Solvent Extraction of Oil from *Arachis hypogea*: The Effects of Extraction Temperature and Liquid/Solid Ratio

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Solvent extraction is one of techniques that can be used to extract oil. Solvent extraction is more preferable technique compared to the other techniques due to the low cost, simple and faster extraction process. It is also important to explore more sources of vegetable oil as the demand of vegetable oil is increasing rapidly due to its numerous applications. The objectives of this research are to study the effect of different extraction temperatures and the liquid/solid (L/S) ratio on the solvent extraction of *Arachis hypogea* oil. Peanut oil was extracted using solvent extraction technique and ethyl acetate was used as solvent. The extraction temperatures were set at 35ºC, 40ºC, 50ºC and 60ºC, 70ºC and 75ºC. The samples then were prepared with L/S ratio of 3:1, 4:1, 5:1, 6:1, 7:1 and 8:1. After the solid-liquid and solvent-oil mixture were separated, the oil yield was calculated. The samples were analyzed using Gas Chromatography-Mass Spectrometry, (GC-MS) to determine the chemical constituent. The optimum condition was at the temperature of 70ºC and L/S ratio of 6:1. The oil yield obtained was 43.8%. The major fatty acid components found in the extracted peanut oil were oleic acid, linoleic acid and palmitic acid.

I. INTRODUCTION

Vegetable oils are chemical compound that are usually obtained either from fruit or seed. They include soybean oil, olive oil, almond oil, sunflower oil, palm oil and peanut oil. Edible vegetable oils are widely used for industrial and domestic purposes [1]. Extracted oil from the seeds of cereals and legumes such as sunflower, canola, peanuts and cotton are widely used for cooking. Vegetable oils have also been considered to be used as solvents in the recent years. Sunflower oils were used to extract astaxanthin from shrimp [2].

These vegetable oils are extracted from numerous types of plants and one of them is from nut plant [3]. Peanuts or groundnuts (*Arachis hypogea*) are plants of the pea family which belongs to the family of Fabaceae and subfamily of Leguminoseae [4]. Peanut was cultivated as early as 2000 to 3000 before century in South America [5]. It is also reported that, peanut initially originated from South America in 950 before century. In the colonial age, peanut was brought to Africa then transported to the North America and recently, in the whole wide world there are more than 300 variety types of peanuts are grown [6].

Peanut plant is different from other plants because the flower which is yellowish-colour is located at the central stem and the fruits (peanuts) are produced underneath the ground. According to Chang *et al.,* [6] once the flowers are self-pollinated, they will lose their petal and small stems will form and extend into the soil. This growth process normally takes about four to five months. The leaves are oval in shape and the plant can reach up until 18 inches in height. One single plant is able to produce more than 40 peanuts. Peanut is a fruit or pod annual legumes in which each pod contains one to three seeds and when they are matured enough, the pods are pushed underground.

Generally, the stem, leaf, flower and fruit of the peanut plant have a variety of applications. The leaves and stems are usually used for animal feeding, fruits are used for direct human consumption and extract for the oil. Peanut contains up to 50% oil content [7]. Peanut has the potential to be marketed widely not only as a food product but also in other applications. Peanut oil represents approximately 7 to 10% of the world production of vegetable oil [5]. Peanut are used in many applications such as cooking, production of soap, margarine, cosmetics, solvent and emollient [8].

Few researchers have reported on various oil extraction techniques such as mechanical pressing, soxhlet extraction, supercritical extraction, microwave extraction, ultrasonic extraction and solvent extraction. However, mechanical pressing, soxhlet extraction, supercritical extraction, microwave extraction, ultrasonic extraction have several drawbacks; most significantly they are complex process and expensive equipment is used. Thus, in this study, solvent extraction was chosen due to its simplicity, low cost and shorter time [9]. In order to achieve the optimum conditions, the effect of different temperature and L/S ratio on the solvent extraction of peanut oil were studied.

II. METHODOLOGY

A. Sample Preparation

1 kg of peanuts was obtained from a supermarket in Shah Alam. Peanut seeds were ground and then placed in the oven for 8 hour at 100ºC to eliminate moisture. After that, dried powder was sieved using a sieve shaker of 750µm.

B. Solvent Extraction of Peanut Oil

The extraction condition was fixed at the extraction time 3 hour and 200 rpm. 5 g of seed powder with ratio of 6:1 was placed in a beaker. The first extraction temperature was set at 35ºC. The experiment was repeated at different temperatures which were 40ºC, 50ºC and 60ºC, 70ºC and 75ºC. Next, the volume of ethyl acetate (solvent) were prepared with the ratio of 3:1, 4:1, 5:1, 6:1, 7:1 and 8:1. The extraction temperature was set at the optimum temperature. All samples were performed duplicate. The mixtures were centrifuged to separate the liquid and solid residue. The solvent in the mixture was evaporated at 80ºC using rotary evaporator. The oil obtained was weighed and the extraction yield was calculated. The samples were stored in refrigerator at 4ºC until further analysis.

$$\text{Oil yield (\%)} = \frac{\text{Weight of oil (g)}}{\text{Weight of seed sample (g)}} \times 100 \ (\%)$$

C. GC-MS Analysis of Peanut Oil

The chemical constituent of peanut oil extracted by solvent was analyzed via GC-MS (Varian 450 GC-240 MS) equipped with a flame ionization detector and a capillary column DB-5 (50 m x 0.25 m x 0.25 m). The flow rate for helium as the carrier gas was set to 3 mL/min. The temperature of injector, ion-source, and detector was set to 260°C, 230°C, and 150°C respectively. 1.0µL was injected to the GC-MS and electron ionization mode was set to 70 eV.

III. RESULTS AND DISCUSSION

A. The Effect of Temperature on Oil Yield

The effect of temperature on oil yield shown in Figure 1. A positive relationship between temperature and oil yield was observed. The oil yield is increasing as the temperature increase until it reached the peak temperature at 70°C (43.8% oil yield). This trend could be explain by the fact that, a higher temperature promotes solvent penetration into the cell tissue and accelerated the release of cell content into the extraction solution [10].

Moreover, a higher temperature resulted in a decrease in viscosity and increase the solubitity of oil in the solvent. Due to the increase in solubility, the diffusivity rate into the pores of seeds also increase thus, improving the mass transfer of oil into the solvent [5]. As a result, more oil yield can be obtained. Meziane *et al.,* [12] reported that olive oil yield increase with the increase of temperature.

However, beyond 70°C, the oil yield started to decrease from 43.8% to 43.0%. The surface tension of the extracting solvent decreased due to the high temperature used [13]. Elkhaleefa & Shigidi [14] reported that the operating temperature above than 40°C did not increase the sesame seed oil yield.

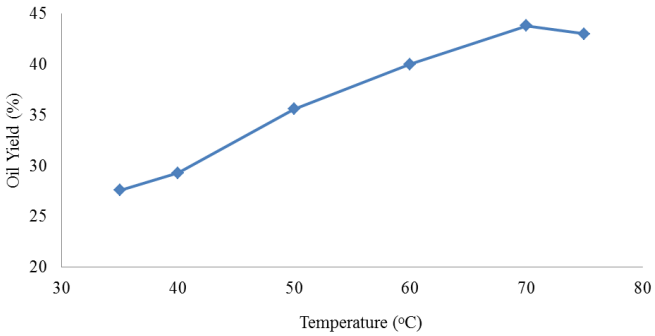

Figure 1: The Effect of Temperature on Oil Yield

B. The Effect of Liquid/Solid Ratio on Oil Yield

In order to investigate the effect of L/S ratio on oil yield, the temperature was fixed at 70°C. Figure 2 shows, the oil yield increased as the L/S increases from 3:1 to 6:1. The optimum oil yield of 43.8% was obtained at the ratio of 6:1. Zou *et al.,* [15] also reported that the oil extraction positively increases with the L/S ratio for oil extraction of mulberry at 43.2°C temperature and 40 minute extraction time.

The result was consistent with the mass transfer principles. The increment of oil yield with the increase of L/S ratio was due to the larger concentration gradient between the seeds and solvent [16]. It promotes a greater driving force that allows the oil to be dissolved in the solvent at a higher rate.

As can be seen in Figure 2, further increase of solvent volume had no impact on the oil yield. The optimum L/S ratio of 6:1 has been reported by Badwaik *et al.,* [17] for solvent extraction of oil from peanut using hexane as the solvent and 5 hour extraction time. The insignificant changes for the oil yield at L/S ratio greater than 6:1 also can be explained by the fact that, beyond certain condition the mass transfer rate became constant due to the maximum yield of extraction [18].

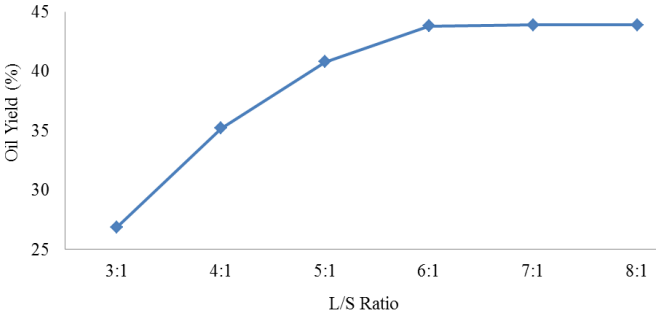

Figure 2: The effect of L/S Ratio on Oil Yield

C. Chemical Constituents in Peanut Oil

Table 1 summarises the result from GC-MS analysis of the peanut oil. Oleic acid was found at the retention time of 26.23 minutes (min). Oleic acid is monosaturated acid which contain single double bond and has the potential to formulate lubricating oil. Previous study by Mahmud & Salimon [19] used oleic acid for the production of bio-lubricant by esterification reaction. Orsavova *et al.,* [20] also stated that peanut oil has high amount of oleic acid which has the characterisation to promote insulin resistance, anti-apoptotic and anti-flammatory agent properties.

The present of linoleic acid was detected at the retention time of 25.87 min. Linoleic acid was also reported as a good fatty acids that benefits the human health from numerous chronic diseases includes heart diseases, cancer, hypertension, diabetes type two and renal diseases [20]. Farvid *et al.,* [21] studied the relationship between dietary linoleic acid and the prevention of coronary heart disease. It was found that the linoleic acid acid intake is inversely proportional to coronary heart disease risk in a dose-response manner.

Palmitic acid also appeared at the retention time of 8.76 min. Orsavova *et al.,* [20] stated that palmitic acid differed from the other saturated acid as the other saturated acid such as lauric acid, raise plasma cholesterol concentrations. Chowdhury *et al.,* [22] also reported that there is no relation between palmitic acid and cardiovascular risk. However palmitic acid and other saturated acid are known to stimulate pro-inflammatory response to human immune cells [19].

Table 1: Chemical Constituent of Peanut Oil

No	Retention Time (min)	Chemical Constituent
1	6.83	9-Hexadecenoic acid
2	8.76	Hexadecanoic acid
3	18.17	Isopropyl Myristate
4	20.82	Estragole
5	20.95	Tridecanoic acid
6	21.11	Pentadecanoic acid
7	21.46	Dodecanoic acid
8	25.87	9,12-Octadecadienoic acid
9	26.23	9-Octadecenoic acid
10	27.71	Octadecanoic acid
11	30.00	11-octadecenoic acid

IV. CONCLUSION

In this study, the effects of different extraction temperature and liquid/solid ratio on the solvent extraction of *Arachis hypogea* oil were evaluated. It was found that, the optimum extraction conditions obtained were liquid/solid ratio 6:1 and temperature 70°C with an oil yield of 43.8%. Peanut oil contains three major fatty acids which are oleic acid, linoleic acid and palmitic acid.

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References

[1] Zhu, F., Fan, W., Wang, X., Qu, L., & Yao, S. (2011). Health risk assessment of eight heavy metals in nine varieties of edible vegetable oils consumed in China. Food and Chemical Toxicology, 49(12), 3081-3085. doi:10.1016/j.fct.2011.09.019.

[2] Trindade, A. S., Dantas, A. F., Lima, D. C., Ferreira, S. L., & Teixeira, L. S. (2015). Multivariate optimization of ultrasound-assisted extraction for determination of Cu, Fe, Ni and Zn in vegetable oils by high-resolution continuum source atomic absorption spectrometry. Food Chemistry, 185, 145-150. doi:10.1016/j.foodchem.2015.03.118.

[3] Arisanu, A. O., & Hodirnau, E. (2011). Particularities of oil extraction by pressing hulled and hydrothermally processed sunflower seeds. Journal of EcoAgriTourism, 7(2), 32-37.

[4] Settaluri, V. S., Kandala, C. V., Puppala, N., & Sundaram, J. (2012). Peanuts and Their Nutritional Aspects—A Review. *Food and Nutrition Sciences*, 03(12), 1644-1650. doi:10.4236/fns.2012.312215.

[5] Gunstone, F. D. (2011). Groundnut (Peanut) Oil. In Vegetable oils in food technology: Composition, properties and uses (pp. 231-240). Chichester, West Sussex: Wiley-Blackwell

[6] Chang, A. S., Sreedharan, A., & Schneider, K. R. (2013). Peanut and peanut products: A food safety perspective. Food Control, 32(1), 296-303. doi:10.1016/j.foodcont.2012.12.007.

[7] Olatunde, O. B., Ajav, E. A., & Fatukasi, S. O. (2014). Design and Fabrication of Groundnut (Arachis Hypogaea) Roaster cum Expeller. International Journal of Science and Technology, 3(3), 117-184.

[8] Eshun, G., Amankwah, E. A., & Barimah, J. (2013). Nutrients content and lipid characterization of seed pastes of four selected peanut (Arachis hypogaea) varieties from Ghana. African Journal of Food Science, 7(10), 375-381. doi:10.5897/ajfs12.136.

[9] Adepoju, T. F., Olawale, O., Okunola, A. A., & Olatunji, E. M. (2014). Solvent Extraction of oil from Sour soup Oilseeds & its Quality Characterization. *International Journal of Sustainable Energy and Environmental Research*, 3(2), 80-89.

[10] Li, L., Zhang, H., Pan, C., Zhou, Z., Jiang, S., & Liu, F. (2007). Multiresidue analytical method of pesticides in peanut oil using low-temperature cleanup and dispersive solid phase extraction by GC-MS. Journal of Separation Science, 30(13), 2097-2104. doi:10.1002/jssc.200700052.

[11] Bhutada, P. R., Jadhav, A. J., Pinjari, D. V., Nemade, P. R., & Jain, R. D. (2016). Solvent assisted extraction of oil from Moringa oleifera Lam. seeds. *Industrial Crops and Products*, *82*, 74-80. doi:10.1016/j.indcrop.2015.12.004.

[12] Meziane, S., Kadi,H., (2008). Kinetics and thermodynamics of oil extrcation from olive cake. *J. Am. Oil. Chem*. 85, 391-396

[13] Charpe, T. W. & Rathod, V. K. (2014). Effect of ethanol concentration in ultrasound assisted extraction of glycyrrhizic acid from licorice root. *Iran J. Chem. Eng.*, 11(4), 21-30.

[14] Elkha.. Elkhaleefa, A., & Shigidi, I. (2015). Optimization of Sesame Oil Extraction Process Conditions. *Advances in Chemical Engineering and Science*, *05*(03), 305-310. doi:10.4236/aces.2015.53031.

[15] Zou, T., Wang, M., Gan, R., & Ling, W. (2011). Optimization of Ultrasound-Assisted Extraction of Anthocyanins from Mulberry, Using Response Surface Methodology. International Journal of Molecular Sciences, 12(12), 3006-3017. doi:10.3390/ijms12053006

[16] Basmadjian, D., & Basmadjian, D. (2007). Rates of Mass Transfer. In *Mass transfer and separation processes: Principles and applications* (pp. 2-7). Boca Raton: CRC Press.

[17] Badwaik, L. S., Prasad, K., & Deka, S. C. (2012). Optimization of extraction conditions by response surface methodology for preparing partially defatted peanut. International Food Research Journal, 19(1), 341-346.

[18] Toda, T. A., Sawada, M. M., & Rodrigues, C. E. (2016). Kinetics of soybean oil extraction using ethanol as solvent: Experimental data and modeling. *Food and Bioproducts Processing*, *98*, 1-10. doi:10.1016/j.fbp.2015.12.003

[19] Mahmud, H. A., & Salimon, J. (2014). Optimization of esterification of oleic acid and trimethylolpropane (TMP) and pentaerythritol (PE). doi:10.1063/1.4895201

[20] Orsavova, J., Misurcova, L., Ambrozova, J., Vicha, R., & Mlcek, J. (2015). Fatty Acids Composition of Vegetable Oils and Its Contribution to Dietary Energy Intake and Dependence of Cardiovascular Mortality on Dietary Intake of Fatty Acids. International Journal of Molecular Sciences, 16(6), 12871-12890. doi:10.3390/ijms160612871.

[21] Farvid, M. S., Ding, M., Pan, A., Sun, Q., Chiuve, S. E., Steffen, L. M., … Hu, F. B. (2015). Response to Letters Regarding Article, "Dietary Linoleic Acid and Risk of Coronary Heart Disease: A Systematic Review and Meta-Analysis of Prospective Cohort Studies". *Circulation*, *132*(3),e23-e24.

[22] Chowdhury, R., Steur, M., Patel, P. S., & Franco, O. H. (2016). Individual Fatty Acids in Cardiometabolic Disease. *Handbook of Lipids in Human Function*, 207-318. doi:10.1016/b978-1-63067-036-8.00010-x