ± 0.06% compared to other species of Mawa, Matak, Rennel Island Tall, Maren and Tagnanan Tall comprising 64.62 ± 0.30%, 63.45 ± 0.37%, 63.42 ± 0.30%, 59.68 ± 0.01%, 58.12 ± 0.03% of oil, respectively. From the experiments, the oil yield and ferulic acid content showed the effects on the studied parameters. The equation of the responses were Oil Yield $= 24.52 - 1.53A + 4.10B - 4.01A^2 - 1.73B^2 -3.79AB$ and Ferulic Acid $= 7.17 - 0.042A + 0.22B - 0.28A - 0.59B^2$, respectively, where A (churning temperature) and B (thawing temperature). For FFA and colour implied the mean responses to the studied parameters corresponding with 0.11% and 0.55 yellowness. From the optimum point at T_c, 7.4 ^oC and T_t as 50.4 ^oC, the oil yield for WAT was 31.44 ± 0.24 % (w/w), $11.3x10^{-2}$ ± 0.11 ppm for ferulic acid, 0.10 ± 0.08 % for FFA and 0.04 yellowness for colour. The moisture content of the final oil 0.11 ± 0.15% was complied with the virgin coconut oil standards. The optimization process showed an increment of oil yield and ferulic acid content in virgin coconut oil using integrated wet process.

ABSTRAK

Suhu penyejukan dan pencairan memberi kesan kepada hasil dan kualiti minyak kelapa di dalam integrasi proses basah. Tesis ini melaporkan pemilihan spesis *Cocos nucifera* yang menyumbang kepada kandungan minyak tertinggi, diikuti dengan pengoptimuman proses integrasi basah. Kandungan minyak tertinggi daripada pelbagai jenis kelapa disampaikan menggunakan ektraksi Sokhlet. Kaedah permukaan respons (RSM) digunakan untuk mendapatkan kesan suhu penyejukan (T_c) dan pencairan (T_t) dengan menggunakan rekabentuk pusat komposit (CCD). Ruang rekabentuk terhad kepada T_c (0.5-17.5 $^oC \pm 1.0$) dan T_t (25.0 - 67.2 $^oC \pm 1.0$). Sebatian kimia asid ferulik digunakan untuk mewakili kandungan jumlah fenolik di dalam minyak kelapa dara. Sebatian kimia asid ferulik diperolehi dengan menggunakan alat kromotgrafi cecair prestasi tinggi (HPLC) dan warna dianalisa menggunakan meter warna. Asid lemak bebas (FFA) diperolehi menggunakan kaedah (Kesatuan Komuniti Analitikal) AOAC 940.28. Kandungan minyak paling signifikan ($p \leq 0.05$) diperolehi daripada *West African Tall* (WAT), yang menyumbang sebanyak 69.07% ± 0.06 dibandingkan dengan spesis lain iaitu *Mawa*, *Matak*, *Rennel Island Tall*, *Maren* dan *Tagnanan Tall* yang mengandungi 64.62 ± 0.30%, 63.45 ± 0.37%, 63.42 ± 0.30%, 59.68 ± 0.01%, 58.12 ± 0.03% minyak, setiap satunya. Daripada ujikaji, hasil minyak dan kandungan asid ferulik menunjukkan kesan kepada parameter-parameter kajian. Persamaan bagi maklumbalas adalah Hasil Minyak = $24.52 – 1.53A + 4.10B – 4.01A^2 – 1.73B^2 - 3.79AB$ dan Asid Ferulik = $7.17 – 0.042A + 0.22B – 0.28A -0.59B^2$ setiap satunya, di mana A (suhu penyejukan) dan B (suhu pencairan). Bagi FFA dan warna menerangkan respons min kepada parameter-parameter kajian selari dengan nilai 0.11% dan 0.55 kekuningan. Daripada titik optimum pada T_c, 7.4 ^oC and T_t sebagai 50.4 ^oC, hasil minyak untuk WAT adalah 31.44±0.24% (w/w), $11.3 \times 10^{-2} \pm 0.11$ppm untuk asid ferulik, 0.10 ± 0.08% FFA, 0.04 kekuningan untuk warna. Kandungan kelembapan bagi minyak akhir, 0.11 ± 0.15% telah menepati piawaian minyak kelapa dara. Proses pengoptimuman mempamerkan peningkatan hasil minyak dan kandungan ferulik asid di dalam minyak kelapa dara menggunakan integrasi proses basah.

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LIST OF ABBREVIATIONS

AOCS	-	American Oil Chemist's Society
APCC	-	Asian Pacific Coconut Community
AR	-	Analytical grade
ASE	-	Accelerated solvent extraction
BS	-	British Standards
CCD	-	Central composite design
DHA	-	Docosahexaenoic acid
DNA	-	Deoxyribonucleic acid
DOE	-	Design of experiments
EPA	-	Eicosapentaenoic acid
FFA	-	Free fatty acid
HIV	-	Human immune efficiency virus
HPA	-	Health protection agency
HPLC	-	High performance liquid chromatography
Hrs.	-	Hours
IBD	-	Institute of Bioproduct Development
Max.	-	Maximum
MC	-	Moisture content
MCFA	-	Medium chain fatty acid
MCT	-	Medium chain triglycerides
MS	-	Malaysia Standards
MPOB	-	Malaysian Palm Oil Board
NA	-	Not available
ND	-	Non detectable
NFPA	-	National Fire Protection Association

PNS	-	Philippines National Standards
RBD	-	Refined, bleached deodorized
STOT RE 2	-	Specific target organ systemic toxicology repeated in HPA
T	-	Temperature
VCO	-	Virgin coconut oil
WAT	-	West African Tall
wt.	-	Weight

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AOCS	-	American Oil Chemist's Society
APCC	-	Asian Pacific Coconut Community
AR	-	Analytical grade
ASE	-	Accelerated solvent extraction
BS	-	British Standards
CCD	-	Central composite design
DHA	-	Docosahexaenoic acid
DNA	-	Deoxyribonucleic acid
DOE	-	Design of experiments
EPA	-	Eicosapentaenoic acid
FFA	-	Free fatty acid
HIV	-	Human immune efficiency virus
HPA	-	Health protection agency
HPLC	-	High performance liquid chromatography
Hrs.	-	Hours
IBD	-	Institute of Bioproduct Development
Max.	-	Maximum
MC	-	Moisture content
MCFA	-	Medium chain fatty acid
MCT	-	Medium chain triglycerides
MS	-	Malaysia Standards
MPOB	-	Malaysian Palm Oil Board
NA	-	Not available
ND	-	Non detectable
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CHAPTER 1

INTRODUCTION

1.1 Research Overview

Coconut (*Cocos nucifera L.*) has been recognized for its oil since 4000 years ago in Ayurvedic medicine. The world demand for coconut oil has been expanding majorly in pharmaceutical, nutraceutical and cosmeceutical industries.

As overall, the coconut industry was almost stable globally during 2003 to 2008, in which Indonesia, India and Philippines were the major player in the world. Malaysia had produced approximately 45,000 tonne coconut oil during 2007-2012, that represented 1.3% from the world output of 3,500, 000 tonne (Euromonitor, 2013).

The conventional wisdom of saturated fat is bad has mislead the virgin coconut oil as unhealthy. The medium chain monolaurin exhibits bioactivities such as antimicrobial, antiviral, antiprotozoal and favor to the body immune system (Kabara, 2001). The coconut oil represented as saturated fat also able to increase the conversion of EPA (6%) and DHA (3.8%) compared to polyunsaturated fat (Enig, 1999). Due to its characteristic of high in saturated fatty acids especially the lauric acid content, coconut oil is known to have the high resistance to oxidation that may inhibits rancidity due to its stability and functionality (O'Brien, 2003). In comparison, the virgin olive oil is the other type of oil which is known rich in monounsaturated fatty acid can be a good source of omega 3 and 6 (Servilli *et. al*., 2012). Both oils play their specific role to fulfill the need of saturated and unsaturated sources for daily human consumption.

In plant, the phenolic constituent is acting as defense to infectious sources (Tuzen, 2003). In virgin coconut oil, the presence of phenolic acid that shows its antioxidant capacity allowing it to be used in cosmetic industry; and its capability to be converted into flavour constituent particularly from ferulic to vanilic acid (the main ingredient in vanila flavour) also enlighten the coconut industry (Faulds *et. al*, 1999). The minor compound of phenolic acid exhibits its antioxidant capacity of “antimutagenic”, “antiproliferative” and “anticarcinogenic” benefits to human being. The major phenolic acid found in virgin coconut oil was ferulic acid of concentration 5.09 mg/kg oil; followed by the “vanilic”, “*p*-coumaric” and “syringic” acids respectively (Marina *et. al*., 2009[a]). A study done by Song *et. al*. (2014) revealed that ferulic acid at concentration of 60 mg/kg gave a significant effect to stimulate the heart and liver cells against oxidative stress that correlated to diabetes in obese rats.

The virgin coconut oil (VCO) is processed from the fresh and mature kernel of coconut by mechanical or natural means with or without the application of heat, which does not alter the oil (APCC, 2009). The VCO is suitable for consumption without the need for further processing. The Philippines National Standards (2004) described further on the definition of VCO that must not undergoing the refining, bleaching, deodorizing (RBD) process. The process to extract the virgin coconut oil (VCO) that requires no heating may retain its biologically active compounds. These compounds provide nutritional and health benefits, mostly in preventing or minimizing chronic diseases (Marina *et.al*, 2009[b]).

Meanwhile, the coconut oil (CO) is derived from the kernel, meat, or copra of the coconut (APCC, 2009). Usually, the copra is kept in a place to get the oil after few months and undergoing the RBD process to cover the unpleasant aroma and colour. The RBD oil that needs refining process may strips away some of the nutrients, which makes it different from the VCO. The RBD process is part of drying process resulting crude coconut oil with high free fatty acid (3-5%) that must be refined, bleached and deodorized before suitable to use (Marina *et.al*, 2009[b]).

There are two main methods producing the virgin coconut oil, the wet and dry. By using the wet method, the oil is extracted from fresh coconut meat without drying first. The "coconut milk" is expressed first by pressing it out of the wet coconut meat. The wet method is practiced by several techniques of chilling and thawing, fermentation, enzymatic, pH or any combination of these methods; as the aim is to destabilize the coconut milk emulsion (Nur Arbainah, 2012, Mansor *et. al*, 2012). The integrated wet process starts with grated coconut is expelled to obtain the coconut milk. The coconut milk is then cooled at desired temperature ($T_{churning}$) before churned to separate the water and butter oil. The butter is then melted in water bath at desired temperature ($T_{thawing}$) before undergoing the subsequent centrifugation and filtration processes to get the clear final oil (VCO).

The dry method is utilizing the expeller to press the dried coconut to obtain the oil. In this method, the fresh kernel is heated under specific conditions until the desired moisture content is obtained to avoid microbial contamination. The dried kernel is then pressed mechanically to obtain the oil (Mansor *et. a*l., 2012).

As overall, it is a perquisite to produce the virgin coconut oil with a proper method than can retain the essential minor compound in it. The integrated wet process offers a condition for the highest total phenolic compound and antioxidant compared to fermentation (wet method) and dry method. The integrated wet process also exhibits its capability in retaining the fresh aroma of coconut and scores the highest acceptance in term of sensory evaluation in comparison to both fermentation and dry processes (Nur Arbainah, 2012).

Instead of selecting the oil processing method, it is an advantage to opt the specific coconut cultivar that containing the high oil. Numbers of research showed that every coconut cultivar has its own particular characteristic. This ascribe the factors of location and varietal differences, age of nuts, time of the year the nuts harvested and age of copra before expelling give significant effect (Carandang , 2008). The cultivar that contains the highest oil can be used in VCO processing to gain better oil recovery.

1.2 Problem Statement

The integrated wet process has been introduced by Institute of Bioproduct Development (IBD) to produce the virgin coconut oil. Despite of the quantitative aspect to increase the yield of virgin coconut oil, the quality characteristic must be improved or at least maintained in order to fulfill the standard of virgin coconut oil. The characteristic chemical and physical properties such as phenolic content, free fatty acid and colour that expected to be affected by processing temperatures are becoming the focus in this study.

The very lack of information on coconut varieties producing high yield of coconut oil especially in Malaysia has come into attention. By identifying the best variety that contributing the highest recovery of the oil had to be a concern in this study. Therefore, six varieties were selected to find the highest oil content so that to enhance the oil recovery in the integrated wet process.

1.3 Hypothesis

The hypothesis of the study is the processing temperatures of respective churning and thawing in integrated wet process affect the oil yield, ferulic acid concentration, free fatty acid and colour attributes.

1.4 Objective of the Study

1) The objective of this research was to optimize the churning and thawing temperatures in integrated wet process and their effects on the yield and quality of the virgin coconut oil.

1.5 Research Scope

The scopes of this research were;

1) To select the coconut varieties could contribute to the highest oil content. The varieties included West African Tall (WAT), Rennel Tall, Matag, MAWA, Maren and Tagnanan Tall.

2) To determine churning and thawing temperatures effects on coconut butter and VCO contents.

3) To optimize the churning and thawing temperatures and their effects on oil yield, ferulic acid concentration, free fatty acid and colour.

1.6 Contribution of Study

The virgin coconut oil is a high value coconut product that consumed for its nutraceutical benefits and as a functional food. The other usage of VCO is in cosmeceutical that used as aromatherapy carrier oil, body moisturizer and hair conditioner. Due to its wide application, the world demand for VCO is significantly increasing, making it a potential business for coconut players (Bawalan & Chapman, 2006).

The quality of VCO differs significantly from how it is processed. The RBD process using copra to produce the coconut oil; undergoes the refine, bleach and deodorize processes to make it suitable for human consumption resulting the bland taste due to the refining process. Meanwhile, the wet method utilizes the fresh coconut milk in the beginning of the process preserves the fresh aroma and taste of coconut. Unfortunately, the disadvantage of the wet method is low oil recovery as compared to the RBD method (Raghvendra & Raghavarao, 2010).

For wet method, the integrated wet process offers the higher quality product and yield compare to fermentation process. The oil recovery in integrated wet process is 85 percent higher than using the fermentation method. When use the fermentation process, the fermented odour is remaining and affecting the oil flavour (Nurarbainah, 2012). From the results, it indicated the integrated wet process is the better option to be evaluated further for better yield and quality of the final oil, compared to the fermentation method.

The integrated wet process is an efficient and quick technique to produce the VCO with the highest heat stability. In integrated wet process, the churning proses is started with solidifying the the coconut milk at low temperature (9 ^{o}C) (Nurarbainah, 2012). The purpose of this process is to crystallize the fat in the coconut milk emulsion and lead to the separation of butter and water during stirring process

(Coupland, 2002). Therefore, it is essential to find the optimum temperature for churning process that may enhance the maximum separation of butter-water to obtain the better oil recovery at the end of the integrated wet process.

In integrated wet process, the thawing process is applied to expedite the melting of the coconut butter, followed by the centrifugation to separate the non-oil fraction in the VCO (Hamid *et.al*, 2011). Currently, the integrated wet process practices the 37^{o}C for its thawing temperature. The thawing process undergone may destroy some of the phenolic compound in the oil, but when use the lower temperature (near to the room temperature), it would take longer time for the butter to melt (Marina *et. al.*, 2009[a]). For this reason, it is a necessary to study the optimum thawing temperature to fasten the thawing process and simultaneously retain the maximum phenolic compound in the oil.

As a conclusion, it is important to establish the optimum condition for churning and thawing temperatures to gain high oil recovery at the best quality.

REFERENCES

Abd. Karim E. (2013). Emulsion Stability. Retrieved on December 14, 2013 from http://www.slideshare.net/akarim717/emulsion-stability.

Al-Alawi A, van der Voot F.R, Sedman J.,Ghetler A. (2006).Automated FTIR Analysis of Free Fatty Acids or Moisture in Edible Oils. *Journal of the Association for the Laboratory Automation.* 11, 23-29.

AL Juhaimi F.Y and Ghafoor K. (2013). Extraction Optimization and In vitro Antioxidant Properties of Phenolic Compound from Cumin *(Cuminum cyminum* 1.) *Seed. International Food Research Journal. 20(4),1669-1775.*

Akpan, EJ., Etim, O.E., Akpan, H.D; and Usoh, LF. (2006). Fatty Acid Profile and Oil Yield in Six Different Varieties of Fresh and Dry Samples of Coconuts *(Cocos nucifera). Pakistan Journal of Nutrition, 5(2), 106-109.*

Anosike, E.O. (1994). *Introduction to Principles of Biochemistry*. Wembley: Sunray Publishers Ltd.

Ariyaprakai S. and Tananuwong K. (2015). Freeze-thaw Stability of Edible Oil-in Water Emulsion Stabilized by Sucrose Esters and Tweens. *Journal of Food Engineering.* 152, 57-64.

Arlee R., Suanphairoch S. and Pakdeechanuan P. (2013). Differences in Chemical Components and Antioxidant Related Substances in Virgin Coconut Oil From Coconut Hybrids and Their Parents. *International Food Research Journal.* 20(50), 2103-2109.

Aranello S.A. (2008).Yield and Quality of Virgin Coconut Oil using Varieties of Coconut. *Liceo Journal of Higher Education Research, 5(2).*

APCC (Asian Pacific Coconut Community) (2009). APCC Standards for Virgin Coconut Oil. Retrieved on February 25, 2014 from http://www.apccsec.org/standards.htm.

Assuncao M.L., Ferreira H.S., dos Santos A.F., Cabral J.R. C.R., Florencio T.M.M.T. (2009). Effects of Dietary Coconut Oil Anthropometric Profiles of Women Presenting Abdominal Obesity. *Lipids. 44,593-601*.

ATSDR (U.S. Agencies for Toxic Substances and Disease Registry) (2014). N-Hexane 147 3 Chemical and Physical Properties. Retrieved on December 17, 2014 from http://www.atsdr.cdc.gov/toxprofiles/tpl13-c3.pdf.

Batugal P., Bourdeix R. and Boudin L., (2009). 'Coconut Breeding'. In Jain S.M and Priyadarshan P.M. *Breeding Plantation Tree Crops Tropical Species.* (pp.327-375). New York: Springer Science.

Bawalan D.D. and Chapman K.R. (2006). Virgin Coconut Oil: Production Manual for micro- and village-scale processing. Bangkok: FAO Regional Office for Asia and the Pacific.

Bawalan D.D. (2011). Processing Manual for Virgin Coconut Oil, Its Products and By-products by Pacific Island Countries And Territories. Retrieved on May 15, 2011 from www.spc.int/lrdlindex.php?option=com_docman&task=doc

Bergsson, G., Amfinnsson, J., Karlsson, S. S. M., Steingri Misson, O., and Thormar, H. (1998). In vitro Inactivation of Chlamydia Trachomatis by Fatty Acids and Monoglycerides. *Antimicrobial Agents and Chemotherapy*, 42(9), 2290-2294.

Beydon, D., Guang, D., Chabra, R.P. and Raper, J.A. (1998). Particle Settling in Oil-InWater. *Powder Technology*. 97, 72-76.

Boekel, M.A.J.S and Walstra, P. (1981). Stability of Oil-In-Water Emulsions With Crystals in the Disperse Phase. *Colloids and Surfaces.* 3, 109-118.

Boode, L., Bisperink, C and Walstra, P. (1991). Destabilization of O/W Emulsion Containing Fat Crystals by Temperature Cycling. *Colloids Surf.* 61, 55-74.

Boode, K. and Walstra, P. (1993). Partial Coalescence of Oil-In-Water Emulsion Containing Fat Crystal by Temperature Cycling. *Colloids Surf.* 61, 55-74.

Bourdeix, R. (1999). Coconut Varieties: Malayan Dwarf. *IPGRl-COGENT. October, 13*-15.

Buldo P., Jacob I., Kirkensgaard T., Wiking L. (2013). Crystallization Mechanism in Cream during Ripening and Initial Butter Churning. *J. Dairy* Sci. 96, 6782-6791.

Calestino, A., Ruther, B., Socorro, B. and Steven, L.H. (2006). Supercritical Fluid Extraction to Determine the Oil Content in Copra and Extracted Meal. *Journal of the American Oil Chemists ' Society (JAOCS).* 83(1), 11-14.

Carandang E.V. (2008). Health Benefits of Virgin Coconut Oil Explained. *PJCS, 31*(2), 1-12.

Chan E. and Elivitch C.R. (2006). *Cocos nucifera* (Coconut). Species Profile for Pacific Island Agroforesty. Retreived on March 18, 2013 from www.traditional tree.org.

Che Man Y.R, Suhardiyono, Ali A, Azudin M.N. (1992). Acetic Acid Treatment of Coconut Cream in Coconut Oil Extraction. *ASEAN Food Journal.7, 38-42.*

Che Man, Y.R., Suhardiyono, A.B., Asbi, M.N., Azudin and Wei, L.S. (1996). Aqueous Enzymatic Extraction of Coconut Oil. *JAOCS.* 73, 683-686.

Che Man Y.R, Abdul Karim M.1.R and Teng C.T. (2007). Extraction of coconut oil with *Lactobacillus planatarum* 1041 IAM. *Journal of the American Oil Chemists Society.* 74, 1115-1119.

Chen, B.K,C and Diosady L.L (2003). Enzymatic Aqueous Processing of Coconuts. *International Journal of Applied Science and Engineering.* 1, 55-61.

Chigbu P.E., Ukaegbu E.C. and Nwaya J.C. (2009). On Comparing the Prediction Variance of Some Central Composite Design In Spehrical Regions: A Review. *STATISCA. 286-297.*

Chile, R. (1974). *Coconuts.* (2nd ed.). London: Longman Group Ltd.

Chopra, V.L. and Peter, K,V. *(2005). Handbook of Industrial Crops.* Binghampton : The Harworth Press.

Chun, J., Junsoo, L., Ye, L., Exler, J.,and Eitenmiller, R.R. (2006). Tocopherol and Tocotrienol Contents of Raw and Processed Fruits and Vegetables in the United States Diet. *Journal of Food Consumption and Analysis* 19, 196-204.

Coconut Production and Cultivation in Philippines. Retrieved on January 7, 2012 from http://blog.agriculture.phicategory/coconut/page/2

Cornell, J.A. (1990). How to Apply Response Surface Methodology. *American Society of Quality Control* .8, 11-22.

Coupland, J.N. (2006). ‘Beyond Hard Spheres: The Functional Role of Lipids in Foods Emulsions’. In: Akoh C.C. (Ed.). *Handbook of Functional Lipids* . (pp. 166-170). Boca Raton, FLA: Taylor & Francis.

Coupland, J.N. (2002). Crystallization in Emulsions. *Current Opinion in Colloid and Interface Science.* 7: 445-450.

Dayrit, F.M., Buenafe, O. E. M., Chainani, E.T., de Vera, I.M. A, Dimzon, I. K, D., Gonzales, E.G. and Santos, J.E. (2007). Standards for Essential Composition and Quality Factors of Commercial Virgin Coconut Oil and Its Differentiation From RBD Coconut Oil And Copra Oil. *Philippine Journal of Science. 136*(2), 119-129.

Dey G. Chakraborty M. and Mitra A. (2005). Profiling C6-C3 and C6-C1 Phenolic Metabolites in *Cocos nucifera. Journal of Plant Physiology.* 162: 375-381.

Enig M.G (1996). Health and Nutritional Benefits From Coconut Oils: An Important Functional Food For The 21st Century. *Avoc Lauric oils Symposium,* 25 April 1996. Ho Chi Minh.

Enig M.G. (1999). Coconut: in Support of Good Health in the 21st Century. *Proceeding of Asian Pacific Coconut Community 36th Session.*

Euromonitor (2013). Production of Coconut Oil. UN Food and Agriculture Organisation FAOSTAT. Retrieved on August 27, 2014 from www.utm.my/psz.

Faulds C.B., Bartolome B. and Williamson G. (1999). Novel Biotransformations of Agro-Industrial Cereal Waste by Ferulic Acid Esterases. *Industrial Crops and Products.* 6, 367-374.

Fife B. (2006). *Virgin Coconut Oil. Nature 's Miracle Medicine.* Colorado: Piccadilly Books Ltd.

Food and Nutrition Board. Institute of Medicine.(2004). ‘Dietary Reference Intakes for Vitamin C, Vitamin E, Selanium and Carotenoids’. In Eitenmiller, R & Lee, J. *Vitamin E Food Chemistry, Composition, and Analysis, (pp.* 39). New York: Marcel Dekker.

Geankoplis, C.J. (2003). *Transport Processes and Separation Proces Principle.* (4th ed.). Prentice Hall: New Jersey.

German J. B., and Dillard, C. J. (2004). Saturated Fats: What Dietary Intake? *American Journal of Clinical Nutrition, 80, 550-559.*

Gosh P.B., Bhattacharjee P., Mitra S. , Poddar-Sakar M. (2014). Physicochemical and Pythochemical Analysis of Copra and Oil of *Cocos nucifera L.* (West Coast Tall variety). *International Journal of Food Science. 20, 1-8.*

Gunetileke K.G. and Laurentius S.F.(1974). Conditions for the Separation of Oil and Protien from the Coconut Milk Emulsion. *Journal of Food Science. 39,230-*233.

Gutfinger T. (1981). Polyphenols in Olive Oils. *JAOCS.* 58, 966-968.

Haaland, P.D. (1989). *Experimental Design in Biotechnology*. New York: Marcel Dekker.

Hamid M.A. (2008) *The Production of Virgin Coconut Oil and Its Downstream Products.* Unpublished note, Chemical Engineering Pilot Plant, Universiti Teknologi Malaysia, Skudai.

Hamid M.A., Sarmidi. M.R., Mokhtar, Sulaiman W.R.W, and Aziz R.A. (2011). Innovative Integrated Wet Process for Virgin Coconut Oil Production. *Journal of Applied Science. 11(13), 2467-2469* .

Harjo B., Wibowo C. and Ng K.M. (2004). Development of Natural Product Manufacturing Processes Pythocemicals. *Chemical Enginerring Research and Design.* 82 (A8), 1010-1028.

Helsel, D.R., and R.M. Hirsh. (2002). Statistical Methods in Water Resources. USGS Retrieved on October 25, 2013 from http://water.usgs.gov/pubs/twri/twri4a3/

Houghton P.J. and Raman A. (1998). *Laboratory Handbook for The Fractionation of Natural Extract.* (1st ed.). London: Thomson Science.

Houston D.X., Ferreira S., Collofello J.S., Montgomery D.C., Mackulak G.T. and Shunk D.L. (2001). Behavioral Characterization: Finding and Using the Influential Factors in Software Process Simulation Models. *The Journal of System and Software* . 59, 259-270.

Institut Kimia Malaysia Workshop (2011).*Measurement Uncertainty in Chemical Analysis (MU13)* Unpublished note. Institut Kimia Malaysia.

Kabara J.J. (2001). Nutritional and Health Aspects of Coconut Oil. *Proceeding of the XXXVII COCOTECH Meeting/ICC.200.* 24-28 July 2000. Chennai, India, 101-109.

Katragadda A.R., Fullana R, Sidhu S. Carbonell - Barrachina A.A. (2010). Emissions of volatile aldehydes from heated cooking oils. *Food Chemistry.* 120, 59-65

Kumoro A.C., Hasan M.and Singh H. (2009). Effects of Solvent Properties on the Soxhlet Extraction of Diterpenoid Lactones from *Andrographis paniculata* Leaves. *Science Asia,* 35, 306-309.

Lam H.S. and Proctor R. (2002). Kinetics and Mechanism of Free Fatty Acid Formation on the Surface of Milled Rice. *J. Agric. Food Chem*, 50, 7161-7163.

Laureles L.R., Rodriguez F.M., Reano C.E., Santos G.A., Laurena A.C and Mendoza E.M.T.(2002). Variability in Fatty Acid and Triacylglicerol Composition of the Oil of Coconut *(Cocos nucifera I.)* Hybrids and Their Parental. *J. Agric. Food. Chem*, 50: 1581-1586.

Lenth R.V. (2014). Response-surface Analysis. Retrieved on January 12, 2014 from http://cran.rproject.org/web/packages/rsm/rsm.pdf.

Luque de Castro M.D. and Garcia-Ayuso L.E.(1998). Soxhlet Extraction of Solid Materials: An Oudated Technique with A Promising Innovative Future. *Analytica Chimica Acta.* 369, 1-10.

Malaysian Standards (2007). MS 2043:2007. Cyberjaya: Department of Standards Malaysia

Mansor T.S.T, Che Man Y.B., Shuhaimi M., Abdul Afiq M.J.and Ku Nurul F.K.M. (2012). Physicochemical Properties of Virgin Coconut Oil Extracted from Different Processing Methods. *International Food Research Journal*, 19 (3), 837-845.

Marina A.M., Che Man Y., Nazimah S.A.H. and Amin 1. (2009). Antioxidant Capacity and Phenolic Acids of Virgin Coconut Oil. *International Journal of Food Science and Nutrition* . 60, 114-123.

Marina A.M, Che Man Y.B. & Amin 1.(2009b).Virgin Coconut Oil: Emerging Functional Food Oil. *Trends in Food Science and Technology.* 20, 481-487.

McClements D.J. (2012). Crystals and Crystallization in Oil-in-Water Emulsion: Implications for Emulsion-Based Delivery System. *Advances in Colloid and Interface Science.* 174: 1-30.

Md. Nazrul Islam Bhuiyan, Jaripa Begum and Md. Nurul Huda Bhuiyan. (2009). Analysis of Essential Oil of Eaglewood Tree *(Aquilaria agallocha roxb.)* by Gas Chromatography Mass Spectrometery. *Bangladesh Journal Pharmacol,4*, 24-28.

Menon K.P.V. and Pandalai K.M. (1960). *The Coconut Palm. A Monograph.* Bombay: Tims of India Press.

Min D.B. and Boff J.M. (2003). *Crude Fat Analysis* In: (3rd Ed.). Nielsen S.S. *Food Analysis.* (pp.121) New York: Springer.

Mohammed Jahurul H.A., Mohammed Zaidul 1.S., Sahena F., Mohd Yazid A.M., Nik Norulaini N.A.B and Mohd Omar A.K. (2012). Applications of Supercritical Fluid Extraction (SFE) of Palm Oil and Oil from Natural Sources. *Molecules. 17,* 1764-1794.

Mohd Aziz C.Y., Muhammad Nairn R., Lee N.Y., Muhammad Syafiq Hazwan R., Siti Hamidah M.S., Muhammad Abbas A.Z.(2014). Extraction of Virgin Coconut *(Cocos nucifera)* Oil using Supercritical Fluid Carbon Dioxide. *Jurnal Teknologi.* 67(2), 11-15.

Montgomery D.C. (1976). *Design and Analysis of Experiments* New York: John Wiley.

Nair K.P.P. (2010). *The Agronomy and Economy of Important Tree Crops of Developing World.* (pp. 67-109). London: Elsevier.

Neo Y.P., Ariffin A., Tan C.P. and Tan Y.A. (2010). Phenolic Acid Analysis and Antioxidant Activity Assesements of Oil Palm *(E.guineensis)* Fruit Extracts. *Food Chemistry. 122,* 353-359.

Nik Norulaini N.A, Setianto W.B, Zaidul I.S.M. , Nawi A.H., Azizi C.Y.M.and Mohd Omar A.K. (2009). Effects of Supercritical Carbon Dioxide Extraction Parameters on Virgin Coconut Oil Yield and Medium-Chain Triglyceride Content. *Food Chemistry.* 116, 193-197.

Nour A.H, Mohammed F.S., M.Yunis R and Annan A. (2009). Deemulsification of Virgin Coconut Oil by Centrifugation Method :A Feasibility Study. *International Journal of Chemical Technology,* 1(2), 59-64.

Nur Arbainah S.A. (2012). Lipid and Pythochemicals Profiles of Non-Heated Treated Virgin Coconut Oil. Master Dissertation, Universiti Teknologi Malaysia.

O'Brien R.D. (2003). *Fats and Oils: Formulating and Processing for Applications.* Florida: CRC Press.

Othman, A., Ngalim, A., Sivapragasam, A. and Mohd. Amir H. (2009). *Manual Teknologi Penanaman Kelapa.* Kuala Lumpur: MARDI.

Owen, R.W., Mier, W., Giacosa, A., Hull, W.E., Spiegelhalder, B. and Bartsch, H. (2000). Phenolic Compounds and Squalene Concentration and Antioxidant Potential of Total Phenols, Simple Phenols, Secoiridois, Lignans and Sequalene. *Food and Chemical Toxicology*, 38, 647-659.

Pairoh G. and Tipvarakamkoon T. (2013). Thermal Analysis of Lipid Crystallization and Water Ice of Coconut Milk Emulsion: Effect of NaCl Concentration. *Journal of Medical and Bioengineering.* 2(3), 191-195.

Particle Science, Inc. (2011). Emulsion Stability and Testing. Retrieved on April 27, 2011 from http://www.particlesciences.com/news/technica1-riefs/2011/emu1sion-stability-and-testing.htm1

Perera, L., Perera, S.A.C.N, Bandaranayake, C.K., and Harriea, H.C. (2010). ‘Coconut’. In Vollmann, J. and Rajan, I. (Vol. A). *Handbook of Plant Breeding. (pp.369*-395). New York: Springer.

Perera S.A.C.N.(2012). *Coconut.* In Gupta S.K *(Vol.1). Technological Innovations in Major World Oil Crops* (pp.201-217). New York: Springer.

Philippine National Standard (2004). PNSIBAFPS 22:2004 rcs 67.200.10. Makati City: Bureau of Product Standards, Department of Trade and Industry. Philippines.

Raghavendra S.N. and Raghavarao K.S.M.S. (2010). Effect of Different Treatments for the Destabilization of Coconut Milk Emulsion. *Journal of Food Engineering*, 97, 341-347.

Reblova Z. (2012). Effect of Temperature on the Antioxidant Activity of Phenolic Acids. *Czech J. Food Sci*, 30(2), 171-177.

Richardson, J.F. and Harker, J.H. (2002). *Chemical Engineering-Particle Technology and Separation Processes.* Woburn: Butterworth-Heinemann.

Rivera L.L., Vi1arem G., Gomezi R.S., Estrada M.J. and Feijoo J.A. V. (2010). Water Soluble Fractions of Caraway *(Carum carvi L.)* Essential Oil. *O Boletin Latinoamericano y del Caribe de Plantas Medicinales y Aromdticas.* 9 (6), 495 - 500.

Rojas E.C., Staton J.A., John V.T. and Papadapoulus K.D. (2008). Temperature Induced Protien Release from Water-Oi1-in-Water Double Emulsion. *Langmuir.* 15, (14), 7154-7160.

Rosenthal A., Pyle D.L. and Niranjan K. (1996). Aqueous and Enzymatic Processes for Edible Oil Extraction. *Enzyme and Microbial Technology.* 19, 402-420.

Rousseau D., Gosh S. and Park H. (2006). Comparison of the Dispersed Phase Coalescence Mechanism in Different Tablespreads . *J Food* Sci.,74:EI-7.

Sant'Anna RP.M., Freitas S.P and Coelho M.A.Z.(2003). Enzymatic Aqueous Technology for Simultaneous Coconut Protien and Oil Extraction . *Grasas y Aceites,),22(3) 77-80.*

Santos, G.A., Batugal, P.A., Othman, A., Bourdin, L. and Laboisse, J.P. (1996). Manual on Standardization Research Technique in Coconut Breeding. *IPGRl-APO.* Serdang, 46.

Sayyar S., Zainal Abidin Z., Yunus R. and Muhammad A (2009). Extraction of Oil from Jatropha Seeds-Optimization and Kinetics. *American Journal of Applied Sciences*, *6*(7), 1390-1395.

Seneviratne K. N., Hapuarachchl C. D.and Ekanayake S. (2009). Comparison of the Phenolic-Dependent Antioxidant Properties of Coconut Oil Extracted Under Cold and Hot Conditions. *Food Chemistry*, 114, 1444-1449.

Seow C.C. and Gwee C.N. (1997). Coconut Milk: Chemistry and Technology. *International Journal of Food Science and Technology,* 32, 189-201.

Servili M. , Taticchi A , Esposto S. Sordini B.and Urbani S. (2012). 'Technological Aspects of oil Production'. In : *Olive Germplasm -The Olive Cultivation, Table Olive and Olive Industry in Italy*. *Innocenzo . CC. 151-171.*

Sessa D.J. and Rakis J.J. (1977). 'Lipid-Derrived Flavours ofLegume Protein Products'. In O'brien, R.D. *Fats and Oils* (2nd ed.). Florida: CRC Press.

Shwartz H., Ollilainen V., Piironen V.and Lampi A.M.(2008). Tocopherol, Tocotrienol and Plant Sterol Contents of Vegetables Oils and Industrial Fats. *Journal of Food Composition and Analysis.21, 152-161.*

St. Onge, M.P. and Jones, P.J.H. (2002). Physiological Effects of Medium-Chain Triglycerides: Potential Agents in the Prevention of Obesity. *Journal of Nutrition.* 132, 329-332.

State Ease. (2002). *Version* 6 *User's Guide Design Expert Software.* Retrieved on 14 July 2013 from www.state-ease.com.

Song Y., Wu T., Yang Q., Chen X., Wang M., Wang Y., Peng X. and Ou S. (2014). Ferulic Acid Alleviates The Symptoms of Diabetes in Obese Rats. *Journal of Functional Food*, 3, 141-147.

Sulaiman S., Abdul Aziz A.R., Aroua M.K. (2013). Optimization and Modeling of Extraction of Solid Coconut Waste. *Journal of Food Engineering.* 114, 228-234.

Synder L.R. (1978). Classification of Solvent Properties of Common Liquids. *Journal of Chromatography.* 92, 223-224.

Szentmihalyi, K., Vinkler, P., Lakatos, B., Illes, V.and Then, M. (2002). Rosehip *(Rosa canina L.)* Oil Obtained from Waste Hip Seeds by Different Extraction Methods. *Bioresource Technology, 82,* 195-201.

Tangsuphom, N. and Coupland, J.N. (2005). Effect of Heating and Homogenization on The Stability of Coconut Milk Emulsions. *Journal of Food Science. 70(8),* 466-470.

Tangsuphom, N. and Coupland, J.N. (2009). Effect of Thermal Treatments on the Properties of Coconut Milk Emulsions Prepared with Surface-Active Stabilizers. *Food Hydrocolloids, 23,* 1792-1800.

The Tintometer Limited. *Colour Measurement*. (2014). Retrieved on February 02,2014 from http://www.lovibond.us/

Toivo J., Phillips K., Lampi A.M.and Piironnen V. (2001). Determination of Sterol in Foods: Recovery of Free, Esterified, and Glycosidic Sterols. *Journal of Food Composition and Analysis,* 14, 631-643.

Tuzen M. (2003). Chromatographic Determination of Phenolic Acid in Snowdrop by HPLC. *Turk J Chem.* 27, 49-54.

Van Immerseel, F., De Buck, J., Boyen, F., Bohez, L., Pasmans, F.and Volf, J. (2004). Medium-Chain Fatty Acids Decrease Dolonization And Invasion Through Hila Suppression Shortly After Infection Of Chickens with *Salmonella enterica* and *Serovar enteritidis. Applied and Environmental Microbiology,* 70(6), 3582-3587.

Villarino, B.J., Marsha, Dy L. and Lizada, M.C.C. (2007). Descriptive Sensory Evaluation of Virgin Coconut Oil and Refined, Bleached and Deodorized Coconut Oil. *LWT,* 40, 193-199.

Waisundra, V.Y., Perera, C.O. and Barlow, P.J. (2006). Effect of Different Pretreatments of Fresh Coconut Kernels on Some of the Quality Attributes of The Coconut Milk Extracted. *Food Chemistry,* 101(2), 771-777.

Walstra, P. (2003). *Physical Chemistry of Foods.* New York: Marcel Dekkar.

Wang, L. and Weller C.L. (2006). Recent Advance in Extraction of Nutraceuticals from Plants. *Trends in Food Science* & *Technology*. 17, 300-312.

Young, F.V.K. (1983). Palm Kernel and Coconut Oils: Analytical Characteristics, Process Technology and Uses. *JADCS,* 60(2), 374-379.

Zarnowski, R. and Suzuki, Y. (2004). Expedient Soxhlet Extraction of Resorcinlic Lipids from Wheat Grain. Journal of Food Consumption and Analysis, 17, 649-663.