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Methodology For Extraction of Essential Oils: A Review

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Abstract:
The majority of concentrated and volatile Essential oils are extracted from various parts of the plants. Essential oils contain hundreds of organic constituents such as natural elements, vitamins, hormones, etc., widely used in the perfumery and pharmaceutical industries. Different techniques are available for the extraction of essential oil, such as hydro and steam distillation, cold pressing/expression, Maceration, solvent extraction, Effleurage, Carbon Dioxide Extraction, Hydro Diffusion, etc., and innovative techniques like Supercritical Fluid Extraction (S.F.E.), Microwave Assisted Hydro distillation (MAHD), Ultrasound-Assisted Extraction (U.A.E.), Solvent-free Microwave Extraction (SFME), Microwave hydro diffusion and Gravity (M.H.G.). This review paper summarizes the research on various methods for essential oil extraction for various raw materials. The summary of this paper included information on different plant materials, the most suitable extraction method with operating conditions, advantages, and disadvantages of extraction methods, etc.

Keywords: Essential oils, Steam Distillation, Hydro Distillation, MAHD, SFME, Solvent Extraction, Solar Distillation.

1.Introduction:

"Essential oils are complex mixtures of volatile compounds produced by living organisms and isolated by physical means only (pressing and distillation) from a whole plant or plant part of known taxonomic origin." It mainly derived the respective main compounds from three biosynthetic pathways: the mevalonate pathway leading to sesquiterpenes, the methyl- erythritol-pathway leading to mono- and diterpene, and the shikimic acid pathway to phenyl propenes. There are an almost uncountable number of single substances and a tremendous variation in the composition of essential oils. K. Husnu et al. (50). Essential oils are plant-based volatile oils with aromatic components prepared from over a hundred chemical compounds. Chanthaphone et al. (20). Essential oils are a complex mixture of volatile compounds such as (i) terpenes hydrocarbons (monoterpenes and sesquiterpenes), phenolics and alcohols, (ii) oxygenated compounds such as aldehydes, ketones, phenols, acids, esters, ethers and (iii) nonvolatile compounds such as paraffine, and waxes Bakkali et al. (18), Saidat et al. (102), Hesham et al. (41), Alberto Arce et al. (7). Essential oils extracted from various plants such as flowers, leaves, roots, buds, branches, twigs, seeds, fruits, and bark. Oztekin et al. (94), Anjum Munir et al. (12). Essential oils are useful in foods, fragrances, cosmetics, medicines, perfumery, aromatherapy, household cleaning products, etc. Hesham et al. (41)., A. Munir et al. (3), Anjum Munir et al. (12).

2.Steam Distillation Method:

N.A. Amenaghawon et al. (77). S. J. Kulkarni (100) studied the kinetics and modeling of steam distillation for lemongrass. Observed that in steam distillation equipment, loose packing of the plant material can be helpful for yield improvement.

Martin Muthee Gakuubi (68) had performed Steam Distillation with Toddalia Asiatica L., Eucalyptus. They chopped about 10-15 cm of eucalyptus leaves and for T. Asiatica, whole fruits distilled in the Clevenger-type apparatus, added 8 l of water and 4 kg of plant material. GC-MS is used for the chemical composition of the oils. Observed that the Yields were 0.5181 % (w/w) in T. Asiatic fruits and 0.2514 % (w/w) in E. camaldulensis leaves.

Australia Damayanti et al. (16) performed steam distillation with fennel seed. The operating parameters were 5 kg of material with black beans, 0.2 mm length, operating P was 1 atm, and distillation time was 7.5 hr. They collected the oil sample until the last drop of fennel oil was in the separator tank. According to the results, the yield by steam distillation of fennel seed was 2.0041 %. The color density of the turbid sample was 0.9500, for the most apparent was 0.949 g/ml, which not fulfilled the food chemical codex (F.C.C.). With the A.A.S. (Atomic Absorption Spectroscopy) test observation, the fennel oil contains 65, 1473 ppm, which does not fulfil the Indonesian National Standards of Patchouli and clove leaf oil.

E.T. Akhihiero et al. (26) performed Lemon grass Steam Distillation in Clevenger apparatus with 150-200 g of lemon grass in different cut pieces boiled with 500 ml of distilled water. The collection time duration for essential oil was 0, 60, 90, and 120 mins. For all the sizes of the leaves, the oil yield increases from 0.53-0.75 % with the increases in temperature from 10- 50 ^{0}C. At the particle sizes of 4 mm, 8 mm, 10 mm, 15 mm, and 20 mm, the highest yields value 0.51, 0.55, 0.58, 0.69, and 0.84 recorded at varying time of 30, 60, 90, and 120 min respectively. The oil yield was more in small particles at a shorter distillation time, but the oil yield decreased with time according to the consumption of oil cells. The creation of oil was less in the beginning for a large particle but increased the output with time accordingly on the large surface.

Seid Yimer et al. (105) experimented with Eucalyptus leaves in the soxhlet apparatus. They added 50 g of powdered leaves in 400 ml of water. The working temperature was 100 ^{0}C, and the distillation time was 1 hr. For the antibacterial application of Eucalyptus leaves on cotton woven fabric, washing fastness tests revealed that the treated materials with eucalyptus oil with acetic acid showed 81.1 % antibacterial resistance and 18.9 % bacterial growth, with citric acid showed 78.2 % resistance and 21.8 % bacterial growth, the untreated sample showed 57.6 % resistance and 42.5 % bacterial growth after 25 washes.

Mijat Bozovic et al. (71) performed with Lamiaceae and Apiaceae in a new 24-hr steam distillation, continued and prolonged use to improve yield. Direct steam distillation subjected to sample, and at different time intervals like 1, 2, 3, 6, 12, and 24 hr, collected essential oil samples were gained. Yield depends on the species types and also on the harvesting period of the plant.

For essential oil yield prediction, using the response surface methodology technique, M.S. Galadima et al. (65) developed an optimization model.; after drying Eucalyptus tereticornis leaves for 7 days at room temperature, with the steam temperature maintained at 97 ^{0}C with atmospheric pressure conducted steam

distillation. The parameters which were affected by the influence of oil yields, such as steam rate, extraction time, experimental data, and their interaction. Optimum conditions for 2.05 % oil yield were 0.032 kg/hr steam rate, and 105 min of extraction time.

Eduardo Cassel et al. (27) used Cymbopogon winterianus in which 0.050 kg of the sample was required for the experiment. They derived the data of experimental results using factorial practical planning 22. For a maximum oil yield of 0.942 %, the experimental conditions such as extraction time 4hr, state of plant– natural. From the factorial experimental planning, the results show that the state mainly influences the oil yield. Used GC-MS for the analysis.

K. Mu'azu et al. (51) used Eucalyptus citriodora for EO production. A measure of return on investment concluded that S.D. is highly profitable for E.O. production from the profitability analysis. The E.O. produced by the plant was 840 l/annum.

M. Malekydozzadeh et al. (62) used 100-200 g of dried rosemary leaves in the packed column with 2000 ml water in a steam source. When condensation is over, collected water and E.O. in 5, 15, 30, 60, 100 min. The longer residence time of steam in the packed bed was helpful for maximum oil extraction. From the results, at least 30 mins required for extraction. Because at the end of 30 mins, around 85 % of the oil is extracted.

D.C. Sikdar et al. (22) used orange peels (citrus Senensis) in the distillation flask. Taking 100 g of the pre-treated sample into that 200 ml of water added. By temperature-controlled basket heater, they supplied the heat to the unit. The optimum conditions such as 60 mins time, 96 ^{0}C temperature, and 100 g/200 ml solid to solvent ratio required for the optimum citrus oil extraction of 2.4 ml/100 g of sample.

Comparison between neural networks feed-forward multi-layer technique and mathematical modeling, Levenberg - Marquardt training algorithm developed for the essential oil yield by John Kabuba (48) for S.D. with Eucalyptus. 0.9737 regression coefficient (R2) values show that the experimental data and the predicted values are agreed excellently. The predicted results concluded that when compared the mathematical model with the applied N.N. technique because it has better adjusted the experimental data.

Nik Amirah Farhana et al. (85) used 0.04 kg of the Cymbopogon winterianus sample with an average thickness of 5.25×10^{-4} m for the experiment. The maximum yield of 1.02 g of E.O. with a total extraction time was 114 min. To get a high yield of oil, factorial experimental planning optimized two processing variables, raw material state, and extraction. For a maximum output of 0.942 %, they found the optimal condition to be an extraction time of 4 hr, the plant's natural state. By using three statistical criteria, they analyzed the experimental data: i) correlation coefficient (r); the root means square error (RMSE), and the mean relative deviation modulus (E). It was the optimum mathematical model for the extraction of E.O. by S.D.

3.H.D., H.D., and SFME Method:

MAHD, SFME investigated by Neeraj Singh et al. (81) and S.J. Kulkarni (100) for Lemon Grass, in which effects of various parameters like microwave power, irradiation time, and studied sample particle size. Observed oil yield increased by increasing microwave power, irradiation, time, and decreasing particle size.

Kalyani Agarwal et al. (52) performed MAHD with Piper Beetle L, where 100 g of pieces with 200 ml, 300 ml, and 400 ml. RBF, Filled with distilled water. The Clevenger apparatus mounted on the top of the microwave and inside the oven connected with RBF. 250 W, 300 W, 400 W, and 500 W power were required for the extraction and time 90 mins until no more extraction, leaves to water ratio (1:2, 1:3, 1:4).

The first droplet gained after 15 mins, the volume of oil at 250 W was 0.117-0.206 ml, at 500 W volume of oil improved were 0.221-0.348 ml the lowest yield 0.206 % at 250 W and the highest yield of oil 0.348 % gained at a microwave power of 500 W and 0.33 L/W ratio in less extraction time. The method was an energy-saving and less time-consuming process.

E.L.- Sayed S. et al. (28) performed H.D., MAHD, and SFME with Mentha Pierita L. For that, 500 g chopped leaves required. The essential oil dried over sodium sulfate & filtered; the oil storage temp was -20 ^{0}C in a brown glass was common for all three methods. The operating parameters for the three methods were; for H.D. 3 l of distilled water, 100 ^{0}C temperature, MAHD, 1.5 l of water, 500 W, 100 ^{0}C temperature, 40mins. For SFME 500 W, 105 ^{0}C temperature, 40 min. The resulting EO yield by HD 0.33 %, MAHD 0.36 %, by SFME 0.31 %. For the completion of the H.D. method, the extraction time was about 150mins, and for MAHD & SFME 40 mins. The time required to get the first drop of E.O. in H.D. and MAHD was about 35 mins and 6 mins, respectively. MAHD is more rapid and energy-saving and reduces the amount of water in the SFME method. GC-MS performed for the chemical analysis of essential oil.

Nurkholis Hamidi et al. (90) used Patchouli for MAHD and H.D. For MAHD, placed 100 g of the sample with 1500 ml of distilled water was in the glass chamber. Glass chamber was placed inside the cavity of the microwave oven, and operated the microwave generator at power levels of 280, 420, 560, and 700 W. Also applied the same method, as mentioned in MAHD for H.D. L.P.G. (composition 50 % propane and 50 % butane) stove used for the heating method where the heating value is 46,280 kJ/kg. Found MAHD as a green technology because, in MAHD, the energy consumption per milliliter of oil was about 2,620.8 – 2,952 kJ. In H.D., energy consumption was 3656.7 kJ. Found that its energy consumption was 30 % higher than MAHD. Also, MAHD can reduce the extraction time and increase the yield.

Alireza Fazlali et al. (8) had used Rosemary for HD and MAHD. For H.D., they added leaves in the Clevenger apparatus with a maximum power of 1000 W and 300 ml of water for 90 mins. For MAHD in a microwave heated 100 g of sample with 300 ml of water, 900 W power, for 15 mins and at atmospheric pressure observed from the experiment, MAHD is better by saving energy, less extraction time, and reduced environmental hazards. From the MAHD method, they gained a similar yield at less extraction time compared to H.D.

Linsheng Wei et al. (58) used Dwarfed Cinnamomum Camphora var., Linaolifera Fujita leaves, and twigs for MAHD and H.D. For MAHD in a 2 l volumetric flask, 100 g of leaf sample or 200 g of twig samples with 500 ml of deionized water was added. They set the flask up in the cavity of an MCL- 3-type continuous microwave reactor operated at a power of 577 W. On the top side, applied a condenser to collect the extracted essential oil. For H.D., they carried a similar procedure out as MAHD. And for ease of comparison, they also operated the electro mantle at 577 W. MAHD was the fast and energy-saving method because for MAHD and H.D., extraction time was 37.5 min and 120 minutes, oil yield was 1.73 % and 1.71 %, operation cost was 0.21 kWh/g and 0.67 kWh/g of E.O., respectively.

Cinnamomum cassia was used for MAHD and H.D. by Nitthiyah Jeyaratnam et al. (88). In MAHD, within the cavity of a microwave oven, they transferred a 1 l capacity reactor with the pre-soaked powdered sample. 800 W was the maximum power output capacity of the microwave. The extraction time is about 150 min. In H.D., with the water to cinnamon powder ratio 6:1, 8:1, and 10:1, weighted 25 g of powder and mix in distilled water. The extraction time was 30, 60, 90, 120, 150, and 180 mins until they separated the last drop of oil. Optimum parameters for MAHD, required 250 W microwave power, 8:1 water to raw material ratio, 90 min extraction time, and 2.55 % oil yield. For the H.D. method, the oil yield was 1.89

%. By effectively, conveniently, and efficiently MAHD is an alternative to the conventional H.D. for laboratory and industrially.

Majda Elyemni et al. (67) performed MAHD and H.D. with Rosmarinus Officinalis L. for MAHD inside the microwave oven. They heated the flask, filled with 100 g of sample and 200 ml of distilled water at a fixed power of 600 W. For H.D., in a 2 l flask, added 100 g of the sample into 800 ml of distilled water. In the balloon heater, they placed the set attached to a refrigerator to ensure condensation of E.O. for 3 hr. Observed that for the exact yield of EO, MAHD required 20 min while H.D. required 180 min.

Bunium luristanicumrech. F used by Mohammad Hadi Meshkatalsadat et al. (73) for MAHD and H.D. In MAHD, 50 g of the sample heated with 600 W power for 3 mins without water or solvent. They carried the extraction out at atmospheric P and 100 ^{0}C. For H.D. in Clevenger apparatus, they added 100 g of the aromatic herb for 1.5 h and extracted with 600 ml of water. In the characterization, observed 57 compounds. Like Anethole–E, gamma-Ter pinene, α- fenchyl pinene, acetate, etc.

SFME and H.D. methods performed by Okoh O.O. et al. (91) with Rosmarinus Officinalis L. for SFME into the reactor added 250 g of the sample without solvent or water. They completed extraction in 40 mins. For H.D. in the Clevenger apparatus, 250 g of the material was hydro distilled at 50 ^{0}C with 4 l of water. Compared to H.D., SFME-extracted oil shows higher activity because of higher amounts of oxygenated compounds with low quantities of monoterpene hydrocarbons in essential oils.

For H.D., SFME, and MAHD Mehran Moradalizadeh et al. (70) experimented with Haplophyllum Robustum. They placed 100 g of a dried sample with 2 l of water in the H.D. apparatus. For SFME, they added 50 g of dried sample into the reactor without solvent or water. 600 W power was required. The extraction time was 15 min, and the pressure was atmospheric. In MAHD at 600 W microwave energy, 100 g of dried samples were hydro distilled with 500 ml of water. After extraction of 30 min oil at atmospheric pressure. The extraction time for MAHD SFME and H.D. was 30 min, 15 min, and 3 hr, respectively. Essential oil yield was 0.54 % for MAHD and 0.63 % for SFME, and 0.50 % for H.D., respectively. So MAHD and SFME were more environments friendly than H.D. Also, MAHD reduced the extraction time and not adversely effected on the composition of essential oil.

For Piperbetle L. Amaresh et al. (9) performed with MAHD, in 2 l RBF, 200 g inserted pre-treated leaves with 600 ml, 800 ml, and 1200 ml of water. For extraction, the selected power levels were 300, 400, and 500 W. CHD (conventional H.D.) in Clevenger apparatus, 200 g of sample leaves with 1000 ml of water with leaves to water ratio 1:5 placed in 2 l RBF. MAHD requires less extraction time of 50 min than 210 min in CHD without adversely changing essential oil quality. Also, MAHD is more energy-efficient, so it is an excellent alternative method for extraction.

Ana Cristina Atti Santos et al. (10) performed experiments with Lime (Citrus latifoliaTanaka). An oil extracted from 60 g of lime peel using the Clevenger setup in the H.D. method. SOME with supercritical CO_2 removed 1 g of whole lime peels. They kept all other variables constant using milled material, with 2 ml/minute CO_2 flow, 10 min equilibrium time, and 30 min extraction time. They found the best results for supercritical extraction for milled peels at 60 ^{0}C temps, 90 bar pressure, and the flow rate of CO_2 1ml/min at 30 min., best-gained yields of lime oil were 5.445 % w/w by H.D. and 7.93 % w/w by supercritical extraction for milled peels.

Heri Septya Kusuma et al. (40) used Basil (Ocimum Basillium) for MAHD and SFME. They performed the MAHD method in the reaction flask microwave irradiation with 380 W for 160 min placed and heated where 40 g of dried basil leaves and 400 ml of distilled water. At every 20 min, they decanted the collected essential oils from the condensate. The SFME method wetted 100 g of dried basil leaves before extraction

by soaking them in a particular proportion of water for 30 min and then removing the excess water. Inside the reaction flask, microwave irradiation with 380 W for 60 min placed and heated the wetted material. The resulting extraction yield of basil oil by the MAHD method for 160 min and the SFME method for 60 min was 0.78 %. Kinetics of oil extraction from basil by MAHD and SFME methods proved that the extraction process was based on the second-order extraction model as the experimentally done in three distinct steps.

4.MAHD Method:

An experiment was performed with Indonesia Sandalwood by Heri Septya Kusuma et al. (39). 80 g of sandalwood powder samples in the flask, with 400 ml of deionized water. The microwave operated at 600 W power level for 2 hr at 100 ^{0}C and atmospheric pressure. The maximum yield of oil extracted by MAHD is higher (1.23 %) than conventional hydro distillation. They identified 23 compounds, representing approximately 97 % of the detected compounds.

As per Jila Asghari et al. (47). Added 750 ml of water with 50 g dried powdered echinophor a platylabo in RBF. Microwave vessel irradiated at 20 to 45 min and irradiation power 400 to 700 W. With increasing the microwave irradiation from 300 W to 700 W, the yield of E.O. rises from 0.1 % to 0.45 % in 45 min.

Ginger and lemongrass were used as raw materials to perform experiments by Abdurahman. H. Nour et al. (4) the Ginger rhizome sliced and dried up to 90 % dryness to ground into small particles. After cutting lemon grass into small pieces, they altered a domestic microwave oven for the distillation. The best condition for max E.O. production was under 250 W microwave power, 90 min, water to a raw material ratio of 8:1. The max yield of Ginger was 0.85% (w/w), and for lemongrass 1.37 % (w/w). GC-MS analyzed the oil samples at different extraction times to evaluate their quality.

For MAHD and H.D. methods with Vetiver roots, H S Kusuma (36) experimented. In the reaction flask, 0.30, 0.40, 0.50 g/ml feed to solvent ratio heated feed with various microwave powers 300, 450, 600 W for extraction times 60, 120, and 180 min. The extraction time for the MAHD method and H.D. was 3 hr and 24 hr. The yield gained from MAHD was 0.49 % and 0.46 % for H.D. So MAHD shows more advantages than H.D.

As per Phan Nhut Nam et al. (97), Vietnamese star anise fruits (illicium Verum Hook f.) in MASE (Microwave-Assisted Soxhlet extraction), 10 g of sample was homogenized and placed in a cellulose thimble. Capped with cotton wool and put into the cartridge vessel in the zone of microwave irradiation. This device operates with microwave power from 100 W to 400 W. Steam Extraction with a Clevenger-type apparatus, in a 1000 ml flask, added 50 g of sample with 500 ml water for the extraction, about 120 mins. The optimal conditions of 325 W microwave power, 20 mins irradiation time, and 0.4 mm particle size obtained an 8.3 % maximum essential oil yield.

Citrus Limon (Lisbon variety) peel used by Mohammad-Taghi Golmakani et al. (74) for the MAHD method, in the reactor added 50 g of dried sample and 450 ml of distilled water with the peel to water ratio of 1:9 and heated by microwave power with 1200 W for 15 mins. SFME method in the microwave reactor with the peel-to-water ratio of 1:1 placed with a fixed 1200 W for extraction. For Hydro distillation, in a Clevenger-type apparatus, a sample and distilled water are added to extract essential oil in 30 min intervals for 120 mins. More yield results from higher extraction rates by microwaves and antioxidant activity could be because of a synergy of mass and heat acting. Constituents of essential oils were almost similar in MAHD, SFME, and H.D. analyzed by GC-MS.

Lavandula Stoechas was taken by Sanaz Sadani et al. (103). 80 g of sample and 600 ml of distilled water in a 1000 ml flat-bottomed flask. With 35 mins time and 400 W microwave oven heated. By microwave, the E.O. yield was 0.112 %. GC-MS analysis identified 28 components.

Arpad Kapas et al. (14) experimented with fennel. In the distillation flask, they added 25 g of dried sample powder with 200 ml of water for extraction. 50 rpm was the rotation speed for the flask. The heating power was 300 W. E.O. quantity is 7.5 % higher in MWHD compared to H.D. By H.D. and MWHD, the composition of the volatile oil was almost similar. To describe both H.D. and MWHD, the semi-empirical model is suitable.

Maryam Khosravinezhad et al. (69) experimented with Oliveria decumbent. Put 70 g of a dried sample and 350 g of distilled water in RBF. The microwave oven was operating at 2450 MHz and 990 W. With GC-MS analysis, the main components of the Oil were m-thymol (34.80 %), thymol (34.36 %), myristicin (20.88 %), etc.

5.Solar Distillation Method:

A. Afzal et al. (2) used eucalyptus for solar distillation. The solar distillation system comprises a primary reflector (10 m^2 Scheffler concentrator), a secondary reflector, a distillation still, a condenser, and Florentine flasks. From 10 kg of fresh eucalyptus leaves, the resulting essential oil extracted was 29.6 ml. By GC-MS, they identified eucalyptol as the most dominant compound of eucalyptus leaves (50.91 %).

Dr. Udaya Bhaskar Reddy Ragula et al. (24) used Lemon Grass for Solar and lab Distillation. For lab distillation, cut 100 g of dried grass into 4-6 cm lengths with distillation time was 90 min. Tested a semicontinuous distillation unit and found 30 % more oil obtained than the batch distillation units. With an increase in temperature, the oil yield is also increasing at all steam-to-grass ratios. They found the suitable temperature and steam-to-grass ratio to be 150 ^{0}C and 8:1, respectively.

Y Kulturel et al. (111) required 5 kg of mint plants, cut into 5 cm long pieces, and fell into a distillation vessel. 7 C.P.C. (compound parabolic solar collector) was used to make the distillation system. To make C.P.C., an anodized aluminum plate with a half acceptance angle of 32 ^{0}C, a concentration ratio of 1.9, and an aperture area of 3.4 m^2 was used. Essential oil of Mentha Piperita L. (31- 41 ml/5 kg plants), Mentha spicata (21-32 ml/5 kg plants). Compared with the Neo Clevenger device, the resultant E.O. by solar distillation with C.P.C. was partially lower. Because of distillation, they sent the used water back to the distillation chamber after condensation. Require partly electrical heating at the time of clouding during daytime. Without clouds, around 78-80 % of the total energy needed for the distillation gets from solar energy.

A. Munir et al. (3) used cumin and Cloves for lab and solar distillation (Scheffler Concentrator). For cumin yield found in lab 1.081, in solar 1.033. For cloves, in lab 5.500, in solar 5.500. For Fennel, in lab 0.784, in solar 0.760 ml/100 g of oil extracted. Energy consumption was 0.574 & 0.719 in cumin, 0.133 & 0.176 in cloves, 0.503 & 0.476 kWh/ml in fennel by lab and solar. Found extraction results by S.D. similar to that of the lab.

Arslan Afzal et al. (15) performed experiments for Hybrid solar distillation. Essential oils from 10 kg of fresh eucalyptus, peppermint, and Pinus were extracted efficiently with 0.59 % w/w, 0.4 % w/w, and 0.31 % w/w, respectively. The yield gained with the biomass boiler was 0.31 % w/w of essential oil. They subjected the leaves to steam using the solar energy steam receiver. GC-MS analysis confirmed that Eucalyptol (50.9 %), Menthol (93.0 %), and α-Pinene (70.9 %) as the major components of Eucalyptus, Peppermint, and Pinus essential oils, respectively.

Anjum Munir et al. (12) used cumin for laboratory and solar distillation systems. In a lab scale with 0-100 ^{0}C temp range, with 0.85 kWh energy, 1.7 ml oil extracted/100g of cumin. In solar distillation with a 0-100 ^{0}C temp range, with 3.01 kWh energy consumption, 4.06 ml oil was extracted from 400 g of cumin with 10 l of water.

6.Hydro Distillation Method:

For Hydro distillation, A Yahya et al. (1) used Kaffir lime leaves. In the Clevenger setup, mix 25 g of sample and distilled water. The amount of water in the ratio of 1:16 for 6 hr, 100 ^{0}C temperature the water and volatile oil started to rise and then condensed in a condenser tube. For different sizes of kaffir lime leaves, the yield of essential oils found for 90 µm was 0.81 %, for 150 µm 0.5226 %, for 300 µm 0.418 %, and for other sizes 0.3484 %. GC-MS analysis found 38 compounds. They increased the yield of essential oil at the decreased particle size.

Fernando Duarte Cabral et al. (30) performed hydro distillation with Spiranth eraodoratisima (Rutaceae). Add 300 g of plant material into the Clevenger apparatus, dividing it into three 100 g samples and 500 ml distilled. By GC-MS analysis, the leaves showed 28 volatile compounds, which represent 93.8 % of the total composition of the oil. Identified components in oils from its flowers showed 94.4 % of the oil composition.

Eucalyptus, Camadulensis leaves used by Khalid M Abed et al. (55) for water distillation, 50 g with particle size 0.5 cm of dried eucalyptus leaves, placed 300 ml of distilled water in the Pyrex extraction flask, an amount of oil determined after every 15 min, until they reached equilibrium, temperature 100 ^{0}C, water to leave ratio (6:1) (ml: g), and mixing at 200 rpm. The amount of Eucalyptus oil increases with extraction time. Extraction increases with temperature. The essential oil upgrade after increasing the agitation speed and ratio of water to Eucalyptus leaves up to a specific limit. Oil yield increased with decreased particle size.

Paul Njenga Waithaka et al. (96) used Lavender flower leaves for water distillation. In 2 l RBF, 400 g of fresh lavender flower and leaves separately containing 1.5 l of water and placed on a heating mantle with 450 W, 100 ^{0}C, atmospheric P. volatile oil evaporated with the water. They took up to 180 mins measurement every 20 min. For flowers %, the yield of essential oil varied from 0.5 after heating for 20 min to 4.5 after heating for 180 min. % yield of leaves ranged from 0.1 for 20 min to 3.5 after heating for 180 min.

Imad Eddine Elkacimi et al. (45) used Thymus satureioides, for the Academic H.D. method. H.D. with Clevenger apparatus, immersing aerial parts of thyme in a boiling water bath. Traditional technique, training with water vapor; by using artisanal alembic. In the perforated tank, the contact of the plant with water vapors is not directly with water. Traditional technique of HD by using artisanal alembic. The perforated Central tank (tank–grid) provided for the intermediation of the volatile mixture. Between the lower (boiler) and upper tank (cooling). Compared to method 1, methods 2 & 3 produce E.O. of thyme, less concentrated in the thymol respectively 47 % and 75 %.

For HD, Nimet Kara et al. (86) used Rosa damascene Mill (oil-bearing Rose)., In a 6 l flask, add 1kg of fresh rose flowers with 3 l distilled or seawater. Connect the flask with the Clevenger apparatus for the 3 hr operating time. Hydro distillation with seawater gave a higher yield of 0.045 %, with pure water as 0.042 % but a significant decrease in citronellol rate from 41.49 to 33.56 % and significant increases in geraniol rate from 17.58 to 27.44 % and nerol rate from 6.45 to 12.21 %. GC-MS analysis detected a total of 23 constituents of essential oil.

Guido Flamini et al. (34) used Rosmerinus officinalis L. 2000 g plant material coarsely cut and used to prepare 40 identical 50 g samples, put into a 2 l spherical flask, 500 ml of water, 500 ml of NACL (5%) water solution, added 500 ml of water, and hydro distilled after 24 hr maceration, 450 ml of water and 50 ml of I.L. (ionic liquid) added and hydro distilled after 24 hr maceration. In H.D., they heated the plant material with a heating mantle to the boiling point for 2 hr in the Clevenger-type apparatus. For the efficient extraction, four different chloride-based I.L. used during the H.D.; (1-hydroxyethyl-3-methyl imidazolium chloride), (N, N, - butyl methyl morpholinium chloride), (N-methylimidazolium chloride) and (chlorine chloride). Among that, IL-1 (1-hydroxyethyl- 3- imidazolium chloride) was used to improve the essential oil yield by about 25 %. Using less expensive methyl imidazolium chloride also observed positive effects.

Taoufi k Haloui et al. (108) used Pistacia lentiscus L. After drying the plant in the open air for seven days, they extracted 100 g of plant material in each test with the help of Clevenger-type apparatus. Moisture from the plant material is determined by stoving at 105 ^{0}C and 4 hr. In the refrigerator, at 4 ^{0}C essential oil is stored in an opaque glass bottle. Response surface Methodology (R.S.M.) proved high efficiency for optimizing the operating parameters for the oil extraction. Under different conditions, essential oil yield varied from 0.4 - 0.58 % (w/w).

Ni Ketut Sari et al. (83) used tobacco leaves. Fed the tobacco and water inside the boiler, with 1:11, 1:13, 1:15, 1:17, and 1:19 tobacco/water ratio (w/w). At 1 atm P and 100 ^{0}C for 4, 5, 6, 7, and 8 hr operating time. 1:17 tobacco to water ratio with the 8 hr refining time is the optimum condition.

Mentha leaves were used by Karanvir Gill et al. (53). In the Clevenger apparatus, placed 200 g of material and 1000 ml water into 2000 ml RBF at 80 ^{0}C temperature for the extraction of essential oil.

Table:1 result analysis

Time (min)	Moisture content %	E.O. yield (ml)
120	74.30 (fresh leaves)	4.60
60	42.30 (shade-dried)	3
60	19.35 (sun-dried)	3.10

Nguyen Dinh Phuc et al. (82) used for the experiment Jasmine al., in 1000 ml globe put 250 g material, flower–water ratio 1:1 to 1:5, temp 110 ^{0}C to 150 ^{0}C, distillation time of 4 to 8 hrs. The optimum distillation conditions temperature of 120 ^{0}C, time 6 hrs, and water material ratio of 2:1. The resultant yield on the lab scale was 0.092 %.

Z. Nazlina et al. (113) used Citrus Sinensis. In the reaction vessel, they mixed 30 g of orange peel powder with 300 ml of water and agitated at 150 rpm. They collected samples every 5 mins, samples. At the steam flow rate of 2.43 ml/min, they found the highest yield of 5.73 w%. When the value of the steam rate increased; the value of the concentration of oil at saturation, the extraction rate, and the initial extraction rate increased.

Muhammad Hazwan H. et al. (76) used Citronella grass. Where chopped 4 kg of citronella grass feed in the ohmic heated hydro distillation unit, the unit comprises a central SS 316 electrode with 0.73 m long and 0.198 m diameter. Electrodes connected to a three-phase alternating current, step-down transformer

415/133/87 V with a power supply of 10 kVA. The optimum parameters at voltage input of 77V up to a boiling point and 50V. 120 mins extraction time, solvent to solid ratio of 3:1, and once chopping frequency. For the kinetics and mechanism, the initial extraction rate was 0.134 g/l.min. The extraction capacity was 5.787 g/l. The second-order extraction constant was 0.004 l/g.min, and the coefficient of determination was 0.976.

As per Ljiljana Stanojevic et al. (59) for Lavandu la officinalis L. In 1st method, Into the flask, fed 15 g of plant material with 150 cm^3 of water. Distillation time was 240 min. In 2nd method, the residue still water was separated under vacuum by Buchner funnel, and the freshwater volume was 150 cm^3. They used a new quantity of plant material of 15 g for each subsequent distillation.

Table:2 Technic I and II results

H.D. tech	Average yield (cm^3/100 g of dry plant material)	Camphor %	Linalool %
I	5.73	19.91	19.99
II	6.15	19.89	19.17

As per Ida Hasmitan et al. (44), in hydrodistillation still added 20 kg of ginger sample was with the steam. The distillation time was 300 min. Found the essential oil yield increase from 0 to 0.055, 0.021 to 0.083, and 0 to 0.057 for 1, 2, and 4 days of drying time with increased time from 30 to 240 min. From GCMS analysis, identified twelve compounds.

Xiao Ni et al. (110) experimented with Boswellia sacra gum. The material was hydrodistilled at 78 ^{0}C and collected fractions at different durations (fraction I at 0-2 hr, II at 8-10 hr, III at 11-12 hr). The second half of the distillation was at 100 ^{0}C. Distillate collected at 11-12 hr (fraction IV). Found High-molecular-weight compounds at longer duration and higher temperatures. In the heterotopic xenograft mouse model, fraction IV exhibited anti-proliferative and pro-apoptotic activities against pancreatic tumors.

Basma A Abdul- Majeed et al. (19) used Eucalyptus Camadulensis. Add 8 g of fresh eucalyptus leaves and water, mixed, and boiled into the 3-necked RBF. The reflux condenser condensed the vapor mixture. The best operating condition was temperature: 100 ^{0}C, stirring speed: 900 rpm, particle size: 0.5 cm, solvent to solid ratio 5:1 (v/w), time:160 min. The maximum yield of eucalyptus oil was 46.25 w%.

Krunal Shah et al. (57) used patchouli leaves. With 2 l capacities of the circulatory Clevenger apparatus, they performed experiments. They successfully optimized hydro distillation using the Taguchi method. They found the optimum conditions 30 g solid loading, a water volume of 900 ml, 4 mm size of the leaves, extraction time of 150 min. Under these conditions, the highest yield of the oil was 1.53 w/w %. Found the most factor affecting the parameter for extraction yields is extraction time at a 57.30 % contribution.

Jutarut Pornpunyapat et al. (49) used Aquilaria crassna. 3000 g of comminuted wood soaked with 27,000 g of distilled water for seven days. The hydrodistillation temperature range was 80, 100, and 120 ^{0}C. For essential oil separation, every 8 hr, the agarwood oil is collected and left in the separator funnel. At 64 hr higher oil yield of 611.67 mg/gm and better quality of the oil gained at a higher operating temperature of 120 ^{0}C, whereas 515.33 and 455.33 mg/g of oil yield at 100 ^{0}C and 80 ^{0}C, respectively. Also, get better physical properties such as darker color, heavier, higher strength of oil fragrance, and long adhesion to human skin at a higher temperature.

Juniperus virginiana, J. excelsa, J. Sabina used by Ivanka B. Semerdjieva et al. (46) In a kitchen food processor, add 100 g of dried leaves and 1.2 l of water. Ground for 48 sec immediately before the

extraction. Observed the highest antioxidant capacity of J. Virginiana by 5-10 mins fraction, J. Sabina with 3-10 min fraction, and J. excelsa by the control. E.O. compositions predicted with the kinetics regression models at different time frames. The results could be beneficial for pharmaceutical, aromatic, and other industries.

7.Solvent Extraction Method:

Ayano Nakamura et al. (17) used Cryopreserved lemon peels and liquefied dimethyl ether. The semi Cryogenic D.M.E. liquefaction unit allows the liquefaction of D.M.E. in an ice-chilled metal cylinder under a partially elevated pressure of 0.4 MPa. With 200 g of liquefied D.M.E., the yield of V.C. extracted from the frozen peel tissues derived from a single lemon fruit exceeded the amount of V.C. found in the juice from a single lemon fruit.

Used Frankincense, hexane, methanol, and ethyl acetate by Alan Joe Dominic et al. (6) The particle size from 0.5 to 2.5 mm, and contact time from 1 to 3 hr selected to determine the optimum solvent extraction conditions using the Taguchi method. They found the optimum conditions by the Taguchi method for solvent extraction to be particle size 0.5 mm, contact time 3 hr, and hexane solvent with 98.065 % yield.

Paini Sri Widyawati et al. (95) used pluchea indicia. Leaves dried and grounded with 45 mesh size. In the Soxhlet extractor, water, methanol, ethanol, ethyl acetate, and hexane were extracted from the raw flour at a boiling point of 3 hr. A rotary evaporator evaporated the extract, then stored it at 4 ^{0}C in a black glass bottle. Compared to other solvents (hexanes, ethanol, ethyl acetate, aqua dest), methanol was the most effective solvent.

Niraj S. Topare et al. (87) added algae onto the thimble of the Soxhlet apparatus. They placed 50 g of a sample of the dried algae with hexane solvent. Operating parameters were 3 hr at 50 ^{0}C temperatures. The method recovers almost all the oil and only 0.5 % to 0.7 % residual oil remaining in the raw material. Algae with 100 % dry, 75 % dry, and 50 % dry parameters gained 1.92 g, 1.58 g, and 1.13 g oil, respectively.

Christy E. Manyi et al. (21) used 100 g of crude honey in a 500 ml separating funnel, diluted with 150 ml of sterile distilled water, and extracted with 150 ml of the chloroform solvent for pure homey (P.H.) and Champagne royal train (C.R.T.), for Goldcrest (G.C.) n-hexane. The shaking time was 15 min. With a rotary evaporator, the organic solvent extract was concentrated under reduced pressure at 40 ^{0}C for n-hexane and 50 ^{0}C for chloroform, respectively. 32 volatile compounds were identified and classified as hydrocarbons.

As per Sara Lago et al. (104) Citrus, Acetate ionic liquids Ternary mixtures comprising limonene, linalool, and ionic liquids were prepared and placed in jacketed glass cells, stirred via magnetic stirring for a minimum of 2 hr at a temperature of 298.15 K. After the stirring settled down the sample for 12 hr. The performance of acetate-based ionic liquids is good compared to any other ionic or molecular solvent.

Khalid M. Abed et al. (56) used Eucalyptus camadulensis, n-hexane, and ethanol in a three-necked extraction flask equipped with a stirrer, add 50 g of fresh leaves and n-hexane. Put the assembly in a water bath. Collected 1 ml sample every 10 min up to the equilibrium. Hexane gives better oil yield at 65 ^{0}C with a stirring speed of 900 rpm for particle size 0.5 cm and solvent to solid ratio 7:1 (v/w) for 210 min, 68.5 w % was the maximum yield. For ethanol, the highest oil yield was 65.07 w % at 75 ^{0}C.

Okonkwo P.C. et al. (92) used neem seed. In the extractor, put 0.3348 kg of ground neem seed with a particle size of 0.425-0.71 mm and 21.33 l of food-grade ethanol. Applied optimization technique with Minitab 14 software, having 22 factorial designs. The maximum % yield was 36.86 % gained when

impeller type A1 operated at 84 rpm, 40 minutes contact time, 50 ^{0}C extraction temperature, and the Particle size of 0.425-0.710 mm.

Ahmed Yamani Rahman et al. (5) used Australian and Chinese garlic. In steam distillation, ground 200 gm of the sample with 400 ml of distilled water at a distillation time of 4 hr. Soaked ground sample in ethanol for 24 hr for solvent extraction. Obtain a higher % of oil from white Australian garlic. Chinese garlic has a higher resistance to decay than red Australian garlic. The solvent extraction method showed higher efficiency in oil extraction.

Ibtehal K. Shakir (43) used Myrtus communis L. (leaves, flowers, stems). Put 50 g of fresh leaves in the extraction column. Put solvent water, n-hexane, and ethanol into the boiling flask. N-hexane has the higher oil extraction yield from leaves at 60.97 %. Obtained 46.85 % yield % with water and 53.1 % with ethanol. They can simulate the mathematical model of the extraction curves with the mass transfer coefficients.

Mohamed Koubaa (72) et al. used Opuntia stricta fruit peels. After separating the peels, the peels blended and were hydro distilled. Then the nonpolar compounds identified with G.C- MS. Hydro distillation from the sample exhibited high antioxidant activities and inhibited the growth of S. aureus because of the nonpolar compounds extracted.

8.SOME Method:

M.S.T. Barroso et al. (64) used Schinus mole L. 99.9 % CO_2 and dried the sample at 313.15 K for 48 hr with a pressure range between 9 MPa to 20 MPa. In a supercritical extraction pilot plant, 200 g is required having a 2×10^{-3} m particle diameter. The extraction vessel used CO_2 with a flow rate of 1.38×10^{-4} kg/s. For obtaining volatile oil, the operating condition was 9 MPa at 323.15 K. For nonvolatile extracts most suitable condition was 15 MPa at 323.15 K. Compared with the experimental data, excellent results concerning the simulated extraction curve gained from the mathematical model.

As per M. Mahfud et al. (61), a Domestic microwave oven used for Cananga (Cananga odorata) with a wave frequency of 2450 MHz. for the SFME method required atmospheric pressure, 0.5+/-, 2.5+/-, 5+/- cm flower size and 0.05 g/ml feed to distilled ratio, wetted before extraction by soaking in a required proportion of distilled water for 30 mins and then remove the excess distilled water. 1 hr is the time to operate the oven at 100, 240, and 380 W power levels. The optimum yield in the extraction was 2.304 %. With feed to the distilled ratio of 0.05 g/ml, microwave power of 380 W, and flower size of +/-0.5 cm.

9.Mix Methods comparison:

Nur Ain. A. H. et al. (89) used Lemongrass (Cymbopogon citrates) for experiments. In P.L.E. (Pressurized liquid extraction), add 3 g of the sliced sample into the 22 ml cells with a cellulose filter at the bottom end. Time: 5min, flush volume: 100 %, purge time: 60 s, static cycle: 1. For H.D., they weighed 900 g of fresh sample in a 500 ml flask, and the processing time for 12 hr. Soxhlet extraction was conducted with n-hexane and ethanol as a solvent for 16 hr using a soxhlet extractor followed the AACC method was 30-25. The yield of total volatile oil by P.L.E. is 2.90 %, soxhlet extraction 3.81 %, and HD 0.01 %. The optimized operating conditions for P.L.E. extraction were heating temperature: 167 ^{0}C, p: 1203 psi, and a static time: 20.43 min.

Tuberose flowers were used by Arita D. Nugrahini et al. (13) to conduct Maceration. The solvent to flower petals ratio was 1:2, Temperature: ambient, time: 24 hrs. The oil yield with hexane (0.12 %) was higher than petroleum ether (0.08 %). The percentage of antioxidants showed that the oil yield with hexane solvent (13.13 %) was higher than petroleum ether (9.27 %).

With Ginger, Maceration was carried out by G J Manuhara et al. (31). For Extraction, solvent like water with a powder-to-water ratio of 1:5. They produced the extracts at temperatures 55, 75, and 95 ^{0}C for 15, 30, and 45 mins. The extract composition by GC-MS contains α- curcumin, α-zingiberene, β- sesqui phellandrene, β- Bisabolene. They observed the effect of temperature and time on the extracted content of ginger.

Venkat S. Mane et al. (109) and S. J. Kulkarni (100) used lemon Grass for Solvent extraction, HD, and Effleurage. Wetting or swelling of the grass inside the distillation still consumes 10-15 mins. The observed oil yield in the solvent extraction method was higher than in steam distillation.

According to Y. C. Wong et al. (112), Cinnamon is a raw material for S.D. and Soxhlet extraction. In SD, 100 to 150 g of mashed cinnamon sticks operated at 100 °C for 5 and 10 hr. The product is collected and separated into a separating funnel. In Soxhlet, 100 g of cinnamon sticks are mashed into smaller pieces, then placed inside a thimble made from thick filter paper and loaded into the main chamber of the Soxhlet extractor. They heated the ethanol solvent to reflux at a temperature above 100 °C for 5 and 10 hr. The products were collected and purified using a rotary evaporator at a fixed temperature of 50 °C from the HPLC (high-performance liquid chromatography) test results. Found Cinnamaldehyde in both extraction methods. In steam distillation, 94.728 % from 5 hr, in 94.747 % from 10 hr. In Soxhlet extraction, 73.16 % from 5 hr, 62.737 % from 10 hr.

Ocimum Grattissimum was the raw material used by S.C. Ibeh et al. (99) to conduct Hydro distillation, Steam distillation, and Microwave Distillation. In HD, 100 g of the sample leaves were cut into pieces less than 2×2 cm and placed into 2000 ml RBF filled with 1000 ml of distilled water, which was attached to a Clevenger-type apparatus. For SD in RBF, they housed 100 g of the sample. Forced steam (containing 1000 ml of water) over the perforated part of the flask to the material. Extraction time of 1 hr 42 mins oil comes to a ceased. In the Clevenger–type apparatus, leave was placed within a microwave oven, and the microwave introduced the heat for 52 min to extract the oil completely. 0.92 % yield of Ocimum Grattissimum in 165 min by HD, 1.33 % yield in 102 min by SD, and 1.84 % yield in 52 min by microwave distillation.

Andrew E. Aziza et al. (11) used Ginger for HD and solvent extraction. In solvent extraction, put 10 g of dried ground ginger into the thimble. Before fixing the thimble into the soxhlet apparatus, wet the sample with 5 ml of the n-hexane solvent and heated to 60 ^{0}C. Add 100 ml of n-hexane into the round bottom flask of the soxhlet extractor. About 30 min heated the setup. In HD, after grinding, 30 g of the ground ginger added into the 500 ml RBF of the distillation apparatus filled with 200 ml of water. The operating conditions for the process: temperature: 100 ^{0}C, extraction time: 20-25 mins, P.H. value: 7.25 and 7.08, Acid value: 9.35 and 8.415, Free fatty acid: 2.81 and 2.49, Moisture content: 12.60 and 12.10, Percentage yield: 4.6 and 3.2, Iodine value: 112.60 and 111.69 by water and n-hexane as a solvent, respectively. Harmonization: the oil extract from solvent extraction lost its flavor faster than the oil extract from hydro distillation. The HD method generated a more edible essential oil than solvent. The extracted oil by hexane solvent is not edible. HD is a valuable technique considering the economy, time, and quality.

Orange peels were the raw material used by Saidat Olanipekun Giwa et al. (102) for steam distillation, water distillation, and Solvent Extraction. Put 150 g of the sample into the distillation flask with the required quantity of water. In Solvent Extraction, 10 g of the raw material for each run with particle size 0.6 mm in the Soxhlet apparatus, with normal hexane as a solvent. The maximum yield of E.O. gained from orange peels used were 4.4 %, 3.47 %, and 2.536 % when the methods employed were S.D., W.D., and solvent extraction, respectively. So, SD can give the highest yield of E.O.

I. A. Dewi et al. (42) used Baby Java orange (citrus Sinensis) solid waste of water and Steam Distillation. The study used a randomized block design with 1 factor, namely the distillation time delay process by air drying consisted of 4 levels; distillation delay for 2, 4, 6, and 8 days. In the distillery kettle, 2.5 kg of air-dried baby java orange waste was added with 2.5 l water at 100-115 ^{0}C for 4 hr. They gained the best essential oil from baby java orange waste from the distillation delay of air drying for eight days. This pretreatment generated a yield of 0.63 % with a moisture content of 24.206 %.

Basil leaves (o. Ocimum basilicum L.) used by Mohammed Chennai El al. (75) in Hydro distillation & SFME. In H.D., 150 g of o. basilicum immersed in water for 1 hr in Clevenger type apparatus. In SFME, 150 g of o. basilicum immersed in 600 g of water for 30 min at 600 W, 100 ^{0}C temperature, and atmospheric pressure. SFME was highly effective enabling a considerable reduction in extraction time and yields are similar to those of H.D. By GC - MS not found difference between constituents of E.O. for SFME & H.D. Essential oil pointed strong antimicrobial & low antioxidant activities by SFME & H.D. E.O. with SFME showed better antimicrobial activity than H.D.

Salvia Officinalis L. and Salvia glutinosa L. sage used by Dragan T. Velikovic et al. (25) In Ultrasonic, the ratio of plant material and extracting solvent was 1:10 w/v. a series of flasks immersed into an ultrasonic cleaning bath, operating at 40 kHz frequency and sonicated at 40+-1 ^{0}C for 20 min. Classical maceration, performed for 6 hr at room temperature. Vacuum filtration separated from the plant material using the extract. Evaporated the solvent under a vacuum and then dried the extract with a vacuum. Found a higher yield of flavonoids with polar solvents (70 % aqueous solution of ethanol and water) than the non-polar one (petroleum ether), independent of the plant species and the type of plant material. The extracts from the residual plant material using ultrasonic extraction contained more flavonoids than those derived by maceration.

Mahfud M. et al. (66) used Bangle (zingiber purpureum Roxb.) for Hydrodistillation and steam distillation. In RBF, 200 g, 300 g, or 400 g of plant material was added with the size of 0.5 to 2 cm and 1 l aqua dest. The plant material-to-solvent ratio was 0.2 g/ml, 0.3 g/ml, or 0.4 g/ml. They heated the mixture for 8 hr at 100 ^{0}C. By both methods, the optimum plant material to solvent ratio was 0.3 g/ml, 0.5 cm of raw material size provides a higher yield, and compared to steam distillation, hydrodistillation was more effective.

In hydrodistillation, Mentha piperita L. was used by Gavahian M. et al. (35). In the Clevenger-type apparatus; placed 15 g of dried peppermint aerial parts were with 0.5 l distilled water. The extraction time was 2 hr. In the steam distillation Clevenger device, 15 g of the dried sample with 0.5 l distilled, heated water for up to 2 hr. Extraction time was the same for both methods. The essential oil gained by H.D. and S.D. are similar in physical properties and chemical compositions.

Kesan Suhu Ke Atas et al. (54) used Kaffir lime for Hydro-diffusion steam distillation. 0.35 kg grounded kaffir lime peels for each steam temperature setting are 80 ^{0}C, 90 ^{0}C, 95 ^{0}C, and 100 ^{0}C. An electrical heater heated the distillation column with 10 l water. In the hydro-diffusion steam distillation plant, they placed the kaffir lime peels in the material tray inside. They performed extraction for approximately 2 hr. The % yield increased as steam temperature increased. Found a total of 26 compounds in kaffir lime oil.

Apium graveolens L. used by M. Moradalizadeh et al. (63) in Hydro distillation, 200 g of fresh aerial parts of the plant homogenized and hydro distilled for 3 hr. In the MAHD method, 200 gm of the plant was operated in the microwave oven at 600 W for 25 min. The extraction time for Hydro distillation and MAHD was 3 hr and 25 min, respectively. So MAHD was more effective according to saving time and energy.

Luis F. Salomeofficinali s Abarca et al. (60) used Calendula. For Hydro distillation, in RBF, 7 g of floral material was placed with 25 ml of distilled water for 3 hr. For organic solvent extraction, put the 4 g of dry plant material to 20 ml of each solvent (hexane or dichloromethane), then macerated for 5 min. For enfleurage, 100 g of Karite fat is heated to 40 ^{0}C until a liquid state without reaching boiling, and then 3 g dry floral material is added for extraction at 40 ^{0}C for 20 min. Filter the cold fat extraction with 50 ml of ethanol (95%) at 60 ^{0}C for extracting the essential oil. The yield of essential oils gained by hydrodistillation, organic solvent, and enfleurage were 0.9, 6.7, and 7.1 g per 100 g of dry floral material, respectively. Hydro distillation provides the highest quality oil and the highest number of nonpolar compounds.

Scutellaria Multicaul is Boiss used by Hamideh Asadollahzadeh et al. (38). For Hydro distillation, mix 100 g of plants in 700 ml of distilled water for 3 hr. In the MAHD method, 100 g of plants with 150 ml of water with microwave power 650 W and 15 min irradiation time required. For the headspace solid-phase micro-extraction, in fiber assembly placed 0.2 g of the plant, into a 5 ml amber glass vial with 1 ml water. Tightly capped with PTFE-coated septa. SPME performed at 50 ^{0}C for 10 mins. HS-SPME was simple and more rapid compared to hydro distillation. Because of time-consuming and need a large amount of sample.

Lemongrass (Cymbopogon citrates) was used by Ranitha M. et al. (98). For the MAHD method, the cavity of the microwave oven was placed with 50 g of the sample with its distilled water. Need water to a raw material ratio of 6:1, 8:1, and 10:1, 200 and 250 W microwave power at 30, 60, 90, and 120 min. Extraction time was 2 hr. For Hydro distillation, in the Clevenger apparatus placed 50 g of sample leaves with 400 ml of distilled water for 30, 60, 90, 120, and 150 min. The system operated at a fixed power of 500 W with atmospheric pressure. The design model predicted the optimum yield of 1.4612 % at the water to plant material ratio of 8:1, 250 W microwave power level, and 90 min of extraction time.

H.S. Kusuma et al. (37) used sandalwood (Santalum album). For microwave air-hydro distillation, filled 20 g of powder sample and 400 ml of deionized water in the 1 l flask. 600 W and 2 hr period required to operate microwave oven. Air flow rates are 0.1, 0.5, 1.5, 3.0, and 5.0 l/min. For MAHD, in a microwave oven, a 1 l flask filled with 20 g of powder sample and 400 ml of deionized water was placed and operated at 600 W for 2 hr. Compared to the MAHD, the extraction by microwave air-hydro distillation is faster and produces a higher yield. The yield and recovery increased with the airflow.

By David R. McGaw et al. (23), Bay (pimenta racemosa) leaves were used. In Supercritical fluid extraction, CO_2 as the extraction fluid, 100 ml extraction vessel, 100 to 300 bar P, -32 to 70 ^{0}C temp, all experiments run for 4.5 hr. S.D. They carried the experiment out with 100 gm of charge. Samples taken every 15 min for chemical analysis S.F.E. preferred to S.D.E. because the phenol content of the extract was higher and the extraction time was less.

Thymus pallescens used by Naima Sahraoui et al. (79). In microwave steam distillation, the M.S.D. apparatus operated at 2.45 GHz with a maximum delivered power of 1000 W variable in 10 W increments. The cartridge containing 20 g of the sample, steam passes, evaporates, and carries the essential oil and is directed toward the condenser. Used same glasswares and operating conditions are used in S.D. as M.S.D. The produced vapor crosses the plant, is charged with the essential oil, and then passes through the condenser to a receiving flask. They continued the extraction until no more oil was left. The extraction time was 5 min for the M.S.D. extraction against 20 min for S.D. They gained the best performance with a power of 400 W and a steam flow rate of 10 g/min.

Obacco seed used by S. Majdi et al. (101) for the experiments. In Soxhlet extraction, add 3 g of the milled and dried sample in an extraction thimble for 8 hr using 100 ml petroleum benzene. At 40 ^{0}C, a rotary evaporator evaporated solvent. For Sonication extraction, an Elma Trassonic model was used to extract the 40-mesh seed. 3 g of sample mixed with 70 ml petroleum benzene. They evaporated the solvent, as mentioned above. In DGF standard (deutsche Gesellschaft f r fettwwissnschaft) method B-I (87) 3 g of milled mixed with 70 ml petroleum benzene. In the twisselmann apparatus carried out extraction in 4 hr. Evaporated the solvent as described above. Carried out Supercritical fluid extraction in a suprex M.P.S./225 system. The supercritical CO_2 flow rate through the aura flow restriction was approximately 0.3-0.4 ml/min. 2 g of the milled seeds mixed with glass beads to reduce the dead space in the extractor vessel and allow the uniform distribution of the solvent flow (99.9 % of pure CO_2) The yield of extracted seed oil using S.F.E. was 9.33 %, by sonication 7.75 % by DGF 8.48 % and by soxhlet 13.72 %.

Basil oil (Ocimum basilicum L.) was used by Nidia Alves de Barros et al. (84). In Soxhlet extraction, 5 g of basil with 200 ml of hexane and extraction time was 4 hr. For Hydro distillation extraction in the Clevenger apparatus, they filled the flask with 30 g of crushed leaves and 300 ml of water, with a 4 hr extraction time. Diluted the extracted oil in hexane and filtered after separation. Supercritical carbon dioxide extraction for 4.5 g of material, the CO_2 pumped into the extractor remained in contact with the herbaceous matrix for about 20mins before starting the extraction. By hydro distillation, the yield was 0.26 %, by soxhlet 2.39 %, and by SC-CO_2 0.43 %.

Calamintha nepeta (L.) savi used by Serena Riela et al. (106). For SFME, 60 g of material was inserted in the glass cylinder in the waveguide using a fixed incident power of 250 W for 40 mins until they gained no more essential oil. For Hydro distillation, they added 60 g of material to the Clevenger-type apparatus for 4 hr using n-pentane as a solvent. Total of 38 compounds constituting 97.6 % of the oil identified in the oil gained by SFME, 46 compounds representing 95.45 of the oil characterized in the H.D.

SiSwati Soe'eib et al. (107) used Jasmin and rose for maceration. They began the process by preparing the adsorbent, which was made by mixing vegetable fat and animal fat in a ratio of 1:1. Heated fat at 60 ^{0}C further stirring for 15 minutes. Smeared a chassis with a layer of fat and placed 1 kg flower on the surface of the fat for 1, 3, 5, 7, 9, and 11 days. Gained the maximum yield for five days, 0.89 % for jasmine, 0.88 % for rose, and 0.84 % for frangipani.

For the Supercritical carbon dioxide method, Geed S.R. et al. (32) used Coriander seed as a raw material. After grinding to 300 µm particle size, dried they subjected samples to extraction. Three different P, T, and supercritical CO_2 flow rates were 30, 35, and 40 MPa, 308, 313, 318 K, and 10, 15, and 20 g/min, respectively. The maximum E.O. gained at the operating conditions of 40 MPa, 313 K, and 15 g/min. 3.20g/100g was the highest yield.

For H.D. and S.D., Ocimum sanctum L was used by Nasim Milani Kalkhor ani et al. (80). For H.D., in Clevenger apparatus subjected 50 g flowers and 300 g leaves of the sample for 2 hr. In S.D., add 90 g of flowers and 400 g leaves for 45 min. By H.D., get oil yield for flowers 0.94 % and 056 % for leaves. By SD, oil yield for flowers was 0.41 % and 0.53 % for leaves.

N.R.M. Nasardin et al. (78) used Agarwood. In H.D., 30 kg raw material with an operation duration of five days. In SD, 30 kg of raw material, an operation duration of seven days, and three gas cylinders as heat equipment. H.D. shows more production oil with 150 ml compared to S.D.

F. Abdellatif et al. (29) used Melissa officinalis. For H.D., in the Clevenger-type apparatus, filled 2000 ml RBF with 100 g leaves and 1000 ml distilled water. The time for the H.D. process was 3 hr after boiling. The same operating conditions are used as S.D. to conduct H.D. For S.E., 100 g of the dried plant was

extracted for 6 h at 25 ^{0}C with 500 ml hexane. For MWHD, heat 100 g of leaves and 50 ml of distilled water using a fixed power of 800 W for 20 min. Conducted the extraction at 100 ^{0}C until no more E.O. left. With HD, in a 180 min yield of 0.24 % (w/w), with MWHD in a 20 min yield of 0.30 % (w/w), with S.D. in 120 min yield of 0.42 % (w/w), and with S.E. yield 0.56% (w//w) on a dry weight basis. They identified 64 compounds representing about 97.34 %, 95.29 %, 97.23 %, and 89.51 % of oil gained by H.D., MWHD, SD, and S.E.

Allium sativum was used by Zakia Boubechiche et al. (114). For H.D., with a commercial blender, about 200 g of fresh bulbs crushed with 100 ml of deionized water for 2 min. Diluted the mixture to a final volume of 2 l with deionized water for H.D. in a Clevenger-type apparatus. For US-HD (Ultrasound-assisted HD) Hielscher UP200Ht ultrasonic processor operating at 200 W performed it at 26 kHz. Prepared the garlic bulbs under the same conditions as H.D. and sonicated for 20 mins at 60 % amplitude. For SHD using the Clevenger apparatus, the ultrasonic titanium probe introduced into the second neck of the boiling flask containing the garlic bulbs to release the ultrasonic waves directly into the matrix the final yield of oil (g oil/100g of garlic bulb) from all the three methods was 1.02 %. But the extraction time for SHD was less than 30 min compared to US-HD with 70 min and H.D. with 90 min.

Ghazi Faisal Najmuldeen et al. (33) used Tongkat Ali root for M.A.E. and Soaked a 5 g sample with 10 ml of methanol for 10 min. Kept 50 ml of sample volume with constant 250 W microwave power for M.A.E., also varied the time 10, 20, 30, 40, and 50 min. Soxhlet extraction was performed with 5 g of powdered sample and 10 ml of methanol for 10 min, with the solvent volume constant at 350 ml. C.S.E. used (conventional steam extraction) 5 g of samples where steam passed through the distillation flask containing 450 ml of distilled water and was heated. Extracted the volatile compounds and collected them for different extraction times as 2, 3, 4, 5, and 6 hr. M.A.E. has a better extraction time of 20 min and yields of 5 % with six chemical components. S.E. and C.S.E. gave a high yield of 28.3 % in 3 h and 2.5 % in 6 hr, where extracted only three chemical compounds.

For Conventional Maceration, used Olive oil with common aromatic plants by Ozren Jovic et al. (93). 0.75 g of dry plant sample put in 5 g of olive oil in 15 ml glass bottles. After at most two weeks, they filtered and stored the macerate at 23-25 ^{0}C for further analysis. For Ultrasound maceration, they put the same amount as in maceration in an ultrasonic bath, and they applied ultrasound at an intensity of ultrasounds < 1 W/cm^2 and a frequency of 40 kHz. The temperature was 23-25 ^{0}C. After 1 min and at most one h, the macerate was filtered and stored at 23-25 ^{0}C for further analysis. The application of ultrasound reduces the time of the entire extraction process from 24 hr or several weeks to only a few minutes.

10.Conclusion:

By comparing various methods, we can get information that, with steam distillation, the % yield of essential oil increased with distillation time. The oil yield improved by using loose packing of the plant material. MAHD provides a better alternative to H.D. and the SFME. Compared to H.D. and SFME, found more % essential oil yield in MAHD. MAHD is less time-consuming with increasing microwave power, oil yield, irradiation time, and decreasing particle size. Solar steam distillation is effective because of its clean and free source. Also, the extraction results found by solar steam distillation are nearer to that of the laboratory results. In steam distillation at a lab scale, applying more steam to grass ratio can increase oil yield. In hydro distillation, the yield of essential oil increases with increasing extraction time, temperature, rate, and agitation speed and also by water to leaves ratio and by decreases the particle size. As compared

to solvent extraction, H.D. generated a more edible essential oil. Also, H.D. is a valuable technique according to economy, time, and quality. Compared to water, steam, and solvent extraction, S.D. gives a maximum yield of essential oil, less time-consuming compared to H.D. and SFME. Found SFME to be highly effective, less time-consuming, and oil yield nearer to H.D. Antimicrobial activity is also high, and it is a green technology, solvent saving, lower cost, etc.

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References

1. A Yahya, I Amadi, S A Hashib and F A Mustapha, 2018. Influence sample sizing of citrus hystrix essential oil from hydro distillation extraction. I.O.P. Conf. Series: Materials Science and Engineering 334
2. A. Afzal, J. Alvarado, A. Munir and A. Ghafoor, 2017. Income generation of the rural community by using a solar distillation system. Renewable Energy and Power Quality Journal.
3. A. Munir and O. Hensel, 2010. Investigation of Optimal Thermal Parameters for Essential Oils Extraction using Laboratory and Solar Distillation Systems. Agricultural Engineering International: the CIGR E journal.
4. Abdurahman. H. Nour, Ranitha.M, Azhari.H. Nour, 2013. Extraction and Characterization of Essential Oil from Ginger (Zingiber Officinale Roscoe) and Lemongrass (Cymbopogon citratus) by Microwave-Assisted Hydrodistillation. International Journal of Chemical and Environmental Engineering.
5. Ahmed Yamani Rahman, Abulkhair Qasabi and Hariri Kadi, 2018. Effect of distillation and solvent extraction methods of oil extracts of Australian and Chinese garlic. Advanced Research Journal of Microbiology, 207-212.
6. Alan Joe Dominic, Al Ameen B, Bijoy Babu, Abhishek Mathew, Jomon Jose K and David, 2018. Optimization of factors influencing Solvent Extraction of Frankincense using Taguchi's Method. Asian Journal of Applied Science and Technology. 2, 1079-1084.
7. Alberto Arce, Ana Soto, 2008. Citrus Essential Oils: Extraction and Determination. Tree and Forestry Science and Biotechnology, Global Science Books.
8. Alireza Fazlali, Sara Moradi, Hamid Hamedi, 2015. Studying of optimization condition of rosemary essence extraction with a microwave-assisted hydro distillation method. American Journal of Essential Oils and Natural Products. 3 (1): 46-50.
9. Amaresh, P Guha, Shafat Khan and Sumaiyah R Zari, 2017. Comparative Study of Microwave-Assisted Hydro-Distillation with Conventional Hydro-Distillation for Extraction of Essential Oil from Piper betel L. Biosciences Biotechnology Research Asia. 401-407
10. Ana Cristina Atti-Santos, Marcelo Rossato, Luciana Atti Serafini, Eduardo Cassel and Patrick Moyna, 2005. Extraction of Essential Oils from Lime (Citrus latifolia Tanaka) by Hydro distillation and Supercritical Carbon Dioxide. Brazilian Archives of Biology and Technology. pp. 155-160.
11. Andrew E. Aziza, Stanley Okay, 2018. Extraction and Characterization of Essential Oil Ginger from Ginger Rhizome. American Journal of Engineering Research (AJER). 7, 266-270.

12. Anjum Munir and Oliver Hensel, 2007. Development of a solar distillation system for essential oils extraction from herbs. Conference on International Agricultural Research for Development, University of Gottingen.
13. Arita D. Nugrahini, Aisyah L. Ristanti, and Jumeri, 2017. Journal of Advanced Agricultural Technologies. Characterization of Essential Oils from Tuberose Flowers Waste (Polianthes tuberosa L.). 4.
14. Árpád Kapas, Csaba D. Andras, Tănase Gh. Dobre, Erika Vass, Gabriella Szekely, Marta Stroescu, Szabolcs Lanyi, Beáta Ábraham, 2011. The kinetic of essential oil separation from fennel by microwave-assisted hydro distillation (MWHD). U.P.B. Sci. Bull., Series B, 73.
15. Arslan Afzal, Anjum Munir, Abdul Ghafoor, Jorge L. Alvarado, 2017. Development of hybrid solar distillation system for essential oil extraction", Renewable Energy.
16. Astrilia Damayanti and Eko Setyawan, 2012. Essential Oil Extraction of Fennel Seed (Foeniculum vulgare) Using Steam Distillation. Int. J. Sci. Eng. 3 (2):12-14.
17. Ayano Nakamura, Yuki Hara and Tomonori Kawano, 2017. Dewatering and Extraction of Hydrophilic Solutes and Essential Oils from Cryopreserved Lemon Peels Using Liquefied Dimethyl Ether. Solvent Extraction Research and Development, Japan. 24, 37- 45.
18. Bakkali, F., S. Averbeck, D. Averbeck, M. Idaomar, 2008. Biological effects of essential oils–a review. Food Chem. Toxicol., 46: 446-475.
19. Basma A. Abdul-Majeed, Asrar A. Hassan and Badoor M. Kurji, 2013. Extraction of Oil from Eucalyptus Camadulensis Using Water Distillation Method", Iraqi Journal of Chemical and Petroleum Engineering. 14, 7- 12.
20. Chanthaphon A., Chanthachum, S. and Hongpattarakere T., 2008. Antimicrobial Activities of Essential Oils and Crude Extracts from Tropical Citrus spp. against Food-Related Microorganisms, Songklanakarin J. Sci. Technol. 30 (1): 125-131.
21. Christy E. Manyi–Loh, Anna M. Clarke, and Roland N. Ndip, 2011. Identification of volatile compounds in solvent extracts of honey produced in South Africa. African Journal of Agricultural Research. 6 (18), 4327-4334.
22. D.C. Sikdar, Rohan Menon, Karan Duseja, Piyush Kumar, Priksha Swami, 2016. Extraction of Citrus oil from orange (citrus Sinensis) peels by steam distillation and its characterizations. International Journal of Technical Research and Applications. 4, 341-346.
23. David R. McGaw, Wayne Clarke, and Sharad Maharaj, 2016. Comparison of Supercritical Fluid Extraction with Steam Distillation for the Extraction of Bay Oil from Bay (Pimenta Racemosa) Leaves. International Journal of Engineering Science Invention, 5, 51-55.
24. Dr. Udaya Bhaskar Reddy Ragula, Dr. Sriram Devanathan, 2016. Solar Based Lemon Grass Essential Oil Distillation for Sustainability and Livelihood in Tribal Community. Global Humanitarian Technology Conference.
25. Dragan T. Velikovic, Millena T. Nikolova, Stephanie V. Ivancheva, Jelena B. Stojanovic and Vlada B. Veljkovic, 2007. Extraction of flavonoids from garden (Salvia officinalis L.) and J. Serb. Chem. Soc. 72, 73–80. UDC, JSCS–3536 Original scientific paper glutinous (Salvia glutinosa L.) sage by ultrasonic and classical maceration.
26. E.T. Akhihiero, B.V. Ayodele and G. E. Akpojotor, 2013. Effect of particle size and temperature variation on the yield of essential oil from lemongrass using steam distillation. African Journal of Physics. 6, 105-112.

27. Eduardo Cassel, Rubem M. F. Vargas, 2006. Experiments and Modeling of the Cymbopogon winterianus, Essential Oil Extraction by Steam Distillation. J. Mex. Chem. 50 (3), 126-129.
28. El-Sayed S. Abdel-Hameed, Mahmood S. Salman, Mohamed A. Fadl, Ahmed Elkhateeb, and Mohamed A. El-Away, 2018. Chemical Composition of Hydro distillation and Solvent-Free Microwave Extraction of Essential Oils from Mentha piperita L. Growing in Taif, Kingdom of Saudi Arabia, and their Anticancer and Antimicrobial Activity", Oriental Journal of chemistry, An International Open Free Access, Peer-Reviewed Research Journal. 34, No. (1): 222-233.
29. F. Abdellatif and A. Hassani, 2015. Chemical composition of the essential oils from leaves of Melissa officinal is extracted by hydro distillation, steam distillation, organic solvent, and microwave hydro distillation. J. Mater. Environ. Sci. 6 (1), 207-213.
30. Fernando Duarte Cabral, Cassia Cristina Fernandez Alves, Rodrigo Sebastiao Cruvinel Cabral, Guilherme Brinker Willrich, António Eduardo Miller Crotti and Mayker Lazaro Dantas Miranda, 2019. Chemical Constituents of Essential Oils Extracted from the Leaves and Flowers of Spiranthera odoratissima A. St. Hil. (Rutaceae). Rec. Nat. Prod. 172-175.
31. G J Manuhara, G P Mentari, L U Khasanah, R Utami, 2018. Aqueous Extract Composition of Spent Ginger (Zingiber officinale var. amarum) from Essential Oil Distillation. I.O.P. Conf. Series: Materials Science and Engineering. 333.
32. Geed S.R. Said P.P., Pradhan. R.C. and Rai B.N., 2014. Extraction of essential oil from the cori ander seed. International Journal of food and nutritional sciences. 3.
33. Ghazi Faisal Najmuldeen, Hariitaraan A/L Fatmanathan, Deeveeya A/P Kirubananthan, Ghasak Ghazi Faisal, 2018. Comparison of Tongkat Ali Root Chemical Composition Extracted by Soxhlet, Conventional Steam, and Microwave-Assisted Extraction Techniques. A Multifaceted Journal in the field of Natural Products and Pharmacognosy, Pharmacogn J. 10 (5):916-920.
34. Guido Flamini, Bernardo Melai, Luisa Pistelli, Cinzia Chiappe, 2013. How to make a green product greener: use of ionic liquids as additives during essential oil hydrodistillation. R.S.C. Advances (Royal Society of Chemistry).
35. Gvahian M., Farhoosh R., Farahnaky A., Javidnia K. and Shahidi F., 2015. Comparison of extraction parameters and extracted essential oils from Mentha piperita L. using hydro distillation and steam distillation. International Food Research Journal 22 (1): 283- 288.
36. H S Kusuma, A Altway, M Mahfud, 2017. Alternative to conventional extraction of vetiver oil: Microwave hydro distillation of essential oil from vetiver roots (Vetiveriazizanioides). I.O.P. Conf. Series: Earth and Environmental Science. 101.
37. H.S. Kusuma, M. Mahfud, 2016. The Extraction of Essential Oil from Sandalwood (Santalum album) by Microwave Air-Hydro distillation Method, J. Mater. Environ. Sci.7 (5), 1597-1606.
38. Hamideh Asadollahzadeh, Moslem Rajaje, 2014. Comparison of the chemical composition of essential oils from aerial parts of Scutellaria multicaulisbioss using hydro distillation, Microwave-assisted hydrodistillation, and headspace solid-phase micro-extraction. Trends in life science. 3, 2319-5037.
39. Heri Septya Kusuma, and Mahfud Mahfud, 2017. Chemical composition of essential oil of Indonesia sandalwood extracted by microwave-assisted hydro distillation, A.I.P. Conference Proceedings 1820.

40. Heri Septya Kusuma, Mahfud Mahfud, 2016. Preliminary study: Kinetics of oil extraction from basil (Ocimum basilicum) by microwave-assisted hydro distillation and solvent-free microwave extraction. South African Journal of Chemical Engineering. 21, 49-53.
41. Hesham H.A. Rassem, Abdurahman H. Nour, Rosie M. Yunus, 2016. Techniques for Extraction of Essential Oils from Plants: A Review. Australian Journal of Basic and Applied Sciences. 117- 127.
42. I A Dewi, A M Prastyo and S Wijana, 2018. Extraction of essential oil from baby Java orange (Citrus sinensis) solid waste using water and steam distillation. I.O.P. Conf. Series: Earth and Environmental Science. 131.
43. Ibtehal K. Shakir, 2017. Mass Transfer Coefficients of the Extraction Process of Essential Oil from Myrtus Communis L. Plants Using Different Solvents. The Eighth Jordan International Chemical Engineering Conference. 7-9.
44. Ida Hasmita, Adisalamun, Pocut Nurul Alam, Satriana, Mahlinda, M. Dani Supardan, 2015. Effect of Drying and Hydrodistillation Time on the Amount of Ginger Essential Oil. International Journal on Advanced Science Engineering Information Technology. 5.
45. Imad Eddine Elkacimi, Yahia Cherrah and Katim Alaoui, 2018. The technological influence of the different methods of extraction on the initial concentration of thymol in the essential oil of thyme (Thymus satureioides). African Journal of Biotechnology. 17, 1180- 1187.
46. Ivanka B. Semerdjieva, Santosh Shiwakoti, Charles L. Cantrell, Valtcho D. Zheljazkov, Tess Astatkie, Vicki Schlegel, and Tzenka Radoukova, 2019. Hydrodistillation Extraction Kinetics Regression Models for Essential Oil Yield and Composition in Juniperus virginiana, J. excels and J. Sabina. Molecules. 24, 986.
47. Jila Asghari, Cheshmnaz Khamoie Touli, and Mohsen Mazaheritehrani, 2012. Microwave-assisted Hydrodistillation of Essential Oils from Echinophora platyloba D.C. Journal of Medicinal Plants Research. 6(28), 4475-4480.
48. John Kabuba, 2017. Comparison between Neural Network Technique and Mathematical Modelling of Steam Extraction of Essential Oil. 9th Int'l Conference on Advances in Science, Engineering, Technology & Waste Management. Parys, South Africa, 27-28.
49. Jutarut Pornpunyapat, Pakamas Chetpattananondh, Chakrit Tongurai, 2011. Mathematical Modeling for extraction of essential oil from Aquilaria Crassna by hydrodistillation and quality of agarwood oil. Bangladesh J of Pharmacol. 6: 18-24.
50. K. Husnu, Can Baser, Gerhard Buchbauer. Handbook of Essential Oil Science, Technology and Application.
51. K. Mu'azu, E.M. Okonkwo and M. Abdullahi, 2009. Economic Analysis of Production of Essential Oil using Steam Distillation Technology. Nigerian Journal of Basic and Applied Science. 17 (2):218-222.
52. Kalyani Agarwal, S.K. Gupta, 2018. An Improved Microwave Extraction Method for Distillation of Essential Oil from Piper betle L. International Journal for Research in Applied Science & Engineering Technology. 6.
53. Karanvir Gill, Rahul Gupta, Suresh Bhise, Manoj Bansal, Gurnaz Gill, 2014. Effect of Hydro Distillation Process on Extraction Time and Oil Recovery at Various Moisture Contents from Mentha Leaves. Research Inventory: International Journal of Engineering and Science. 4, 08-12.

54. Kesan Suhu Ke Atas Minyak Limau Purut Dengan Menggunakan Sistem Penyulingan Penyebaran Hidro, 2013. Effect of temperature on Kaffir lime oil by using hydrodistillation steam distillation system" The Malaysian Journal of Analytical Sciences, 17: 326- 339.
55. Khalid M Abed and Tariq M Naife, 2018. Extraction of Essential Oil from Iraqi Eucalyptus Camadulensis Leaves by Water Distillation Methods. I.O.P. Conf. Series: Materials Science and Engineering, 454.
56. Khalid M. Abed, Badoor M. Kurji, Basma A. Abdul-Majeed, 2015. Extraction and Modelling of oil from eucalyptus camadulensis by Organic Solvent. Journal of Materials Science and Chemical Engineering. 3, 35-42.
57. Krunal A Shah, Darshak R Bhatt, Meghal A Desai, Girirajsinh C Jadeja & Jigisha K Parikh, 2017. Extraction of essential oil from Patchouli leaves using hydrodistillation: Parametric studies and optimization. Indian Journal of Chemical Technology, 24, 405-410.
58. Linsheng Wei, Yafang Zhang, and Boquan Jiang, Comparison of Microwave-assisted Hydrodistillation with the Traditional Hydrodistillation Method in the Extraction of Essential Oils from Dwarfed Cinnamomum Camphora var. Linaolifera Fujita Leaves and Twigs, 2013. Advance Journal of Food Science and Technology 5 (11): 1436-1442.
59. Ljiljana Stanojević, Mihajlo Stanković, Milorad Cakić, Vesna Nikolić, Ljubiša Nikolić, Dušica Ilić, Niko Radulović, 2011. The effect of hydro distillation techniques on yield, kinetics, composition and antimicrobial activity of essential oils from flowers of Lavandula officinalis L. Lj. Hem. ind. 65 (4) 455–463.
60. Luis F. Salome-Abarca, Ramon M. Soto-Hernandez, Nicacio Cruz-Huerta and Victor A. Gonzalez-Hernandez, 2015. Chemical composition of scented extracts obtained from Calendula officinalis by three extraction methods. Botanical Sciences. 93 (3):633-638.
61. M. Mahfud, D.K.Y. Putri, I.E.P. Dewi and H.S. Kusuma, 2017. Extraction of Essential Oil from Cananga (Cananga odorata) using Solvent-free Microwave Extraction: A Preliminary Study. Rasayan J. Chem. 10, 86-91.
62. M. Malekydozzadeh, P. Khadiv-Parsi, Sh. Rezazadeh, H. Abolghasemi, Z. Salehi, Q. Li, 2012. Application of Multistage Steam Distillation Column for Extraction of Essential Oil of Rosmarinus Officinalis L. Iranian Journal of Chemical Engineering, 9.
63. M. Moradalizadeh, M.R. Akhgar and A. Faghihi - Zarandi, 2013. Microwave-Assisted and Conventional Hydrodistillation of Essential Oils from Apium graveolens L., Asian Journal of Chemistry. 25, 79-81.
64. M. S. T. Barroso, G. Villanueva, A. M. Lucas, G. P. Perez, R. M. F. Vargas, G. W. Brun and E. Cassel, 2011. Supercritical Fluid Extraction of Volatile and Nonvolatile compounds from Schinus molle L., Brazilian Journal of Chemical Engineering. 28, 305–312.
65. M.S. Galadima, A.S. Ahmed, A.S. Olawale and I. M. Bugaje, 2012. Optimization of Steam Distillation of Essential Oil of Eucalyptus tereticornis by Response Surface Methodology. Nigerian Journal of Basic and Applied Science. 20(4): 368-372.
66. M. Mahfud, M. Dwiki Darmawan, Derrick Hertha Diamanta, Heri Septya Kusuma, 2017. Extraction of Essential Oil from Bangle (Zingiber purpureum Roxb.) by hydro distillation and steam distillation methods. Journal of Chemical Technology and Metallurgy, 52, 5.
67. Majda Elyemni, Bouchra Louaste, Imane Nechad, Taha Elkamli, Abdelhak Bouia, Mustapha Taleb, Mahdi Chaouch, and Noureddine Eloutassi, 2019. Extraction of Essential Oils of Rosmarinus

officinalis L. by Two Different Methods: Hydrodistillation and Microwave-Assisted Hydrodistillation. Hindawi the Scientific World Journal. 2.

68. Martin Muthee Gakuubi, 2016. Steam distillation extraction and chemical composition of essential oils of Toddalia Asiatica L. and Eucalyptus camaldulensis Dehn. Journal of Pharmacognosy and Phytochemistry. 5(2): 99-104.
69. Maryam Khosravinezhad, Ebrahim Talebi, Shivakumar, Zahra Nemati and Iman Nasrollahi, 2017. Essential oil composition and antimicrobial, antioxidant activities of Oliveria decumbens Vent, International Journal of Herbal Medicine. 5 (2): 102-106.
70. Mehran Moradalizadeh, Naghmeh Samadi, Peyman Rajaei, 2013. Comparison of Hydrodistillation. Microwave Hydrodistillation and Solvent-Free Microwave Methods in the analysis of the essential oils from aerial parts of Haplophyllum robustum Bge. By GC/MS method. International Journal of Advanced Biological and Biomedical Research. 1, 1058-1067
71. Mijat Božović, Alberto Navarra, Stefania Garzoli, Federico Pepi & Rino Ragno, 2017 Essential oils extraction: a 24-hour steam distillation systematic methodology, Natural Product Research
72. Mohamed Koubaa, Ameni Ktata, Fatma Bouaziz, Dorra Driss, Raoudha Ellouz Ghorbel and Semia Ellouz Chaabouni, 2015. Solvent extract from Opuntia stricta fruit peels: Chemical composition and Biological activities, Free Radicals and Antioxidants. 5(2).
73. Mohammad Hadi Meshkatalsadat, Shahrbanoozarei, 2011. Determination of volatile components of Bunium Luristanicumrech. F using MAHD and H.D. extraction techniques and antioxidative activity of methanolic extract – a green chemistry approach, Digest Journal of Nanomaterials and Biostructures. 6, 515-521
74. Mohammad-Taghi Golmakani & Mahsa Moayyedi, 2015. Comparison of heat and mass transfer of different microwave-assisted extraction methods of essential Oil from Citrus Limon (Lisbon variety) peel. Food Science & Nutrition. 3(6): 506–518
75. Mohammed Chenni, Douniazad El Abed, Njara Rakotomanomana, Xavier Fernandez and Farid Chemat, 2016. Comparative Study of Essential Oils Extracted from Egyptian Basil Leaves (Ocimum basilicum L.) Using Hydro-Distillation and Solvent-Free Microwave Extraction. Molecules. 21, 113
76. Muhammad Hazwan H., Hasfalina C. M., Hishamuddin J., and Zurina Z. A., 2012. Optimization and Kinetics of Essential Oil Extraction from Citronella Grass by Ohmic Heated Hydro Distillation" International Journal of Chemical Engineering and Applications. 3, No. 3.
77. N. A. Amenaghawon, K. E. Okhueleigbe, S. E. Ogbeide, and C. O. Okieimen, 2014. Modeling the Kinetics of Steam Distillation of Essential Oils from Lemon Grass (Cymbopogon spp.), International Journal of Applied Science and Engineering. 12(2), 107-115.
78. N.R.M., Nasardin, M.A.M., Hanafiah, M., Zainon, M., Ibrahim, A.A., Zulkefle, A.I.A., Rahman, 2018. Comparative Study on Steam Distillation and Hydro-Distillation Methods for Agarwood Oil Extraction. International Journal of Applied Engineering Research. 13, (8), 6253-6256
79. Naima Sahraoui and Chahrazed Boutekedjiret, 2015. Innovative Process of Essential Oil Extraction: Steam Distillation Assisted by Microwave. Springer International Publishing Switzerland 2015 I. Dincer et al. (eds.), Progress in Clean Energy, Volume 1.
80. Nasim Milani Kalkhorani, Mohsen Dadgar, Mohammad Bagher Rezaei and Fatemeh HeroAbadi1, 2016. Comparison of Essential Oil of Ocimum sanctum L. from Fresh and Dry Aerial Parts by Hydro-distillation and Steam Distillation. Journal of Medicinal Plants and By-products. 1: 45-50

81. Neeraj Singh, Prashant Shrivastava, and Mumtaj Shah, 2014. Microwave-assisted extraction of lemongrass essential Oil: Study of the influence of extraction method and process parameters on extraction process, Journal of Chemical and Pharmaceutical Research. 6(11), 385-389.
82. Nguyen Dinh Phuc, Le Hoang Phuong Thy, Tri Duc Lam, Vo Hoang Yen, Nguyen Thi Ngoc Lan, 2019. Extraction of Jasmine Essential oil by Hydrodistillation method and application on Formulation of Natural Facial Cleansers, I.O.P. Conf. Series: Material Science and Engineering 542(2019) 012057.
83. Ni Ketut Sari, Ketut Sumada, Hendrix Abdul Ajiz, Winda Yulniar Fajarriani, February 2018. Atsiri Oil Production of Tobacco Leaves by Water Distillation Method, International Journal of Scientific & Technology Research 7, 2.
84. Nídia Alves de Barros, Robson Raposa Rocha, André von Randow de Assis & Marisa Fernandes Mendes, 2013. Extractio of Basil oil (Ocimum basilicum L.) using Supercritical fluid, III Iberoamerican Conference on Supercritical Fluids Cartagena de Indias (Colombia).
85. Nik 'Amirah Farhana Nik Ahmad Lutfi, Mohd Farid Atan, Nazeri Abdul Rahman, Shanti Faridah Salleh and Noraziah Abdul Wahab, 2016. Study on the mathematical model in simulating Cymbopogon winterianus essential oil extraction by steam distillation, Journal of Applied Science & Process Engineering, 3, 1.
86. Nimet KARA, Sabri ERBAŞ, Hasan BAYDAR, 2017. The Effect of Seawater Used for Hydrodistillation on Essential Oil Yield and Composition of Oil-Bearing Rose (Rosa damascena Mill.), International Journal of Secondary Metabolite, Int. J. Sec. Metabolite, V 4:3, 423-428
87. Niraj S. Topare, Sunita J. Raut, V. C. Renge, Satish V. Khedkar, Y. P. Chavan and S. L. Bhagat, 2011. Extraction of Oil from Algae by Solvent Extraction and oil Expeller method, Int. J. Chem. Sci.: 9(4), 1746-1750.
88. Nitthiyah Jeyaratnam, Abdurahman Hamid Nour and John Olabode Akindoyo, February 2016. Comparative study between hydrodistillation and microwave-assisted hydrodistillation for extraction of Cinnamomum cassia oil, Asian Research Publishing Network (ARPN), 11, 4.
89. Nur Ain. A. H., Zaibunnisa, A. H., Halimahton Zahrah, M. S. and Norashikin, S., 2013. An experimental design approach for the extraction of lemongrass (Cymbopogon citratus) oleoresin using pressurized liquid extraction (P.L.E.), International Food Research Journal, 20(1), 451-455.
90. Nurkholis Hamidi, January 2016. Extraction of essential oils from Patchouli plant using advanced techniques of microwave-assisted hydrodistillation, Asian Research Publishing Network (ARPN), 11, 2.
91. Okoh O. O., Sadimenko A. P. and Afolayan A. J., May, 2011. Antioxidant activities of Rosmarinus officinalis L. essential oil obtained by hydrodistillation and solvent-free microwave extraction, African Journal of Biotechnology. 10(20), 4207-4211, 16.
92. Okonkwo P.C. and Mukhtar B. August 2013. Approach to Evaluation of Solvent Extraction of Oil from Neem Seed, International Journal of Applied Science and Technology, 3, 6.
93. Ozren Jović, Iva Habinovec, Nives Galić, and Marijan Andrašec, 2018. Maceration of Extra Virgin Olive Oil with Common Aromatic Plants Using Ultrasound-Assisted Extraction: An UV-Vis Spectroscopic Investigation, Hindawi Journal of Spectroscopy.
94. Oztekin, S., M. Martinov, 2007. Medicinal and aromatic crops, harvesting, drying and processing, Haworth Food & Agricultural Products Press, An Imprint of the Haworth Press, Inc.,

95. Paini Sri Widyawati, Tarsisius Dwi Wibawa Budianta, Fenny Anggraeni Kusuma, Evelyn Livia Wijaya, 2014-15. Difference of Solvent Polarity to Phytochemical Content and Antioxidant Activity of Pluchea indicia Less Leaves Extracts, International Journal of Pharmacognosy and Phytochemical Research, 6(4); 850-855
96. Paul Njenga Waithaka, Eliud Mugu Gathuru, Benson Muriuki Githaiga, and Jane Mbithe Kwoko, December 2016. Making of Perfumes from Essential Oils Extracted from Lavender Plant Collected from Egerton University, Main Campus Njoro, Kenya, Pyrex Journal of Biomedical Research, 2 (6), 35-40
97. Phan Nhut Nam, Phan Thi Kim Lien, Tran Thanh Hoa, Chatain Mai Huong, Dao Thien, 2017. Microwave-assisted Soxhlet extraction of essential Oil from Vietnamese Star anise fruits (Illicium verum Hook.f.) and their chemical composition, Emirates Journal of Food and Agriculture. 29(2): 131-137
98. Ranitha M., Abdurahman H. Nour, Ziad A. Sulaiman, Azhari H. Nour, and Thana Raj S., 2014. A Comparative Study of Lemongrass (Cymbopogon Citratus) Essential Oil Extracted by Microwave-Assisted Hydrodistillation (MAHD) and Conventional Hydro distillation (H.D.) Method, International Journal of Chemical Engineering and Applications, 5(2).
99. S. C. Ibeh, O. D. Akinlabi, I. Asmau, J. Audu, A. M. Muritala, May, 2017. Extraction of Ocimum gratissimum Using Different Distillation Techniques, International Journal of Scientific & Technology Research. 6, 05
100. S. J. Kulkarni, November 2016. Oil Extraction and Perfume Formulation from Plants: A Review, International Journal of Research and Review. 3, 11.
101. S. Majdi, M. Barzegar, A. Jabbari, and M. AghaAlikhani, 2012. Supercritical Fluid Extraction of Tobacco Seed Oil and its Comparison with Solvent Extraction Methods, J. Agr. Sci. Tech., 2012. 14: 1043-1051
102. Saidat Olanipekun Giwa, Mahmood Muhammad and Abdulwahab Giwa, January, 2018. Utilizing Orange peels for essential oil production, ARPN Journal of Engineering and Applied Sciences, 13, 1.
103. Sanaz Sadani and Alireza Shakeri, 2016. Antimicrobial activity of the essential oils of Lavandula stoechas flowers extracted by Microwave, Journal of Medicinal Plants Studies. 4(3): 224-228
104. Sara Lago, Hector Rodriguez, Alberto Arce, Ana Soto, Improved concentration of citrus essential oil by solvent extraction acetate ionic liquids
105. Seid Yimer, Manoharan and Omprakash Sahu, March, 2014. Extraction of Essential oil from Eucalyptus leaves as Antibacterial Application on Cotton Woven Fabric, International Journal of Bacteriology, Virology, and Immunology, 1(1): 001-007
106. Serena Riela, Maurizio Bruno, Carmen Formisano, Daniela Rihano, Sergio Rosselli, Maria Luisa Saladino, Felice Senatore Sep 2008. Effects of solvent-free microwave extraction on the chemical composition of essential Oil of Calamintha nepeta (L.) Savi compared with the conventional production method, J. 31, 1110-1117
107. SiswatiSoe'eib, Nyoman Puspa Asri, A.S. Dwi Saptati N.H., dan Diah Agustina P, 2016. Enfleurage essential oil from Jasmin and rose using cold fat adsorbent, Widya Teknik, 15, 1.
108. Taoufik Haloui, Abdellah Farah, Sara Lebrazi, Mouhcine Fadil, Aziz Belrhiti Alaoui, January 2018. Application of response surface methodology for the optimization of hydrodistillation extraction of Pistacia lentiscus L. essential oil, Journal of Applied Pharmaceutical Science. 8 (01), 050-054

109. Venkat S. Mane, Dilip D Rajguru, Prajakta R. Pawar, Rukhsar G. Shaikh, June 2015. Formulation of Perfume from Lemongrass, Proceedings of 28th I.R.F. International Conference, 56-60
110. Xiao Ni, Mahmoud M Suhail, Qing Yang, Amy Cao, Kar-Ming Fung, Russell G Postier, Cole Woolley, Gary Young, Jingzhe Zhang, and Hsueh-Kung Lin, 2012. Frankincense essential Oil prepared from hydrodistillation of Boswellia sacra gum resins induces human pancreatic cancer cell death in cultures and a xenograft murine model. Ni et al. B.M.C. Complementary and Alternative Medicine. 12:253
111. Y Kulturel and S Tarhan, November 2016. Performance of a Solar Distillery of Essential Oils with Compound Parabolic Solar Collectors, Journal of Scientific & Industrial Research. 75, 691-696.
112. Y.C. Wong, M. Y. Ahmad-Mudzaqqirand W.A. Wan-Nurdiyana, 2014. Extraction of Essential Oil from Cinnamon (Cinnamomum zeylanicum), Oriental Journal of Chemistry, 30, 1. 37-47.
113. Z. Nazlina, M. K. Chan, J. G. Angelynn, C. M. Choo, Kinetic Study of Hydrodistillation of Citrus Sinensis and Quality of the Oil, International Journal of Engineering & Technology IJET-IJENS,17,1.
114. Zakia Boubechiche, Nour-Eddine Chihib, Charafeddine Jama, Amina Hellal, Jul-Sep, 2017. Comparison of Volatile Compounds Profile and Antioxidant Activity of Allium sativum Essential Oils Extracted using Hydrodistillation, Ultrasound-Assisted, and Sono-Hydrodistillation Processes, Indian Journal of Pharmaceutical Education and Research |.51,3.