Preliminary Study of Ohmic Heated Hydro Distillation for Essential Oil's Plant Extraction

M.H. Hamzah[a], S.S. Sudin[c], T.N.A. Tengku Ab Mutalib[c], N.F.H. Ab. Malek[c], N. Yusof[c], H. Jamaludin[c], N.F. Jamaludin[c], H. Che Man[a] and Z. Zainal Abidin[b]

[a]Department of Biological and Agricultural Engineering, [b]Department of Chemical Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia. Email: hazwan@eng.upm.edu.my

[c]Bioengineering Technology Section, Universiti Kuala Lumpur Malaysian Institute of Chemical Engineering Technology (MICET), Lot 1988, Vendor City, Taboh Naning, 78000 Alor Gajah, Melaka, Malaysia.

***Abstract*— Essential oils can be extracted by various extraction methods such as hydro distillation, steam distillation and solvent extraction. However, the application of ohmic heated hydro distillation has not been reported much elsewhere. In this study, ohmic heated hydro distillation of four types of plants; *Cymbopogon atratus* (Lemon grass), *Cymbopogon nardus* (Citronella grass), *Backhousia Citriodora* (Lemon myrtle) and *Syzygium aromaticum* (Clove) were studied in terms of yield and power consumption with electrical element heated hydro distillation. Generally, in most cases ohmic heated hydro distillation required less power and produce more essential oils yield for the same duration of extraction time. The results of the extraction process were presented.**

***Keywords*— Ohmic heating; Hydro distillation; Essential Oil**

I. INTRODUCTION

Various extraction methods can be used to produce essential oils such as hydro distillation, steam distillation and solvent extraction. The main disadvantages of solvent extraction are long extraction time, degradation of thermo labile compounds and limited solvent choice [1]. Currently in Malaysia, hydro distillation is commonly used to extract essential oil from plants. In this process, the mixture of plant material and water in a vessel is heated by means of electrical heating elements, or by flame heating at the bottom surface of the vessel. Since the plant material has low thermal conductivity as compared to water, the heated water conducts heat into the plant material and thereafter the plant material to the oil-bearing cell. The process is governed by convective or conduction heat. Methods to improve steam distillation and hydro distillation have been reported [2, 3]. However it has been used for analytical purposes and only in small volumes. Another method is to heat the plant material using microwave heating prior to extraction. The method is limited by the penetration depth of microwave energy into the material. Microwave heating is a heating method by which heat energy is generated within the material by rapid oscillation of the bipolar molecules as a result of the penetrating microwave.

A similar mode of heat generation can also be achieved by ohmic heating, which is not limited by depth penetration. Ohmic heating has been used since the early 1900. Ohmic heating has been used to enhance various extraction processes. Ohmic heating also has been used as a pretreatment to enhance lipid extraction from the rice bran oil [4]. Extraction efficiency of sucrose from sugar beets was increased with ohmic heating whereby ohmic heating increased diffusion of beet dye from beet root into a carrier fluid and the amount of dye extracted was proportional to the electrical field strength used [5]. In an exploratory study, orange peel oil can be easily extracted by circulating the peel puree through an ohmic heating cell and the resultant heated mass at 100°C is flashed to yield orange peel oil after 20 minutes of circulation and the whole process took 30 minutes to extract 2.5 litres of orange rinds [6]. In another trial, a 1 litre batch ohmic heater connected to a condensing unit was used as an ohmic heated hydro distillation was able to produce traces of oil from 250 grams low quality agar wood powder compared to conventional hydro distillation which did not yield any oil after 3 hours of heating [7].

In this preliminary study, the application of ohmic heating was introduced in order to speed up the breakage of plant cell's wall. Thus reduces the mass transfer resistances and would easily release the cell's contents into the extraction medium during the hydro distillation process. When electricity pass through a mixture of solid and liquid material, the material with the greatest resistance will have more heat generated in them as compared to material with lower resistance [8]. This process occurs almost instantly. The aqueous component of the plant material or the absorbed water in the plant material will generate heat within the material at a rate proportional to the electrical conductivity of the aqueous components [9]. Since the volume of water in a hydro distiller is much greater than that of the solids, most of the heating will occur in the aqueous phase. Therefore apart from electrical heat generation within the plant material heat is also conducted to the plant material from the aqueous phase. As the temperature between the two materials equilibrates, no heat transfer can occur [10]. At this point the aqueous phase will begin to boil at the boiling temperature. If at this juncture the oil has diffused out of the solid matrix aided by the heating process, the oil will be carried away by the generated steam, which is then condensed in the condenser.

The application of ohmic heated hydro distillation for essential oil's plant from extraction has not been reported much. A study regarding hydro distillation of caraway (*Carum Carvi L.*) by direct induction heating assisted by a magnetic field process based on ohmic heating showed that the extraction time is much shorter than conventional hydro distillation [11]. In this research, the author attempted to verify the potential of this method. The objective of this research is to compare the performance of ohmic heated hydro distillation with electrical element heated hydro distillation.

II. METHODOLOGY

Raw material preparation

Four types of plants were used in this study; *Cymbopogon atratus* (Lemon grass), *Cymbopogon nardus* (Citronella grass), *Backhousia Citriodora* (Lemon myrtle) and *Syzygium aromaticum* (Clove). Lemon grass samples were obtained from local shop in Alor Gajah, Melaka while Citronella grass samples were obtained from local farmer at Sri Wangi, Batu Pahat, Johor. These two samples were chopped into smaller sizes by a EUMA™ Three-Phase Asynchronous Motor Y90L-2 chopper. Lemon myrtle samples were reduced into smaller sizes by a SIMA™ Frond Chopper Model FC 3000 C. Clove samples were extracted without any grinding process. Lemon myrtle samples were obtained from local farmer in Sekinchan, Selangor while clove samples were obtained from a sundry supermarket in Ayer Keroh, Melaka.

Measurement of electrical conductivity

The electrical conductivity of the samples in different water ratio was measured using conductivity meter Model HI 8633 Hana™ Instrument in 250 ml beaker. Average electrical conductivity and electrical conductivity at boiling point temperature were recorded.

Set up of ohmic heated hydro distillation

The ohmic heated hydro distillation unit is as shown in Figure 1. The unit consists of a central stainless steel 316 electrode with 0.73 m long and 0.198 m diameters. An electrically insulated outer shell serves as the outer electrode. The electrodes were connected to a three-phase alternating current step down transformer 415/133/87 V power supply rated at 10kVA. The connection to the electrodes was either single phase or phase to phase based on the desired voltage to apply. The water sample mixtures were filled into the distiller until the central electrode is completely immersed. The distillation unit is then connected to a multi tube condenser made from stainless steel 304. The extracted oil was collected using the separator funnel. The oil yield extracted was calculated in volume/weight (ml/kg).

Figure 1. Ohmic heated hydro distiller

Electrical element heated hydro distillation

For electrical element heated hydro distillation, the same unit was used except the central electrode is replaced with a 3 kW/3 phase heating element.

III. RESULTS

There were several factors need to be considered when applying desired voltage for ohmic heating process. These are the electrical conductivity, the influence of extraction temperature, size, density of particle, behavior of the load at different voltages and frequencies [12]. However, the electrical conductivity is the most critical factor. Measurement of electrical conductivity is very essential to ensure that only suitable electrical power supply is supplied to the ohmic heating system. It is important to consider electrical conductivity because there is linear relationship between rate of heating with square of electric field strength and also the electrical conductivity. By adjusting the voltage applied, the electrical field strength can be varied.

TABLE I. MEASUREMENT OF ELECTRICAL CONDUCTIVITY

Sample	Lemon grass	Citronella grass	Lemon myrtle	Clove
Sample to water ratio	1:6	1:6	1:5	1:3
Average electrical conductivity (S/m)	3.03	0.935	0.980	1.260
Electrical conductivity at boiling point (S/m)	5.08	1.890	2.400	2.660

Thus, the power consumption was calculated using this formula as follows [13]:

Phase to phase voltage:

$$P = \sqrt{3}\ E \times I \qquad (1)$$

Phase to neutral voltage:

$$P = E \times I \qquad (2)$$

Whereby; P = Power (watts), E = Voltage (voltage), I = Current (amperes)

The phase to phase voltages used were 133 V and 87 V whereas the phase to neutral voltages were 80 V and 50 V. Comparison between ohmic heated hydro distillation and electrical element heated hydro distillation for lemon grass, citronella grass, lemon myrtle and clove are presented in Table II, III, IV and V respectively.

TABLE II. OHMIC HEATED HYDRO DISTILLATION AND ELECTRICAL ELEMENT HEATED HYDRO DISTILLATION (LEMON GRASS)

Type	Ohmic heated hydro distillation		Electrical element heated hydro distillation
Amount of sample used (kg)	4	4	3
Time of extraction (hour)	2	2	2
Voltage used (V)	80	80 (up to boiling point) 50 (until the end of extraction)	240
Yield (ml/kg)	1.15	1.05	1.19
Power consumption (kW)	2.7	2.5	3

For lemon grass essential oils, as comparison made between ohmic heated hydro distillation with different voltage supplied, the highest voltage supplied which is 80 V constantly throughout the extraction gave 1.15 ml/kg of yield.

However in terms of power consumption, the voltage supply of 80 V up to boiling point and 50 V until the end of extraction consumed less power (2.5 kW) even the yield produced is lesser than the yield of voltage supply 80 V. Even though the electrical element heated hydro distillation resulted more yields (1.19 ml/kg), the power consumption was higher than the ohmic heated hydro distillation method (TABLE II).

TABLE III. OHMIC HEATED HYDRO DISTILLATION AND ELECTRICAL ELEMENT HEATED HYDRO DISTILLATION (CITRONELLA GRASS)

Type	Ohmic heated hydro distillation	Electrical element heated hydro distillation
Amount of sample used (kg)	4	4
Time of extraction (hour)	2	2
Voltage used (V)	80	415
Yield (ml/kg)	3.85	3.75
Power consumption (kW)	2.5	3

As result tabulated in TABLE III, it showed that ohmic heated hydro distillation increased the yield of oil extracted and reduced the power consumption of the extraction process. The yield of ohmic heated hydro distillation is 3.85 ml/kg which is higher than the electrical element heated hydro distillation (3.75 ml/kg). Moreover, by ohmic heated hydro distillation, the power consumption is 2.5 kW, lesser than 3 kW of electrical element heated hydro distillation.

TABLE IV. OHMIC HEATED HYDRO DISTILLATION AND ELECTRICAL ELEMENT HEATED HYDRO DISTILLATION (LEMON MYRTLE)

Type	Ohmic heated hydro distillation		Electrical element heated hydro distillation
Amount of sample used (kg)	4	4	4
Time of extraction (hour)	2	2	2
Voltage used (V)	80 (up to boiling point) 50 (until the end of extraction)	133 (up to boiling point) 87 (until the end of extraction)	415
Yield (ml/kg)	30	30	25
Power consumption (kW)	1.7	4.9	3

For lemon myrtle essential oils, as comparison made between ohmic heated hydro distillation with different voltage supplied, both voltage used gave the same amount of yield. However, power consumption reduced when the voltage used was 80 V up to boiling point and 50 V until the end of extraction. In this case, it is better to use low voltage (80 V up to boiling point and 50 V) because it gave the same amount of yield and at the same time reduced the power consumption. Besides that, it is also proved that the ohmic heated hydro distillation (80 V up to boiling point and 50 V until the end of extraction) increased the yield (30 ml/kg) and reduced the power consumption (1.7 kW) rather than electrical element heated hydro distillation, which yielded 25 ml/kg with power consumption of 3 kW (TABLE IV).

TABLE V. OHMIC HEATED HYDRO DISTILLATION AND ELECTRICAL ELEMENT HEATED HYDRO DISTILLATION (CLOVE)

Type	Ohmic heated hydro distillation	Electrical element heated hydro distillation
Amount of sample used (kg)	3	3
Time of extraction (hour)	2	2
Voltage used (V)	50	240
Yield (ml/kg)	60	17
Power consumption (kW)	1.4	3

According to TABLE V, the ohmic heated hydro distillation resulted higher yield (60 ml/kg) and less power consumption (1.4 kW) rather than electrical element heated hydro distillation (yield 17 ml/kg and power consumption 3 kW).

Generally, in most cases ohmic heated hydro distillation requires less power and yields more oil for the same duration of extraction time. A more detail study will be conducted since particle has a bearing on time for extraction. This is more in ohmic heated hydro distillation when the cell contents tend to yield a solution of higher electrical conductivity. Smaller particle sizes are more conducive for rapid mass transfer.

IV. CONCLUSION

The result of this study indicated that ohmic heated hydro distillation could be proposed as another method for essential oil's plant extraction as it had positive effect on amount of yield extracted. This method definitely eased for released oil and enhanced the amount of essential oil yield. Since large boilers are more effective than small boilers, the use of electrical energy from the grid can help conserved fuel for heat generator.

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