Microwave-Assisted Hydro-distillation of Annona Muricata

Jealonovier Sayas anak Jemon, Dr Atikah Kadri

Faculty of Chemical Engineering, Universiti Teknologi Mara

***Abstract*—Essential oil from natural products contains abundant medicinal and therapeutic values. *Annona Muricata* itself had proven to have significant antioxidants and anticancer activities. The development of microwave-assisted hydrodistillation (MAHD) as the alternative extraction methods has gain a lot of attention to produce better quality of essential oil over shorter period of time to overcome to increasing demand of essential oil worldwide. The study aimed to compare the conventional hydro-distillation (HD) and microwave-assisted hydro-distillation (MAHD) to evaluate their effectiveness in the extraction of essential oil from *Annona Muricata.* The effect of different parameters, such as extraction methods (hydro-distillation and microwave-assisted hydro-distillation) and microwave power on the extraction yield, extraction time and its major chemical compounds were investigated. 100 grams of *Annona Muricata* leaves were immersed in distilled water and heated by different heating medium, that are heating mantle and microwave oven, using the Clevenger extraction apparatus. The extraction was then carried out under three microwave power levels (100, 300 and 600 W) to determine the best power for higher yield of essential oil. The result found out that MAHD had produced higher yield than HD (0.045%) over shorter period of time (180 minutes). The best microwave power to produce higher yield was found at power level of 600 W with the yield obtained under this condition was 0.045% w/w. Yellowish white essential oil with a strong smell was extracted and the chemical compounds were analyzed using gas chromatography-mass spectrometry (GC-MS). MAHD (600 W) was found to be effective in producing higher yield at shorter extraction time.**

Keywords— Annona Muricata; extraction; essential oil composition; Microwave-assisted hydro-distillation

I. INTRODUCTION

Essential oils are natural products that are usually extracted from the plant, which are useful in daily life as food flavoring, fragrances and also contained traditional values and pharmaceuticals potentials. Over centuries, the extraction methods have been developed to produce more essential oils from natural sources such as plant with medicinal value or herbs (Wang, Liu, Wei, Yan, & Lu, 2010). Essential oils are chemical constituents that made up of mixtures of aromatic and volatile substances generally present at low concentrations (Costa et al., 2015). The essential oils have gain a lot of attention. Their beneficial uses in many industries have been stronger recently. For example, demand in natural medicine (Elaissi et al., 2012), negative response from consumer of synthetic food preservatives (Jiao et al., 2012), natural aromatherapy (Jeyaratnam et al., 2016) and natural antioxidants sources (Harkat-Madouri et al., 2015).

Annona muricata or also known as *Annona muricata Linn* is belong to the Annonaceae family. It is among the tropical fruits that are considered as beneficial and receive a lot of interest due to its therapeutic potential and medicinal value. The medicinal advantages of *Annona muricata* have attracted the attention due to its bioactivity and toxicity (Coria-Téllez et al., 2016). *Annona muricata* is a native plant found in warmest tropical regions in South and Central America and nowadays can also be found in other tropical countries, including Western Africa, India and South East Asia (Moghadamtousi et al., 2015).

Among the industrial applications of the essential oils extracted from the soursop pulp is improving the flavor in the processed fruits. This is because the presence of esters of aliphatic acid in the pulp extracts that have the potential to give tasty flavor. Meanwhile, the essential oil from the soursop leaves containing chemical components such as δ-cadinene, epi-α-cadinol and α-cadinol (Moghadamtousi et al., 2015).

Other than that, *Annona muricata* also provides biological properties which are vital to human health. Bioactive compounds such as vitamin C and carotenoids are also found in this fruit. Other biological compounds found in *Annona muricata* is antioxidants. The antioxidant activities contribute in controlling and make body system more resistant to diseases including cancer, rheumatoid arthritis and cardiovascular diseases. The most abundant antioxidants in the *Annona muricata* are phenols, flavonoids, vitamins and carotenoids.

Antioxidants are a group of substances that form naturally in plants and have great advantages in fighting cancer and other diseases such as diabetes and heart disease (Hrycay & Bandiera, 2015; Rajendran et al., 2014; Tong et al., 2015). Antioxidants play an important role in cells as they can prevent the uncontrolled growth and enlargement of cancer cells. Besides, production of enzyme and non-enzymatic molecules such as flavonoids, vitamin C and vitamin K are capable in slow down and avoid the damage of lipids, protein and nucleic acids (Walton, 2016). The presence of oxidants in the body can cause bad effects to the important cells and macromolecules in body such as enzymes and DNA.

According to the National Cancer Institute of United States, cancer is defined as a cell that grows and divides without control and become invasive as they can affect other parts of the body. Cancer cells develop as they start to disregard signals that give instructions for the cells to stop dividing and can affect the normal cells and molecules around them. The dangerous part of cancer cells are they also able to invade the immune system that helps to protects the body from infections. When the immune system damages, it cannot produce antibodies and thus cannot fight against any disease and infections. In Malaysia only, there are about 100,000 people are suffering from the cancer diseases and one out four Malaysians will having cancer at the age of 80. Among the cancer cases recorded in Malaysia, the top three leading cancers, both male and female are breast, colorectal and lung cancers.

Many studies had been carried out and found out the significant anticancer and antioxidant activities of different extracts of *Annona muricata* leaves and acetogenins (Astirin et al., 2013; Gavamukulya et al., 2014; Hamizah et al., 2012; Moghadamtousi et al., 2015). Since the existent of the therapeutic advantages are abundant in soursop, the purpose of the study is to determine the active chemical compounds that can be yielded from the leaves by using different extraction time using hydro-distillation (HD) and microwave-assisted hydro-distillation (MAHD) methods.

The most common techniques used for obtaining essential oils or other extraction from plant materials are including hydro-distillation (HD), organic solvent distillation and steam distillation (Jeyaratnam et al., 2016). All of these techniques are referred as conventional or traditional methods of extraction and among those, hydro-distillation (HD) is the most frequently used technique (Djouahri et al., 2013). However, the main problems of using traditional method are higher potential loss or damage of unstable compounds due to longer exposure to heat at higher temperature and long extraction time. Longer exposure to heat at higher temperature leads to high energy consumption (Bustamante et al., 2016).

Recently, the development of alternative extraction methods for herbal plants has gain a lot of attention to produce greener and effective extraction methodologies in order to reduce energy consumption and helping in preserving environment (Memarzadeh et al., 2015). In addition, increase demand of good quality of essential oil and herbal extraction in food, pharmaceutical and perfume industries is also one of the reasons. Thus, new alternatives have been identified such as microwave assisted hydro-distillation (MAHD) method. This method has become popular to isolate essential oils or other plant extractions because it has shorter extraction time, improve the extraction yield, produce good quality of the extracts and reduce the energy usage (Bellumori et al., 2016; Franco-Vega et al., 2016; Jiao et al., 2013; Kusuma & Mahfud, 2015).

In this research, the advantages of microwave-assisted hydro-distillation (MAHD) over hydro-distillation (HD) were studied. The effects of operating parameters, namely extraction methods and microwave irradiation on the extraction time and extraction yields of *Annona Muricata* leaves were investigated. Additionally, the chemical constituents of the essential oil were analyzed using GC-MS in order to compare the compositions of essential oil extracted through MAHD with those extracted using conventional HD.

II. METHODOLOGY

A. Plant materials

The fresh *Annona Muricata* leaves used for this research were collected from open environmental areas in Sarawak, Malaysia. After cleaning and washing to remove the dirt, the leaves were dried in an ambient condition (28-40°) for three days on a large tray. The dried leaves were blended using a commercial blender and sieved to get equal size. The blended leaves were then stored in a closed plastic bag in a cool room (4°C) until required for the experiments.

B. Hydro-distillation using the conventional Clevenger apparatus

100 grams of *Annona Muricata* leaves were immersed in 1000 ml of distilled water in a round bottom flask. A ratio of 1:10 sample to water ratio was used. The flask was set up on the heating mantle and a condenser was used on the top to collect the extracted essential oils (Figure 1). The condenser upper hole was closed using aluminum foil to avoid the vaporization of essential oils. The extraction process was operated at room temperature (25°C) and atmospheric pressure. The extraction was observed in 10 minutes intervals for 300 minutes. This period was sufficient to extract all the essential oils from the sample. The essential oils were collected in amber vials, dried under anhydrous sodium sulfate to remove water and stored again in amber vials at 4°C until they were used for analysis. The extraction yield of essential oil was calculated according to the equation given:

$$\text{Extraction yield (\%, w/w)} = \frac{\text{mass of oil extracted (g)}}{\text{mass of the sample (g)}} \times 100\%$$

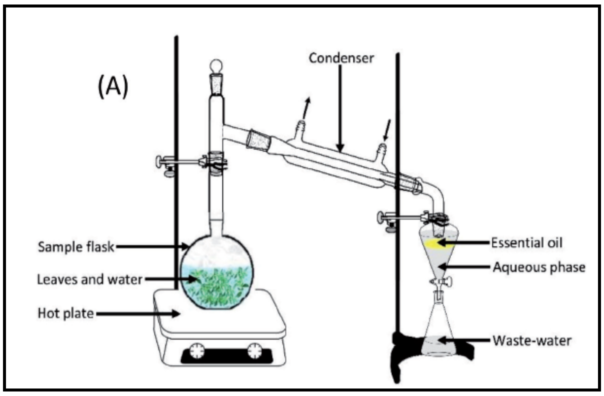

Fig. 1: Hydrodistillation Clevenger apparatus

C. Microwave-assisted Hydro-distillation (MAHD)

MAHD was carried out in a similar manner as the one explained for HD. However, in employing MAHD, a domestic microwave oven (NN-ST651M, Panasonic, Japan, 32L, 1000 W, metallic silver colour) was used. The dimensions of the PTFE-coated cavity of the microwave oven were 355 mm(W) x 365 mm(D) x 251 mm(H). The microwave oven was modified by drilling a hole on top. A round bottom flask was placed inside the oven and a condenser was used on the top (outside the oven) to collect the extracted essential oils (Figure 2).

100 grams of *Annona Muricata* leaves were immersed in 1000 ml of distilled water in a round bottom flask. A ratio of 1:10 sample to water ratio was used. The reaction flask was heated by microwave irradiation of 100 W. The extraction process was operated at room temperature (25°C) and atmospheric pressure. The extraction was observed in 10 minutes intervals until no more oils were produced. The essential oils were collected in amber vials, dried under anhydrous sodium sulfate to remove water and stored again in amber vials at 4°C until they were used for analysis. The extraction yield of essential oil was calculated. The experiments were repeated for microwave powers of 300 and 600 W.

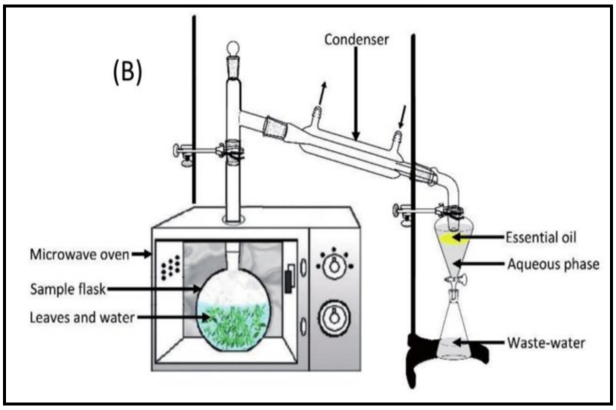

Fig. 2: Microwave-assisted Hydrodistillation Clevenger apparatus

D. Chemical analysis of essential oil constituents

Gas chromatography-mass spectrometry (GC-MS) (Model QP 2010, Shimadzu, Tokyo, Japan) equipped with a mass selective detector operating in the electron impact mode (70eV) was used to study the compositions of the extracted essential oils. The GC part was equipped with a VF-5ms fused silica capillary column of 80m length, 0.25mm diameter and 0.25μm film thickness.

The samples were diluted with n-hexane and a volume of 1.0 ml was injected to the GC. Carrier gas, He, was adjusted to a linear velocity with flow rate 1.51 ml/min. The compounds of the extracted essential oils were identified by comparing their mass spectral fragmentation patterns with those of similar compounds from a database. For each compound of the chromatogram, the percentage of peak area relative to the total peak areas from all compounds was determined and reported as relative amount of that compound.

III. RESULTS AND DISCUSSION

A. Temperature profile

A temperature profile illustrates the rate of temperature rise of samples or materials. In Figure 3, it showed the temperature profile of the extractions of essential oil from *Annona Muricata* leaves by hydro-distillation (HD) and microwave-assisted hydro-distillation (MAHD) methods.

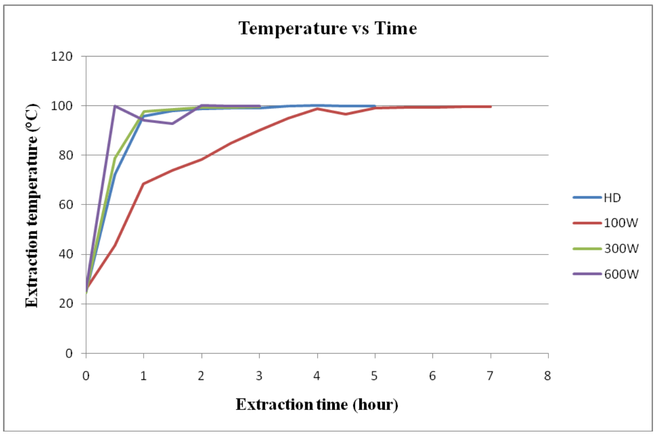

Fig 3: Time-temperature profile of *Annona Muricata* leaves essential oil with HD and MAHD

In all extraction methods, the initial temperature of samples was around 25°C and temperature profile curves for both extraction methods became constant when reaching the temperature around 98°C. This showed that the extraction temperature of *Annona Muricata* was equal to the boiling point of distilled water at 100°C. These results were similar with the extraction of essential oil from Patchouli (*Pogostemon cablin*) leaves using the same extraction methods that reported the same initial temperature of the samples and showed constant temperature profile curve when the boiling point of distilled water was already achieved (Kusuma & Mahfud, 2015).

The highest extraction temperature recorded during the experiment, 101°C was achieved by using microwave power of 600 W. The reason that contributes to this phenomenon is high microwave power can bring up the temperature of the system. In a research conducted to analyze and model the extraction kinetics of essential oil from *Pogostemon cablin* Benth, it stated that the high power operation can raise the temperature above the boiling point of the solvent (Kusuma & Mahfud, 2016). It was also proven in a similar research carried out in different year that showed the temperature achieved by microwave assisted hydro-distillation was higher than 110°C using water as a solvent (Kusuma & Mahfud, 2015).

Other than that, it was noticed that time taken to reach boiling point (induction time) was shorter at higher microwave power level. The shorter induction time was recorded for 600 W that only took less than one (1) hour then followed by 300 W and hydro-distillation with induction time of 1.2 hours and two (2) hours, respectively, under the constant samples to water ratio (100g :1000 ml).

Table 1: Rate of temperature rise for HD and MAHD

Extraction parameter	y-intercept (b)	Rate of temperature rise (°C/min) (m)	Rate equation (y = mx + b)
Hydro-distillation	24.5	60	y = 60x + 24.5
100 W	25.7	16.592	y = 16.592x + 25.7
300 W	24.6	72.125	y = 72.125x + 24.6
600 W	25.2	150	y = 150x + 25.2

Difference in induction time can also be explained from the rate of temperature rise. The rate of temperature rise that was measured by determining the slope of the linear part of temperature profile is tabulated in Table 1. The details in Table 1 showed that the rate of temperature elevation using 600 W was 2.5 times greater than that of the hydro-distillation method and 1.2 times greater for 300 W. This phenomenon could be attributed to the effect of microwaves on polar solvent, such as water, which has high dielectric constant. Polar molecules strongly absorb the irradiation from the microwaves because of the permanent dipole moment. The degree of microwave absorption increases with the dielectric constant, which directly increases the temperature inside the sample. Therefore, it can be concluded that higher microwave power might tend to accelerate the induction time perhaps due to the higher density of waves at such power level, compared to the case of hydro-distillation.

B. Effect of extraction methods

The essential oil yield extraction from *Annona Muricata* leaves using microwave assisted hydro-distillation had been compared with that of conventional hydro-distillation in Figure 4. Table 2 showed that the extraction with microwave assisted hydro-distillation started at much earlier time than that of hydro-distillation. The first essential oil droplets were observed within one (1) hour in microwave-assisted hydro-distillation and took 90 minutes in hydro-distillation. Full recovery of essential oil or total essential oil extraction time was achieved within 180 minutes of operation in microwave assisted hydro-distillation, respectively, whereas it took 300 minutes for the conventional hydro-distillation to complete the extraction process.

Table 2: Effect of HD and MAHD on Annona Muricata leaves essential oil extraction yield

Extraction parameter	Hydro-distillation (HD)	Microwave Assisted Hydro-distillation (MAHD)	
		300 W	600 W
Rate of temperature increase (°C/min)	60	72.125	150
Starting time of essential oil accumulation (min)	90	60	30
Total extraction time (min)	300	180	180
Extraction duration (min)	210	120	150
Yield (%,w/w)	0.03	0.04	0.045
Rate of essential oil accumulation (w/min)	0.0001	0.00022	0.00025

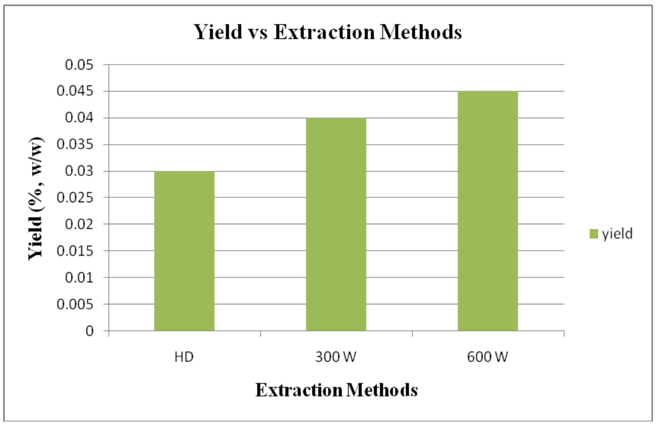

Fig 4:Yield by different extraction methods

A few studies conducted by different groups of researchers proven that microwave did speed up the full recovery of essential oil from raw material. (Wang et al., 2010) found that it only took 75 minutes to fulfill the extraction process of essential oil from Mango (*Mangifera indica* L.) flowers via microwave extraction method than via hydro-distillation, which took four (4) hours. Also, (Memarzadeh et al., 2015) presented similar findings in their research on the essential oil extracted from Bakhtiari savory (*Satureja bachtiarica* Bunge.) where it took 30 minutes for the microwave assisted steam hydro-diffusion to accomplish the extraction, compared with hydro-distillation that took four (4) hours.

However, the most significant difference observed between microwave extraction and hydro-distillation methods was the ability of the microwave-assisted hydro-distillation process to raise the extraction yield of the sample quickly within a short time. By referring to Table 2, after 180 minutes of extraction, microwave-assisted hydro-distillation resulted in almost similar oil recovery to that obtained by 300 minutes of hydro-distillation (0.045% vs 0.03%, respectively). The rates of essential oil accumulation showed that the average rates by microwave-assisted hydro-distillation were 2.2 and 2.5 times greater than that of hydro-distillation. The previous finding revealed that the shorter extraction time in microwave-assisted hydro-distillation caused by the higher extraction rates which was mainly due to the efficient heat transfer in the microwave (Kusuma & Mahfud, 2015).

According to (Golmakani & Rezaei, 2008), microwave delivers heat energy more rapidly and efficiently to the water and also to the raw material, unlike the conventional heating method. The entire sample can be heated homogenously and at higher rate. Since the water within the *Annona Muricata* leaves absorbs microwave energy, the structure of plant cell membranes were broke up, enhance the essential oil extraction from the leaves. Moreover, the decrease in the extraction time contributed to cell wall degradation, resulting in higher extraction efficiency (Jeyaratnam et al., 2016).

Another significant reason for difference in rate of essential oil accumulation can be due to the combination of mass and heat transfer acting in the same way for microwave extraction method (Golmakani & Moayyedi, 2015). Generally, mass transfer occurs from the inside to outside of samples for both extraction methods. In the case of heat transfer, microwave assisted hydro-distillation applies three (3) ways of heat transfer within the samples, which are conduction, convection and irradiation, whereas only conduction and convection take place in hydro-distillation. Heat transfer occurs in the opposite way of mass transfer because of conduction and convection through the water immersing the *Annona Muricata* leaves. However, in microwave, the irradiation power gives internal heating to the sample, causes some of heat transfer to happen from the inside to outside of the leaves. When mass and heat transfer acting in the same direction inside the microwave, more oil diffuse from the leaves, which increasing the extraction yield. Thus, it can be conclude that the same action of mass and heat transfer do accelerate the rate of essential oil accumulation and increase the yield. Microwave assisted hydro-distillation is indeed the best technology to replace the conventional extraction method.

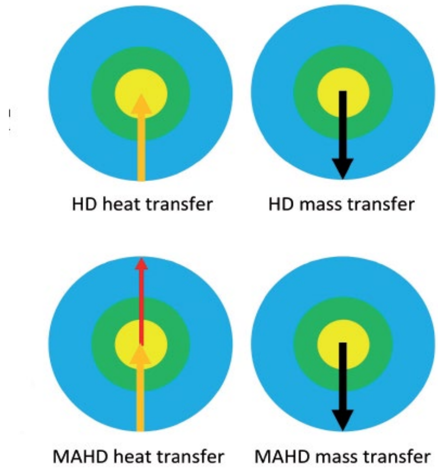

Fig 5: Schematic display of heat and mass transfer in HD and MAHD

C. *Effect of microwave power*

Among the parameters that affecting the extraction process, power was found to be one of the key influential factors. The effect of heating rate on the extraction of *Annona Muricata* yield at fix water to raw material ratio of 1:10 was determined at 100 W, 300 W and 600 W.

From Table 2, it can be seen that when the microwave power increased, the yield of extracted essential oil also increased. Since microwave power and temperature are interrelated, greater microwave power had resulted in higher operating temperature. At the same time, rate of extraction (evaporation) becomes faster and cause an increase in the extraction yield result (Samadi et al., 2016). Similar observation was also reported in a previous research work (Linsheng wei, 2013). This could be associated with the amount of microwave energy absorb by the immersed soursop leaves. Higher power level builds rapid generation of heat inside the immersed sample as more microwave energy being absorbed. Thus, the pumping effect to force the oil out of the cell gets stronger (Hamidi, 2016).

For the lowest microwave level of 100 W, no essential oil was extracted throughout the total extraction time of 7 hours. It was likely that at this power, the heat transfer at the flask containing the sample and water was much slower in comparison to other powers. The slower heat transfer could affect the vapor formation process, resulting in incomplete extraction (Samadi et al., 2016). This was proven by no condensation occurred and the rate of temperature rise in Table 1 showed that it was much slower than hydro-distillation method. The study by (Hamidi, 2016) said that very low power level was not effective for microwave-assisted hydro-distillation process since it needed longer time, which lead to decomposition of sample cell due to prolonged exposure to irradiation energy. Hence, it is very crucial to properly select the microwave power to fasten the extraction rate and maximize the yield of oils.

D. *Effect of extraction time*

Another important parameter in this study is extraction time. The time of the extraction process should be long enough to get full recovery of the existing essential oil from the plant cell. Obviously, the required extraction time varies depending on the type of plants and extraction method used. Since there was no research been carried out to extract essential oil from *Annona Muricata* leaves using microwave-assisted hydro-distillation method, it was hard to choose the suitable time to stop the extraction process. In order to find the suitable time for extraction of *Annona Muricata* leaves essential oil, the amount of essential oil during the extraction time was observed from the start until there was no increase in amount of essential oil observed. For hydro-distillation, the extraction process was stopped at 300 minutes because there was no change in the amount of oil. So, the yield collected was 0.03%.

For microwave-assisted hydro-distillation, the amount of essential oil did not increase after 180 minutes for both 300 W and 600 W. Thus, we could say that the extraction process was considered to be done after 180 minutes. There was also slight difference in the yield for 300 W and 600 W power levels (0.04% versus 0.045%). This showed that the maximum yield of essential oil extracted from soursop leaves was at 0.045%, although the microwave power did increase. Observation reported in literature said that variation of microwave power from 500 to 1000 W had no significant effect on the extraction yield (Jeon, Kim, Koo, Kim, & Lee, 2009; Kusuma & Mahfud, 2015; Li, Li, & Tang, 2009). Other than that, the small increase in yield for 600 W could also associate with the possible degradation of the plant material due to prolonged exposure to higher irradiation power.

E. Composition of essential oil

The mass spectra of essential oils and the identities of the extracted essential oils for both methods are shown in Figure 6 and Table 3, respectively.

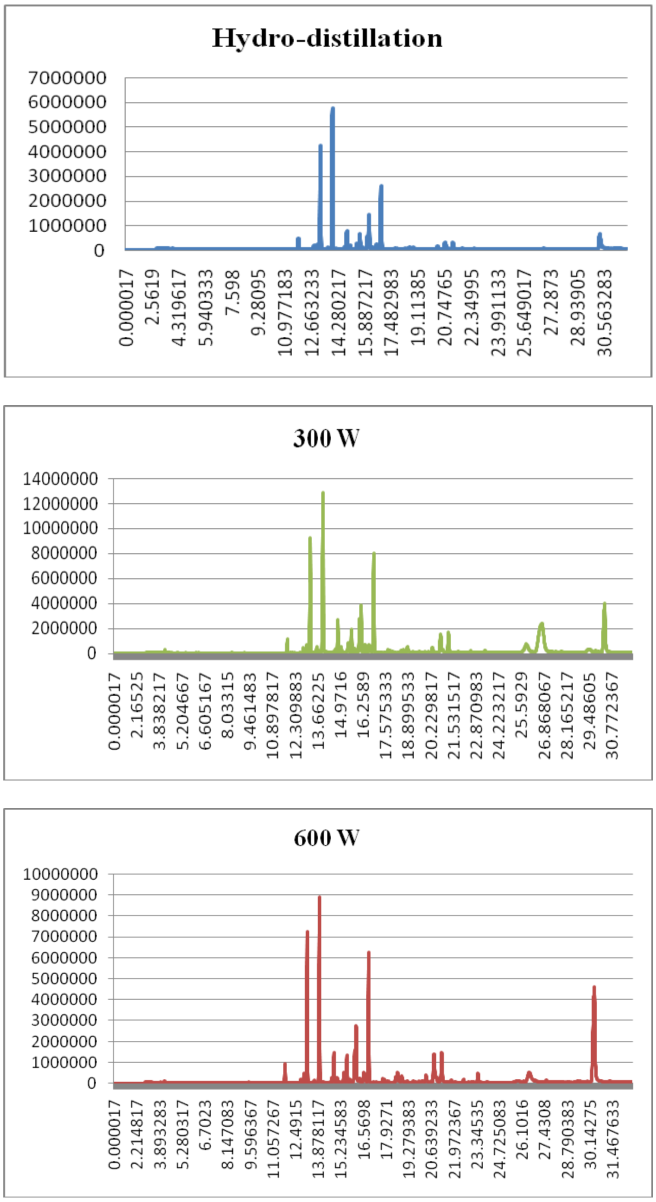

Fig 6: Mass spectra of essential oil of *Annona Muricata* leaves

The essential oil from the *Annona Muricata* leaves, grown in Kuching was extracted by the hydro-distillation and microwave-assisted hydro-distillation and analyzed using Gas Chromatography-Mass Spectrometry (GC-MS). A total of 25 chemical compounds were identified in soursop leaves using two methods, consists of major GC peak areas. From Table 3, it showed that 600 W had detected 17 compounds, while 11 and 9 compounds were detected in power levels of 300 W and hydro-distillation, respectively.

Table 3: Chemical compositions of essential oil of *Annona Muricata* leaves

No.	Compounds	RT (min)	Area (%)		
			HD	300 W	600 W
1	α-Pinene	11.8504	nd	nd	1.297
2	3-Carene	11.8608	1.562	1.132	nd
3	Ecgonine	12.9176	nd	nd	0.279
4	Azulene	13.2321	11.703	1.132	9.312
5	Caryophyllene	13.6225	0.052	0.488	nd
6	α-Phellandrene	13.9584	nd	13.876	nd
7	α-Cubebene	15.9700	9.594	0.099	11.723
8	α-Caryophyllene	14.8431	nd	2.762	2.821
9	1H-cycloprop(e) azulene	15.0307	nd	nd	0.475
10	1,6-cyclodecadiene	15.6140	2.418	2.183	2.120
11	Napthalene, decahydro-4α-methyl-1-methylene-7-(1-methylethen)	16.0703	0.213	nd	nd
12	c-Elemene	16.0924	nd	nd	7.121
13	Valencene	16.8676	nd	nd	1.687
14	Naphthalene,1,2,3,5,6,8α-hexahydro-4,7-dimethyl-1-(1-methyle)	16.8867	nd	9.521	10.623
15	Aristolene	16.9058	9.594	nd	nd
16	α-Farnesene	18.8712	nd	nd	1.160
17	Azulene (gurjunene)	19.1995	1.746	nd	0.270
18	epi-bicyclosesquiphellandrene	20.7979	1.779	nd	nd
19	Limonene oxide, cis	20.8448	nd	nd	4.052
20	Humulane-1,6-dien-3-ol	20.8458	nd	0.402	nd
21	Caryophyllene	21.2301	nd	nd	17.199
22	Camphene	23.4532	nd	nd	0.976
23	Anisaldehyde dimethyl acetal	26.8872	nd	14.636	3.226
24	6-octanal	30.3485	nd	8.605	nd
25	3-cyclohexen-1-ol,4-methyl-1-(1-methylethyl)	30.3979	nd	nd	17.019
Total identified (%)			38.661	54.836	91.36

*nd = not detected

The identified major compounds showed the presence of mostly sesquiterpenes. It could be seen that the previous investigations of the volatile compounds of *Annona Muricata* had reported the abundance of sesquiterpenes constituents in the leaves (Thang, Dai, Hoi, & Ogunwande, 2013). The major compounds present were caryophyllene and α- caryophyllene. The presences of caryophyllene and α- caryophyllene were identified in all samples. This was proven by the same result in previous study of *Annona Muricata* essential oils (Coria-Téllez et al., 2016; Moghadamtousi et al., 2015). Other than that, α-Pinene and 3-Carene were also reported among the most abundance sesquiterpenes in the oils, supported by previous study (Moghadamtousi et al., 2015).

For the major compounds detected in this study, it showed that percent amount of compounds present was higher in 600 W, followed by 300 W and hydro-distillation. As explained before, the microwave did play very important roles in extraction of essential oil. The higher power can easily force the oils from the plant cells, results in more compounds being extracted. This suggests that microwave-assisted hydro-distillation is more effective in essential oil extraction from *Annona Muricata* compared to conventional methods.

IV. Conclusion

Microwave-assisted hydro-distillation (MAHD) offers advantages over conventional hydro-distillation (HD) extraction method. The result found out that MAHD had produced higher yield compared to HD (0.045% vs 0.03% for HD) over shorter period of time (180 minutes vs 300 minutes for HD). The best microwave power to produce higher yield was found at power level of 600 W with the yield obtained under this condition was 0.045% w/w (versus 0.03% and 0.04% in HD and 300 W, respectively). Higher yield results from higher extraction rates by greater power level**.** Significantly, microwave-assisted hydro-distillation (MAHD) can be considered as cost saving and environmental friendly due to production of greater essential oil yield at shorter extraction time.

GC-MS results indicated that more chemical compounds were identified at higher power, 600 W. There were 17 chemical constituents presented at power level of 600 W, than that of 300 W and hydro-distillation with 11 and 9 chemical compounds, respectively. Significantly, microwave-assisted hydro-distillation was proven to be good technology to produce better quality of essential oils.

Acknowledgment

This study has been partially funded by a grant provided by Dr Atikah Kadri for purchasing of the equipment and apparatus. Gratitude is expressed to Dr Atikah Kadri for supervision and guidances throughout the whole study. The author would also like to thank Universiti Teknologi Mara (UiTM) for allowing the use of chemical and laboratories equipments for the study.

References

Astirin, O. P., Artanti, A. N., Fitria, M. S., Perwitasari, E. A., & Prayitno, A. (2013). <i> Annonaa muricata </i> Linn Leaf Induce Apoptosis in Cancer Cause Virus. *Journal of Cancer Therapy, 04*(07), 1244-1250.

Bellumori, M., Innocenti, M., Binello, A., Boffa, L., Mulinacci, N., & Cravotto, G. (2016). Selective recovery of rosmarinic and carnosic acids from rosemary leaves under ultrasound- and microwave-assisted extraction procedures. *Comptes Rendus Chimie, 19*(6), 699-706.

Bustamante, J., van Stempvoort, S., García-Gallarreta, M., Houghton, J. A., Briers, H. K., Budarin, V. L., . . . Clark, J. H. (2016). Microwave assisted hydro-distillation of essential oils from wet citrus peel waste. *Journal of Cleaner Production, 137*, 598-605.

Coria-Téllez, A. V., Montalvo-Gónzalez, E., Yahia, E. M., & Obledo-Vázquez, E. N. (2016). Annona muricata: A comprehensive review on its traditional medicinal uses, phytochemicals, pharmacological activities, mechanisms of action and toxicity. *Arabian Journal of Chemistry*.

Costa, P., Medronho, B., Gonçalves, S., & Romano, A. (2015). Cyclodextrins enhance the antioxidant activity of essential oils from three Lamiaceae species. *Industrial Crops and Products, 70*, 341-346.

Djouahri, A., Boudarene, L., & Meklati, B. Y. (2013). Effect of extraction method on chemical composition, antioxidant and anti-inflammatory activities of essential oil from the leaves of Algerian Tetraclinis articulata (Vahl) Masters. *Industrial Crops and Products, 44*, 32-36.

Elaissi, A., Rouis, Z., Salem, N. A. B., Mabrouk, S., Salem, Y. b., Salah, K. B. H., . . . Khouja, M. L. (2012). Chemical compostion of 8 eucalyptus species' essential oils and the evaluation of their antibacterial, antifungal and antiviral activities.

Franco-Vega, A., Ramírez-Corona, N., Palou, E., & López-Malo, A. (2016). Estimation of mass transfer coefficients of the extraction process of essential oil from orange peel using microwave assisted extraction. *Journal of Food Engineering, 170*, 136-143.

Gavamukulya, Y., Abou-Elella, F., Wamunyokoli, F., & Ael-Shemy, H. (2014). Phytochemical screening, anti-oxidant activity and in vitro anticancer potential of ethanolic and water leaves extracts of Annona muricata (Graviola). *Asian Pacific Journal of Tropical Medicine, 7*, S355-S363.

Golmakani, M. T., & Moayyedi, M. (2015). Comparison of heat and mass transfer of different microwave-assisted extraction methods of essential oil from Citrus limon (Lisbon variety) peel. *Food Sci Nutr, 3*(6), 506-518.

Golmakani, M. T., & Rezaei, K. (2008). Comparison of microwave-assisted hydrodistillation withthe traditional hydrodistillation method in the extractionof essential oils from Thymus vulgaris L. *Food Chem, 109*(4), 925-930.

Hamidi, N. (2016). Extraction of Essential Oils From Patchouli Plant Using Advanced Techniques of Microwave-Assisted Hydrodistillation. *ARPN Journal of Engineering and Applied Sciences, 11(2)*.

Hamizah, S., Roslida, A. H., Fezah, O., Tan, K. L., Tor, Y. S., & Tan, C. I. (2012). Chemopreventive Potential of Annona Muricata L Leaves on Chemically-Induced Skin Papillomagenesis in Mice. *Asian Pacific Journal of Cancer Prevention, 13*(6), 2533-2539.

Harkat-Madouri, L., Asma, B., Madani, K., Bey-Ould Si Said, Z., Rigou, P., Grenier, D., . . . Boulekbache-Makhlouf, L. (2015). Chemical composition, antibacterial and antioxidant activities of essential oil of Eucalyptus globulus from Algeria. *Industrial Crops and Products, 78*, 148-153.

Hrycay, E. G., & Bandiera, S. M. (2015). Chapter Two - Involvement of Cytochrome P450 in Reactive Oxygen Species Formation and Cancer. In P. H. James (Ed.), *Advances in Pharmacology* (Vol. Volume 74, pp. 35-84): Academic Press.

Jeon, S., Kim, N. H., Koo, B. S., Kim, J. Y., & Lee, A. Y. (2009). Lotus (Nelumbo nuficera) flower essential oil increased melanogenesis in normal human melanocytes. *Exp Mol Med, 41*(7), 517-525.

Jeyaratnam, N., Nour, A. H., Kanthasamy, R., Nour, A. H., Yuvaraj, A. R., & Akindoyo, J. O. (2016). Essential oil from Cinnamomum cassia bark through hydrodistillation and advanced microwave assisted hydrodistillation. *Industrial Crops and Products, 92*, 57-66.

Jiao, J., Fu, Y.-J., Zu, Y.-G., Luo, M., Wang, W., Zhang, L., & Li, J. (2012). Enzyme-assisted microwave hydro-distillation essential oil from Fructus forsythia, chemical constituents, and its antimicrobial and antioxidant activities. *Food Chem, 134*(1), 235-243.

Jiao, J., Gai, Q.-Y., Fu, Y.-J., Zu, Y.-G., Luo, M., Zhao, C.-J., & Li, C.-Y. (2013). Microwave-assisted ionic liquids treatment followed by hydro-distillation for the efficient isolation of essential oil from Fructus forsythiae seed. *Separation and Purification Technology, 107*, 228-237.

Kusuma, H. S., & Mahfud, M. (2015). Microwave-assisted Hydrodistillation for Extraction of Essential Oil from Patchouli (Pogostemon cablin) Leaves. *Periodica Polytechnica Chemical Engineering*.

Kusuma, H. S., & Mahfud, M. (2016). Microwave hydrodistillation for extraction of essential oil from Pogostemon cablin Benth: Analysis and modelling of extraction kinetics. *Journal of Applied Research on Medicinal and Aromatic Plants*.

Li, W., Li, T., & Tang, K. (2009). Flavonoids from mulberry leaves by microwave-assisted extract and anti-fatigue activity. *African Journal of Agricultural Research, 4 (9)*.

Linsheng wei, y. Z., Boquan Jiang. (2013). Comparison of Microwave-assisted Hydrodistillation with the Traditional Hydrodistillation Method in the Extraction of Essential Oils from Dwarfed Cinnamomun Camphora var. Linaolifera Fujita Leaves and Twigs. *Advance Journal of Food Science and Technology, 5(11)*(1436-1442).

Memarzadeh, S. M., Ghasemi Pirbalouti, A., & AdibNejad, M. (2015). Chemical composition and yield of essential oils from Bakhtiari savory (Satureja bachtiarica Bunge.) under different extraction methods. *Industrial Crops and Products, 76*, 809-816.

Moghadamtousi, S. Z., Fadaeinasab, M., Nikzad, S., Mohan, G., Ali, H. M., & Kadir, H. A. (2015). Annona muricata (Annonaceae): A Review of Its Traditional Uses, Isolated Acetogenins and Biological Activities. *Int J Mol Sci, 16*(7), 15625-15658.

Rajendran, P., Nandakumar, N., Rengarajan, T., Palaniswami, R., Gnanadhas, E. N., Lakshminarasaiah, U., . . . Nishigaki, I. (2014). Antioxidants and human diseases. *Clin Chim Acta, 436*, 332-347.

Samadi, M., Abidin, Z. Z., Yunus, R., Biak, D. R. A., Yoshida, H., & Lok, E. H. (2016). Assessing the kinetic model of hydro-distillation and chemical composition of Aquilaria malaccensis leaves essential oil. *Chinese Journal of Chemical Engineering*.

Thang, T. D., Dai, D. N., Hoi, T. M., & Ogunwande, I. A. (2013). Study on the volatile oil contents of Annona glabra L., Annona squamosa L., Annona muricata L. and Annona reticulata L., from Vietnam. *Nat Prod Res, 27*(13), 1232-1236.

Tong, L., Chuang, C. C., Wu, S., & Zuo, L. (2015). Reactive oxygen species in redox cancer therapy. *Cancer Lett, 367*(1), 18-25.

Walton, E. L. (2016). The dual role of ROS, antioxidants and autophagy in cancer. *Biomed J, 39*(2), 89-92.

Wang, H. W., Liu, Y. Q., Wei, S. L., Yan, Z. J., & Lu, K. (2010). Comparison of microwave-assisted and conventional hydrodistillation in the extraction of essential oils from mango (Mangifera indica L.) flowers. *Molecules, 15*(11), 7715-7723.