IOSR Journal of Applied Chemistry (IOSR-JAC)
e-ISSN: 2278-5736.Volume 9, Issue 11 Ver. II (November. 2016), PP 11-18
www.iosrjournals.org

Study of Variation and Identification of Chemical Composition in Rosa Species Oil Collected From Different Countries

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Abstract: *Amongst 200 species of rose flowers[1], Rosa damascena Mill.species is widely used in many industries for different purposes. Rose oil being the most expensive oil, the rose oil extracted from Rosa damascena Mill. Species is studied in this review article. Rose oil has many applications in different fields such as cosmetics, perfumery, aromatherapy, flavors, medicines for e.g. anticancer, astringent, anti-inflammatory etc. As the constituents of rose oil differs with the geological variations, in this study data is compiled from nine different countries such as India, Turkey, Iran, Pakistan, China, Saudi Arabia, Romania, Syria and Bulgaria . The volatile rose oil was extracted using different extraction methods and the oil was analyzed using GC and GC-MS. In this article a comparative study of the rose oil from different locations of world showing variation in composition of rose oil due to the climatic, geographical and environmental changes has been carried out.*
Keywords: *Rosa species, Hydrodistillation, Anticancer oil, Antioxidizing properties, Aromatherapy*

I. Introduction

Rosa genus, belonging to the Rosaceace family, includes 200 species [1]. Four major species of rose (Rosa damascene Mill., Rosa gallica L., Rosa moshata Herrm and Rosa centifolia L.) [6], which are used in the production of essential oil are available throughout the world [2]. One of the most important Rosa species is Rosa damascene Mill, which is known as "Gol-e-Mohammadi" in Persian [1]. This plant is called Damask rose because it was originally brought to Europe from Damascus [1]. It is an erect shrub of 12m in height [1] and primarily cultivated in Turkey, Bulgaria, Iran, India, Morocco, South France, China, South Italy, Libya, South Russia and Ukraine in the world [12,15]. The oil bearing rose (Rosa Damascena Mill.) has a pink flower with 30 petals and heavy rosy scent [8]. The amount and composition of rose oil distilled from the rose petals is strongly affected by the genotype of the cultivated Damask rose, climatic conditions, the time of rose petals harvesting and the technology used for processing and distillation [4]. Because of the low oil content and the lack of natural and synthetic substitutes, rose oil is one of the most expensive essential oil in the global markets [4, 12, 13]. One kg of rose oil can be obtained from about 3,000kg of rose petals [12, 13].

Rose oil is mainly used in the perfumery and cosmetics industry as a base component of the many of the modern perfumes but it also finds the application in the food industry as a flavor additive [1]. Roses have been used since the earliest times in rituals, cosmetics, perfumes, medicines and aromatherapy [6]. The main producers of rose oil are Bulgaria, Turkey, Iran and India [1]. In the Indian system of medicine, various rose preparations are used as an astringent tonic, mild laxative, antibacterial, anticancer, anti aging, antidiabetic, antimicrobial, antispasmodic, antidepressant, antiseptic, sedative, blood cholesterol altering, antioxidizing, analgesic, hypnotic activities, antihepatis, anti-inflammatory, antiviral, anti HIV [1, 3, 4, 7, 10, 13, 26, 27,31, 32, 33, 34] and in the treatment of sore throat, enlarged tonsils, cardiac troubles, eye disease, gall stones, for their cooling effect and as a vehicle for other medicines [3, 13, 26, 29, 34]. The rose essential oil comprises of a number of different types of complex constituents [2]. There are different kinds of traditional and modern devices for the distillation of rose oil [6]. Several reports have appeared on the chemical evaluation of rose oils around the world [6]. Different methods of extraction have been reported to be used for extracting rose oil from rose petals. The methods reported are such as hydrodistillation using Clevenger's apparatus [1, 3, 8, 11, 13, 16, 19, 20, 22, 23, 25, 26, 28, 29, 33], solvent extraction method using Soxhlet apparatus [2, 30], six different extraction methods using water, ethanol, liquefied 1,1,1,2-tetrafluroethane gas, n-hexane solvents of rose concrete and absolute [5], simple hydrodistillation method [6, 17, 27, 31] and extraction using Headspace-Solid Phase Microextraction [5, 12]. As most of the studies reported use of hydrodistillation extraction method using Clevenger's apparatus, hence in this paper also the rose oil extraction by hydro distillation using Clevenger's apparatus is focused.

The amount and composition of rose oil distilled from the rose petals is strongly affected by the genotype of the cultivated Damask rose, climatic conditions, the time of rose petals harvesting, and the technology used for processing and distillation [4]. The aim of this study is to identify the different chemical constituents present in rose oil (*Rosa damascena* Mill.) by GC-MS and study the variation in the constituents of the composition of rose oil collected from different locations of different countries such as India, Pakistan, Turkey, China, Iran, Saudi Arabia, Romania, Syria and Bulgaria.

II. Materials and Methods

1.1 Plant Material: -

The fresh rose flowers were handpicked mainly before sunrise [6, 11, 20] and in between 5:00 – 11:00 am [3, 4, 8, 19, 22, 28]. The rose flowers were collected from different regions of the world as mentioned in the below table mainly in the month of March – June [4, 6, 11, 13, 16, 19, 26, 27, 29, 31]. The below table gives the detail information of location from where the rose petals were harvested, extraction method and country.

Sr. No.	Locations/ regions from where the rose petals were harvested	Extraction method	Country's name
1	Local market in New Delhi	Hydrodistillation method using Clevenger's apparatus	India [1]
2	Postgraduate Agriculture Research Station, Jhang road, Faisalabad	Soxhlet extraction using 95% n-hexane solvent	Pakistan [2]
3	Fruit Research Station, Isparta	Hydrodistillation method using Clevenger's apparatus	Turkey [3]
4	Western suburb of Beijing	Desorption using automatic thermal desorber	China [4]
5	Kashan and Kerman locations	Hydrodistillation	Iran [6]
6	Rose & Rose Products Research and Implementation Centre at Suleyman Demirel University at Isparta	Hydrodistillation method using Clevenger's apparatus	Turkey [8]
7	Al-Shafa, Al-Hada and Al-Hawiah at Taif region	Hydrodistillation	Saudi Arabia [10]
8	Institute's Farm, Western Himalayas (Dhauladhar range)	Hydrodistillation method using Clevenger's apparatus	India [11]
9	Central Institute of Medicinal & Aromatic Plants, Research Centre, Purara, Uttarakhand	Hydrodistillation method using Clevenger's apparatus	India [13]
10	Fars market	Hydrodistillation method using Clevenger's apparatus	Iran [14]
11	Kamfiroz near to Shiraz, Fars	Hydrodistillation method using Clevenger's apparatus	Iran [16]
12	Flowers were handpicked from rose gardens, Isparta	Hydrodistillation method using Clevenger's apparatus	Turkey [19]
13	Fars1, Fars2, Tehran, Mazandaran, Gilan, East Azar, Ardabi, Kermanshah & Qom (nine different sites)	Hydrodistillation method using Clevenger's apparatus	Iran [20]
14	Institute of Rose & Aromatic Plants, Kazanluk	Hydrodistillation method using Clevenger's apparatus	Bulgaria [22]
15	Vidorj region	Hydrodistillation method using Clevenger's apparatus	Iran [23]
16	Authentic fresh and air-dried rose flowers procured from Institute of Himalayan Bioresource Technology, Palampur (H.P.)	Hydrodistillation method using Clevenger's apparatus	India [25]
17	Rosa damascena was collected from Rasht (Guilan province)	Hydrodistillation method using Clevenger's apparatus	Iran [26]
18	Flowers were collected from different local farms of Al-Hada and Al-Shefa	Hydrodistillation	Saudi Arabia [27]
19	Bab Alnayrab (Aleppo) and Almarah, Ernah, Issal Alward, Mesraba, Rankoos (Rural Damascus)	Hydrodistillation method using Clevenger's apparatus	Syria [28]
20	Flowers were harvested from Bucharest	Hydrodistillation method using Clevenger's apparatus	Romania [29]
21	Rose Project area, Institute of Horticulture Sciences, University of Agroculture, Faisalabad	Solvent extraction using Soxhlet apparatus using n-hexane and ether	Pakistan [30]
22	Taif region	Hydrodistillation	Saudi Arabia [31]
23	Isparta region	Hydrodistillation method using Clevenger's apparatus	Turkey [33]
24	Sebat Ltd. Isparta commercial producer of rose oil	Hydrodistillation	Turkey [34]

Table no. 1 Collection of rose flowers from different regions of world, extraction method and country name. In some research papers along with hydrodistillation using Clevenger's apparatus other extraction were also used.

1.2 Experimental Method: -

The selection of a GC column is a very crucial step in analysis. The selection of column should be done keeping in mind the stationary phase polarity as it dictates selectivity, or the ability of the column to separate sample components. Phase selection is based on the general chemical principle that "like dissolves like". A non-polar column is best for the analysis of non-polar compounds. Polar columns most effectively separate polar compounds. For the study of chemical composition of rose oil, it is observed in this study that non-polar column has been used majorly. This can be further illustrated as; the rose oil also contains hydrocarbons (monoterpenes, sesquiterpenes) along with oxygenated monoterpenes and oxygenated sesquiterpenes. Use of programmed oven temperature is also widely used so that compounds can be separated with better resolution. Since a non-polar column will separate on the basis of boiling point, and since it is quite

possible that oxygenated and purely hydrocarbon components might have a similar boiling point, then for a sample that has a wide component composition including oxygenated compounds, the analytical elution range of the sample will be contracted into a narrow retention time range. This contraction of retention time range will lead to greater overlap probability. A more polar column will have the benefit of providing a mechanism for extending the elution range of the components by retaining the more polar components (the oxygenated compounds) to a greater retention time [35]. The use of 25 – 60 m long column, with 0.2 – 0.32 mm I.D. and 0.25 µm is most commonly used and is used as an industry standard. Stationary phase development seek to (i) produce more thermally and chemically stable phases, (ii) give greater selectivity in the separation of components by different phase chemistry, (iii) better efficiency by making a more regular surface coating or producing a thinner film phase coating or using narrow bore column, (iv) incorporate specific compounds to the phase to allow new interactions such as those available with chiral selectors, (v) use different technology to optimize the phase available to the specific regions of the analysis which require better resolution [35]. Almost all of these factors are relevant to essential oil analysis. Since most essential oils elute before the upper temperature range which means analysis to be carried out at high temperature range (ranging from 60 - 290°C), the use of such thermally stable columns is preferred [35]. Split mode is used while injecting the sample onto the column to avoid overload of sample in the column and also to avoid tailing or fronting of peaks. Use of "ms" column is most commonly observed as they served to be low bleed column. This improves the signal-to-noise ratio for better sensitivity, higher upper temperature limit and excellent inertness to active compounds, including acidic and basic compounds. The analysis of volatile compounds was carried on using Gas chromatograph (GC) and Gas chromatograph hyphenated with mass spectrometer detector (GC-MS) is tabulated in the below Table 2.

Experimental conditions Research paper Ref. no.	Instrument Name	Column name	Column dimensions	Carrier gas and flow rate (ml/min)	Oven temperature and its programming	Injector temperature (°C)	Detector temperature (°C)	Split ratio/Split flow	Injection mode	Sample volume (µl)	Electron energy (eV)	Mass range (amu)
1	Shimadzu QP 2010 GC-MS	AB- Innowax 7031428 WCOT fused capillary column	60m x 0.25mm x 0.25µm	He, 1.21	50°C for 1min & subsequently held isothermal for 2min	250	280	1:50	Split	1	70	40-750
3	Perkin Elmer Clarus	CPSil5CB fused silica capillary column	25m x 0.25mm x 0.4 µm	He, 1	6°C//5°C/min//260°C for 20min	250	NA	NAP	Splitless	5ml of sample placed into 100ml vial 7 PDMS fiber inserted into vial	70	30-425
4	Perkin Elmer Clarus 600T GC-MS	Elite-5ms capillary column	30m x 0.32mm x 0.25 µm	N_2, 2.0	40°C for 2min, then increased to 180°C @ 6°C/min, hold for 2min then increased to 270°C @ 15°C/min, hold for 3min	Tubes were heated to 260°C for 10min. Desorbed compounds were cold trapped at -25°C & then heated to 300°C at 40°C s-1 for 5min.	NA	NA	NA	Desorption method using automatic thermal desorber was used	70	29-500
8	Shimadzu 2010 Plus GC-MS	CP-wax 52 CB	50m x 0.32mm x 0.25 µm	He, 20	60°C for 10min hold to 90°C rising at 4°C/min and increasing to 240°C hold for 11.5 min rising at 15°C/min	240	240	NA	NA	1	70	NA
10	Varian GC CP-3800 & MS Saturn 2200	VF- 5ms	30m x 0.25mm x 0.25 µm	He, 1	60°C for 5min, 60°C to 290°C at 6°C/min and held for 5 min finally at 290°C	140	300	1:40	Split	1	70	NA
11	Perkin Elmer 910 GC-MS	SE-30 column	30m x 0.25mm	He, NA	NA	NA	NA	NA	NA	NA	NA	NA
13	Perkin Elmer Auto System XL GC MS	Equity-5 fused silica capillary column	60m x 0.32mm x 0.25 µm	He, 1	60-210°C at 3°C/min	210	NA	1:40	Split	0.1	70	40-450
14	Agilent Technologies 7890 GC with model 5975C MS	HP- 5MS capillary column	30m x 0.25mm	He, 1	Increased from 60°C (0min) to 220°C at 5°C/min & subsequently held for 10min	NA	280	NA	NA	NA	70	30-600 m/z
16	Hewlett-Packard 6890/5973 GC- MS	HP-5 capillary column	25m x 0.25mm	He, 0.9	60°C (3min) to 260°C at 3°C/min	NA	260	1:20	Split	NA	70.1	NA
19	Hewlett-Packard 6890 series	CP-Wax 52 CB	50m x 0.32mm x 0.25 µm	He, 40	60°C raised to 220°C for 10 min at a rate of 5°C/min	250	250	1:20	Split	NA	NAP	NAP
20	Saturn – 3400	DB-5 fused silica column	30m x 0.25mm x 0.25µm	He, NA	60°C and programmed to 230°C at 4°C/min	NA	NA	1:60	Split	NA	70	40-300
23	Hewlett Packard 6890	HP- 5MS capillary column	30m x 0.25mm x 0.25µm	He, 1	60°C for 3 min hold and then programmed to 220°C @ 6°C/min	290	200	1:20	Split	0.1	70	NA
25	QP-2000 Shimadzu GC-MS	Fused silica capillary column coated with SE-30	20m x 0.25mm x 0.25µm	He, NA	90°C - 270°C at a programmed rate of 4°C/min	NA	NA	NA	NA	NA	NA	NA
26	Hewlett Packard 5973/6890 GC-MS	HP- 5MS capillary column	30m x 0.25mm x 0.25µm	He, 1	60°C for 5 min and programmed to 220°C @ 6°C/min	NA	NA	NA	NA	NA	70	NA
27	Clarus 500 GC-MS	Elite-1 GC capillary column	30m x 0.25mm x 0.25µm	He, 0.9	80°C for 5 min, increased to 150°C @ 5°C/min for 5 min and increased to 270°C @ 5°C/min for 5 min	220	270	1:50	Split	1	70	45-350 m/z
28	NA	CP Wax 52	52m x 10.32mm x 1.2µm	He, NA	60°C to 240°C	240	NA	NAP	Splitless	20	70	NA
29	Agilent 5975C	DB5-MS capillary column	30m x 0.32mm x 0.25µm	H_2, 1	40°C & then progressively raised to 80°C @ 3°C/min, to 180°C @ 5°C/min and finally raised to 280°C @ 8°C/min hold for 20 min	280	200	1:40	Split	30	70	10-350
31	Model CP 3800 Varian	VF-5 fused silica capillary column	30m x 0.25mm x 0.25µm	He, 1	2 mins at 50°C, raised gradually to 131 @ 1.5°C/min, 131-250°C @ 2°C/min, 250-260°C @ 5°C/min & held for 3 mins	240	280	1:40	Split	1	70	50-450 m/z
33	Practvap Carlo Erba 4300	MN-DB—23 column	60m x 0.25mm	He, NA	120°C/3min//3°C/min// 220°C/6min//3°C/min, 120°C/3min	250	240	1:50	Split	1	NAP	NAP
34	Shimadzu GC-MS QP 5050	CP WAX 52 CB capillary column	50m x 0.32 x 1.2µm	He, NA	60°C heated to 220°C @ 2°C/min & held for 20 min	240	250	NA	NA	1	70	NA

Table no. 2 Experimental conditions such as instrument used, column name and dimensions, oven temperature, injector and detector conditions, sample volume and mass spectrometer conditions against the research paper reference no. mentioned in references section.

* NA – Not available, the information was not available in the research paper; NAP – Not applicable

III. Results and Discussions

The result of the chemical composition of rose essential oils extracted and analyzed from different countries is tabulated in Table no. 5.The chemical composition of *Rosa damascena* oil from different countries comprises of saturated and unsaturated long chain hydrocarbon compounds, monoterpenes hydrocarbons, oxygenated monoterpenes, sesquiterpenes hydrocarbons, oxygenated sesquiterpenes as well as sesquiterpenes alcohols and esters. Quantitatively these chemical compounds have been found to be present in varying amounts as the flowers collected are from different parts of the world. The common constituents found in the Rosa damascena Mill. throughout the research papers are Citronellol, Geraniol and Nerol. Besides these, presence of Phenyl ethyl alcohol (Phenethyl alcohol), Eugenol, Geranyl acetate, α-Pinene, β-Pinene and Linalool has also been reported in the research papers. In addition to these oxygenated terpenes, hydrocarbons such as Tricosane, Pentacosane, Heptacosane, Heneicosane, Eicosane, Heptadecane and Nonadecane were also detected. These hydrocarbons contribute to the waxy structure of the rose oil. Along with the detection of these common class of compounds, some peculiar or characteristic compounds were also detected and identified such as t-Cadinol, Bisabolol oxide, Patchouli alcohol, α-Guaiene, δ-Guaiene, Rose oxide, cis-Ocimene, 1-Nitropan, Valencene, α-Phellandren-8-ol, 1,2,4-Oxadiazole-3-carboximidamide,N'-(1-propionyloxy), α-bulnesene and γ-Muurolene.
The fragrance is determined by mixtures of volatiles that can be grouped into the following five major series: hydrocarbons (mostly sesquiterpenes), alcohols (mostly terpenes such as geraniol, nerol and citronellol), esters (mostly acetates such as hexyl acetate or Geranyl acetate), aromatic ethers (methyl eugenol), and others such as aldehydes, aliphatic chains and rose oxides) [29]. The citronellol/geraniol ratio is significant for the aroma quality [22]. Oils with variation limits of 2.5-4.3 and 1.25-1.30 are preferred [22]. It is also reported that the high quality rose oil can also be characterized by the ratio of (citronellol + nerol)/geraniol, which should be between 1.2 and 1.3 [8]. The citronellol/geraniol ratio for India was observed to be 0.9-1.8 [13,25], for Saudi Arabia it was 0.6-2.6 [10, 27,31], for Iran it was 3.3-4.3 [6], for Turkey the ratio ranged from 0.5-3.7 [3,8, 19,33], for Pakistan it was 2.4 [2], for Syria it varied from 0.8-1.0 [28] and for Bulgaria the ratio was 3.7 [22]. The citronellol + nerol/geraniol ratio was increased as compared to citronellol/geraniol ratio for rose oil for countries such as for Turkey 0.9 to 1.3 [8], for Saudi Arabia 1.5 to 2.1 [31], for Bulgaria 3.7 to 4.0 [22], for Turkey 2.0 to 2.5 [33], for Syria it was 1.0 to 1.4 [28] and for India it was calculated to be from 0.9 to 1.5 [25]. Thus, good quality rose oil should possess a higher amount of monoterpenes alcohols and a lower amount of alkanes [13]. The citronellol/geraniol ratio is high for Iranian rose and Bulgarian rose.

Citronellol, geraniol and Phenylethyl alcohol are considered to be the chief constituents in the rose oil. The chemical composition of Pakistan rose oil showed presence of Phenylethyl alcohol (70.86%) as the major constituent. The Chinese rose oil reported main constituents as β-Myrcene (13.301%), α-Pinene (14.233%) along with aldehydes such as Hexanal, Octanal, Nonanal, Decanal, Heptanal and hydrocarbons like Tridecane, Heptadecane and Undecane. The citronellol content was very low (0.232%) and geraniol was not detected in Chinese rose oil. Germacrene D which has an antimicrobial and insecticidal property was found good amount (6.95-8.00%) in Syrian rose collected from different locations followed by Iranian rose oil (1.78-4.0%) [6, 14, 16, 28]. The Turkish rose oil showed the presence of citronellol, nerol, geraniol, linalool, phenylethyl alcohol as its main chemical composition. *Rosa damascena* is found only in Isparta region in Turkey [33]. Nerol was detected in Fruit research station flowers, while rest all the research papers reported presence of nerol. The citronellol + nerol/ geraniol ratio is higher for first oil (4.1) harvested from Isparta region (exact location is not mentioned, Buket, 2002) and the ratio descended to Fruit research station (3.7) > Rose & Rose products research and Implementation Centre (1.3) > Sebat Ltd. (2.1). Hasan [19] reported the changes in the concentration of citronellol, nerol and geraniol content of rose flowers harvested at different dates. The citronellol content increased from May 24 to June 15) and was found to be high in amount on June 8 while nerol and geraniol content decreased and was least for June 8. The citronellol/geraniol ratio was highest for June 8 (0.81) as well as the citronellol + nerol/ geraniol ratio was also highest for June 8 (1.03). The concentration of Phenylethyl alcohol showed less variation from May 24 to June 15.

The chemical composition of Romanian rose oil showed the presence of hydrocarbons (74.417%) as its main constituent. Along with presence of hydrocarbons, monoterpenes and sesquiterpenes such as β-Citronellol (0.729%), Nerol (1.039%), β-Pinene (1.665%), Caryophyllene (0.135%), δ-Cadinene (0.539%) were detected in low amounts. The Romanian rose oil also showed the presence of some representative compounds such as cis-Ocimene (1.024%), Linalyl anthranilate (1.266%), 1,2,4-oxadiazole-3-carboximidamide,N'-(1-propionyloxy) (4.094%) and 1-Nitropan (6.086%). Caryophyllene which is known to contribute the spiciness to aroma was detected in Turkish rose oil [3,8], Iranian rose oil [6,14] and Saudi Arabian rose oil [31] in greater than 1%. Saudi Arabian rose essential oil showed good amount of presence of citronellol, geraniol, nerol, linalool, phenyl ethyl alcohol and eugenol as its main components. Germacrene D was detected Al-Hada and Al-Shefa local farms as well as Taif rose oil factory. The citronellol + nerol/ geraniol ratio was highest for Al-Hada and Al-Shefa local farm rose essential oil (3.6). The increasing order of the citronellol + nerol/ geraniol ratio with respect to the regions from where the rose flowers were harvested is as follows:-

Al-Hada & Al-Shefa local farm (3.6) > Taif region (2.1) > Al-Shafa region > Alhaweiah (1.2) > Al-Hada (1.2).The mono and sesquiterpenes were reported for essential rose oil from Taif region of Saudi Arabia. Some representative compounds such as α-Phellandren-8-ol (1.1%), γ-Muurolene (1.3%), β-Cubebene (0.7%), γ-Cadinene (0.7%), α-Gurjunene (0.7%), β-Selinene (0.8%) and (α,γ)-Eudesmol (0.5%) were reported to contribute to Taif rose essential oil. Bazaid S.A. [10] reported the presence of only main components with geraniol > citronellol > nerol > Nonadecane > Heneicosane > linalool in their decreasing order of relative percentages. The table no. 3 shows the comparison of the chemical composition of rose flowers collected from different parts of India. The rose oil from New Delhi showed the presence of Bisabolol oxide (12.18%) and Patchouli alcohol (11.54%) as major component in sesquiterpenes class of compounds; these components were not reported in any other research papers. The common compounds detected in rose oil from New Delhi and Uttarakhand are the hydrocarbons such as Heptadecane, Eicosane, Docosane, Tricosane, Pentacosane and n-Nonacosane; amongst this n-Nonacosane reported to be highest component (26.31%). Citronellol, nerol, geraniol and Phenylethyl alcohol were not detected in rose flowers from New Delhi. The rose oil extracted from Palampur rose flowers showed the presence of higher amount of monoterpenes such as citronellol, nerol, geraniol and Phenylethyl alcohol and lower amount of hydrocarbons as compared to that of other three regions. The ratio of citronellol + nerol/geraniol for western Himalayan and Palampur rose oil was approximately equivalent (1.8 and 1.5 respectively). The western Himalayan rose oil also reported the detection of higher amounts of hydrocarbons such as Nonadecane (24.67%), Heptadecane (6.02%), 9-Eicosane (5.00%) and stearoptenes (36.21%).The table no. 4 provides correlation of the major components of rose essential oil extracted from flowers collected from different regions of Iran. Nerol was not detected in any of the rose oil extracted from different parts of Iran. The detection and identification of number of peaks also depends on the experimental conditions such as column I.D., film thickenss, β-phase ratio. Ali Mostafavi [6] reported presence of approximately 100 compounds in rose flowers collected from Kashan region (the experimental conditions were not mentioned in the research paper). Rest all the research papers reported to use 25m - 30m x 0.25mm column with 5% phenyl 95% dimethylpolysiloxane phase. Use of shorter columns can also be one of the reasons for overlapping of peaks. The citronellol content was found in higher amount for Vidorj region (47.43%) as compared to other regions. Akbar Karami [20] reported the variation of composition of *Rosa damascena* Mill. from nine different regions. A very interesting fact can be seen from the table no. 4 for the variation of nine distinct genotypes i.e. citronellol and geraniol were detected in the nine different parts of Iran alternatively. Kashan and Kerman regions showed the presence of high amounts of monoterpenes and sesquiterpenes in addition to hydrocarbons. The common compounds found to be present in the fifteen regions tabulated in table no. 4 is Eicosane, Heneicosane and Nonadecane. Phenylethyl alcohol was detected only in Vidroj and Rasht regions only in low amounts (0.26 and 0.86% respectively). Hydrocarbons had the highest contribution to the rose essential oil from East Azar region (78.6%). Nonadecane dominated amongst all the hydrocarbons with 51.2% for East Azar. This region showed absence of mono and sesquiterpenes. Germacrene D was found to contribute in Kashan, Kerman, Fars and Kamfiroz regions. The representative compound of α-Humulene was detected in Kashan and Kerman regions only. Another important aspect with respect to the retention indices reported in majority of the research papers is the Kovats retention indices. Kovats retention indices are calculated using the formula:

$$K = 100 \times \left[n + \frac{\log t_{Rx} - \log t_{Rn}}{\log t_{Rn+1} - \log t_{Rn}} \right]$$

where:

a) x is the test compound;
b) n is the alkane with n carbon atoms into the molecule,
c) whose peak is placed on the left side of the analyzed peak from the chromatogram;
d) n+1 is the alkane with n carbon atoms into the molecule, whose peak is placed on the right side of the analyzed peak from the chromatogram.

Results and Discussions (Contd.): -

Sr. No.	Main constituents	New Delhi [1]	Western Himalayas (Dauladhar range) [11]	Palampur [25]	Uttarakhand [13]
1	2- Phenylethyl alcohol	ND	3.80	30.8	0.4
2	Citronellol + Nerol	ND	27.83	NA	NA
3	Citronellol	ND	NA	15.6	7.1
4	Nerol	ND	NA	9.2	0.1
5	Geraniol	ND	15.37	16.8	4.1
6	Geranyl acetate	ND	3.84	ND	0.8
7	Eugenol	ND	1.86	>0.1	ND
8	Methyl eugenol	ND	ND	ND	ND
9	Heptadecane	0.72	6.02	ND	0.6
10	Farnesol	ND	5.43	ND	0.4
11	9-Eicosene	ND	5.00	ND	ND
12	Eicosane	0.63	ND	>0.1	2.5
13	Nonadecane	0.32	24.67	0.3	13.0
14	Heneicosane	ND	ND	>0.1	19.7
15	Docosane	0.19	0.52	ND	1.1
16	Tricosane	0.29	ND	ND	11.3
17	Pentacosane	0.33	ND	ND	5.3
18	n-Nonacosane	26.31	ND	ND	ND
19	Patchouli alcohol	11.54	ND	ND	ND
20	Bisabolol oxide	12.18	ND	ND	ND

Table no. 3 shows the main constituents (in percentages) identified, detected and quantified in rose oil extracted from rose flowers collected from different locations of India. NA- Not applicable and ND – Not detected.

Sr. No.	Main constituents	Kashan [6]	Kerman [6]	Fars [14]	Kamfiroz [14]	Fars 1 [20]	Fars 2 [20]	Tehran [20]	Mazandaran [20]	Gilan [20]	East Azar [20]	Ardabil [20]	Kermanshah [20]	Qom [20]	Vidorj [23]	Rasht [26]
1	Citronellol	20.6	12.6	9.26	6.14	42.2	19	26	ND	40.3	0.6	ND	ND	2.2	47.43	ND
2	Geraniol	4.8	3.8	4.47	ND	ND	ND	ND	2	ND	ND	1.9	37.5	ND	ND	15.5
3	Phenylethyl alcohol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.26	0.86
4	α-Pinene	1.7	3.1	0.96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
5	β-Pinene	0.4	0.7	0.25	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6	β -Myrcene	0.6	1.1	0.38	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.13
7	Germacrene D	3.5	4.0	3.67	1.78	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
8	Caryophyllene	1.2	1.2	1.59	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9	α-Guaiene	1.5	1.6	2.11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
10	α-Humulene	1.3	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11	Geranyl acetate	1.9	3.1	3.97	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.24
12	δ-Guaiene	1.2	1.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
13	Linalool**	0.3	0.1	0.26	ND	6	39.2	17.8	1.7	3	1	12.3	11.7	30.8	ND	3.68
14	Pentadecane	1.1	1.0	1.39	ND	ND	ND	ND	ND	1.3	ND	ND	ND	ND	0.16	ND
15	Heptadecane	6.0	4.4	10.33	2.40	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.10	2.84
16	Eicosane	3.1	2.4	3.63	4.52	0.9	0.8	1.4	1.3	2.3	6.2	1.5	0.9	1.7	0.66	0.32
17	Heneicosane	13.5	9.6	13.28	32.38	3.5	3.7	5.3	5.7	8.9	18	6.5	3.8	7.4	17.45	ND
18	Nonadecane	2.7	22.8	23.81	39.73	15.9	10.7	22.4	20	26.3	51.2	20.5	13.9	26.5	ND	ND
19	Tricosane	2.6	2.0	ND	ND	0.5	0.6	0.7	1	1.4	2.4	1.1	0.6	0.9	ND	16.68
20	Heptacosane	0.6	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.47
21	Docosane	0.4	0.3	0.40	7.34	ND	ND	2.9	ND	ND	0.8	ND	ND	ND	ND	ND
22	Nonadecene**	12.9	8.6	8.40	5.69	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.63	18.56

Table no. 4 shows the main constituents (in percentages) identified, detected and quantified in rose oil extracted from rose flowers collected from different locations of Iran.

*ND – Not detected. ** Isomers of Nonadecene and Linalool were detected in rose oil of different locations of Iran.

Sr. No.	Main constituents and their percentages	Origin	References
1	α-Hexyl benzoate (2.98%), trans-2-Hexenyl-α-octanoate (4.79%), t-Cadinol (7.75%), Bisabolol oxide (12.18%), Patchouli alcohol (11.54%), (2Z,6E)-Farnesyl acetate (6.53%), Methyl octadecane (1.90%), n-Octadecanol (4.70%), n-Hexacosane (3.35%), n-Octacosane (2.29%), n-Nonacosane (26.31%)	India	[1]
2	Geraniol (1.53%), Eugenol (1.68%), Rhodinol (2.69%), Citronellol (3.72%), Linalool (1.02%), Citranellyl acetate (2.46%), Phenyl ethyl alcohol (70.86%), Rhodinyl acetate (0.42%)	Pakistan	[2]
3	Cis-Rose oxide (1.50%), δ-3-Carene (1.83), β-Pinene (1.77%), Citronellol (43.40%), Geraniol (11.81%), Eugenol (3.82%), Geranyl acetate (1.78%), Methyleugenol (4.04%), Phenol (2.85%), trans-Caryophyllene (2.12%), α-Guaiene (0.98%), α-Caryophyllene (1.29%), Pentadecane (4.53%), Azulene (2.28%), Heptadecane (1.69%), Farnesyl acetate (2.44%), E-15-Heptadecenal (1.79%), Heneicosane (6.53%), Nonadecane (2.01%)	Turkey	[3]
4	Hexanal (2.841%), Butanal,3-methyl- (1.237%), Octanal (4.067%), Nonanal (6.303%), Decanal (3.736%), Heptanal (2.128%), α-Pinene (14.233%), β-Myrcene (13.301%), Sabinene (2.871%), 2-Phenethyl-β-phenylpropinate (2.446%), (Z)-Rose oxide (0.754%), β-Pinene (4.488%), Propylene glycol (0.714%), Phenyl ethyl alcohol (0.367%), Citronellol (0.232%), Ethylbenzene (1.706%), O-Xylene (2.353%), Benzene (5.966%), Nonane (7.207%), Undecane (1.691%), Hexadecane (3.419%), Eicosane (0.342%), Tridecane (1.249%), Heptadecane (3.419%), Heneicosane (0.444%), Azulene (0.340%), β-Damascenone (0.026%), Geranyl acetate (0.246%), Geraniol (ND)	China	[4]
5	α-Pinene (1.7, 3.1%), β-Pinene (0.4,0.7%), β-Myrcene (0.6, 1.1%), Phenyl ethyl alcohol (ND), cis-Rose oxide (0.2, 0.1%), trans-Rose oxide (0.1, 0.1%), Citronellol (20.6, 12.6%), Geraniol (4.8, 3.8%), cis-2,6-Dimethyl-2,6-octadiene (1.2, 1.7%), Geranyl acetate (1.9, 3.1%), β-Caryophyllene (1.2, 1.2%), α-Guaiene (1.5,1.6%), α-Humulene (1.3, 1.1%), Germacrene D (3.5, 4.0%), δ-Guaiene (1.2, 1.2%), Pentadecane (1.1,1.0%), (ZE)-Farnesol (1.8, 0.1%), Heptadec-8-ene (1.1, 1.0%), Heptadecane (6.0, 4.4%), 1-Nonadecene (12.9, 8.6%), Nonadecane (2.7, 22.8%), Eicosane (3.1, 2.4%), Heneicosane (13.5, 9.6%), Tricosane (2.6, 2.0%)	Iran	[6]*
6	Linalool (0.3%), Phenethyl alcohol (1.3%), Citronellol (31.6%), Nerol (15.3%), Geraniol (35.4%), Geranyl acetate (2.3%), Eugenol (0.5%), Methyl eugenol (0.8%), β-Caryophyllene (0.7%), Hexadecane (1.3%), Nonadecane (7.2%), Eicosane (0.5%), Heneicosane (1.8%)	Turkey	[8]
7	β-Linalool (8.22, 8.18, 10.27%), Phenyl ethanol (3.54, 3.24, 3.62%), α-Terpineol (4.67, 4.81, 4.22%), Nerol (11.72,12.00, 11.89%), β-Citronellol (14.64, 14.13, 13.92%), Geraniol (20.62, 22.77, 21.55%), Eugenol (3.55, 3.76, 4.13%), Nonadecane (11.36, 11.20, 12.47%), Heneicosane (6.22, 6.01, 7.89%)	Saudi Arabia	[10]*
8	2-Phenylethyl alcohol (2.49%), Linalool (23.04%), α-Terpineol (9.20%), Citronellol + Nerol (34.89%), Geraniol (21.30%), Eugenol (2.79%), Methyl eugenol (1.52%), Heptadecane (1.87%), Steroptenes (1.87%), Rose alcohols (96.00%)	India	[11]
9	α-Pinene (0.1%), Linalool (0.5%), 2-Phenyl ethyl alcohol (0.4%), Citronellol (7.1%), Nerol (0.1%), Geraniol (4.1), β-Caryophyllene (ND), Geranial (0.1%), Geranyl acetate (0.8%), Heptadecane (0.6%), (2E,6E)-Farnesol (0.4%), 1-Nonadecene (1.6%), Nonadecane (13.0%), Eicosane (2.5%), Heneicosane (19.7), Docasane (1.1%), Tricosane (11.3%), Pentacosane (5.3%)	India	[13]
10	α-Pinene (0.96%), β-Pinene (0.25%), β-Myrcene (0.38%), Linalool (0.26%), Phenyl ethyl alcohol (ND), β-Citronellol (9.26%), trans-geraniol (4.47%), Citronellyl acetate (1.60%), Eugenol (0.38%), cis-geranyl acetate (3.97%), trans-Caryophyllene (1.59%), α-guaiene (2.11), β-selinene (1.39), Germacrene D (3.67%), Pentadecane (1.39%), α-bulnesene (1.77%), Heptadecane (10.33%), 1-Nonadecene (8.40%), Nonadecane (23.81%), Eicosane (3.63%), Heneicosane (13.28%), Tetracosane (3.72%)	Iran	[14]
11	Citronellol (6.14%), Germacrene D (1.78%), Heptadecane (2.40%), 9-Nonadecene (5.69%), Nonadecane (39.73%), Eicosane (4.52%), Heneicosane (32.38%), Docosane (7.34%)	Iran	[16]
12	Citronellol (23.92%), Geraniol (44.44%), Nerol (14.55%), Linalool (1.24%), Phenyl ethyl alcohol (1.80%), Monoterpenes (85.96%)	Turkey	[19]
13	Dihydro-linalool (6, 1.7, 17.8, 3, 1, 30.8, 12.3, 11.7, 39.2%), Citronellol (42.2,ND, 26, 40.3, 0.6, 2.2, ND, ND, 19%), Neral (7.1, 44.8, 3.7, ND, ND, ND, 31.7, ND, 7%), Geraniol (ND, 2, ND, ND, ND, ND, 1.9, 37.5, ND%), Geranial (12.3, ND, 6.4, ND, ND, 4.9, ND, 3.6, 11.2%), Citronellyl formate (ND, 7.5, ND, ND, ND, ND, 7.8, 14.6%), Undecanal (2.3, ND, 1.2, ND, ND, 5.5, 0.7, 0.7, 2.7%), Occidentalol acetate (3.3, 4, 3.6, ND, 3, 2.5, 3.8, 2.7, ND%), n-Hexadecanol (ND, 7.2, 6.4, ND, 7.8, 4.8, 7, 4.5, 2.7%), n-Nonadecane (15.9, 20, 22.4, 26.3, 51.2, 26.5, 20.5, 13.9, 10.7%), n-Eicosane (0.9, 1.3, 1.4, 2.3, 6.2, 1.7, 1.5, 0.9, 0.8%), n-Heneicosane (3.5, 5.7, 5.3, 8.9, 18, 7.4, 6.5, 3.8, 3.7%), n-Tricosane (0.5, 1, 0.7, 1.4, 2.4, 0.9, 1.1, 0.6, 0.6%)	Iran	[20]*
14	α-Pinene (1.13%), β-Pinene (0.45%0, Linalool (0.95%), Cis-rose oxide (0.36%0, Citronellol (48.24%), Nerol (4.19%), Geraniol (13.06%), Caryophyllene (0.55%), Geranyl acetate (0.88%), Methyl eugenole (1.29%), Caryophyllene oxide (1.79%), E,E-Farsenol (1.56%0, Nonadecene (2.23%), Nonadecane (7.78%), Eicosane (0.51%), Heneicosane (1.77%)	Bulgaria	[22]
15	β -Citronellol (47.43%), Phenyl ethyl alcohol (0.26%), Henicosane (17.45%), 9-Nonadecene (2.63%), Eicosane (0.66%), Heptadecane (1.10%), Pentadecane (0.16%), Nerol (1.15%), Disiloxane (17.58%), Octadecane (6.13%)	Iran	[23]
16	Linalool (7.5%), Citronellol (15.6%), Nerol (9.2%), Geraniol (16.8%), 2-Phenylethanol (30.8%), Nonadecane (0.3%0, Nonadecene (0.1%), Methyl eugenol (0.4%)	India	[25]
17	β-Myrcene (0.13%), Linalool (3.68%), Phenyl ethyl alcohol (0.86%), Rose oxide (0.1%), Nerol (3.05%), Geraniol (15.5%), Linalyl acetate (0.3%), Eugenol (0.18%), Geranyl acetate (0.24%), n-Heptadecane (2.84%), 1-Nonadecene (18.56%), n-Octadecane (2.8%), n-Eicosane (0.32%), n-Heptacosane (2.47%), n-tricosane (16.68%), n-pentacosane (5.11%), n-hexatriacontane (24.6%),	Iran	[26]
18	Phenyl ethyl alcohol (1.276%), Citronellyl formate (1.421%), β-Citronellol (29.013%), β-Citronellol, trimethylsilyl ether (14.83%), Nerol, trimethyl ether (11.66%), Geraniol (11.395%), Germacrene D (0.636%)	Saudi Arabia	[27]
19	Linalool (2.44, 2.02, 2.08, 2.01, 1.79, 1.98, 2.45%), Germacrene D (7.48, 7.72, 7.67, 7.05, 8.00, 7.82, 6.95%), Geranyl acetate (2.27, 2.42, 2.30, 2.31, 2.40, 2.28, 2.09%), Citronellol (28.96, 28.02, 27.97, 28.05, 28.32, 29.02, 26.32%), Nerol (12.57, 12.42, 12.41, 12.75, 12.59, 12.63, 13.31%), Geraniol (28.75, 28.77, 28.65, 28.74, 28.66, 28.36, 30.75%), Nonadecane (5.17, 5.40, 4.15, 4.04, 4.06, 4.15, 5.41%), Phenyl ethyl alcohol (2.18, 2.11, 2.12, 2.17, 1.92, 2.10, 2.14%), Methyl eugenol (1.02, 1.00, 1.08, 1.01, 1.08, 1.03, 0.96%), Heneicosane (3.50, 3.50, 3.56, 3.21, 3.29, 3.25, 3.12%)	Syria	[28]*
20	β-Pinene (1.665%), cis-Ocimene (1.024%), Linalyl anthranilate (1.266%), Nonanal (2.485%), β –Citronellol (0.729%), Nerol (1.039%), 9-Nonadecene (8.470%), 1,2,4-Oxadiazole-3-carboximidamide,N'-(1-propionyloxy) (4.094%), Nonadecane (15.541%), Eicosane (3.624%), Heneicosane (35.553%), 1-Nitropan (6.086%), Tricosane (7.977%), Octacosane (3.252%)	Romania	[29]
21	α-Pinene (4.5%), β-Pinene (0.9%), Myrcene (2.3%), Linalool (5.9%), Phenyl ethyl alcohol (3.6%), α-Phellandren-8-ol (1.1%), Terpinen-4-ol (1.6%), α-Terpineol (2.6%), Nerol (6.4%), β-Citronellol (17.6%), Neral (1.5%), Geraniol (11.4%), Geranial (1.4%), Citronellyl actate (1.1%), Eugenol (1.7%), Geranyl acetate (1.8%), Methyl eugenol (1.5%), β-Caryophyllene (1.0%), α- Guaiene (1.1%), Germacrene-D (0.7%),γ-Muurolene (1.3%), δ-Guaiene (1.1%), Nonadecene (2.1%), Nonadecane (6.5%), Heneicosane (0.9%), Eicosene (0.1%), Valencene (0.9%), Heptadecene (0.4%), Heptadecane (0.6%)	Saudi Arabia	[31]
22	Citronellol (10.3, 46.7%), Geraniol (2.8, 23.3%), Nerol (1.3, 11.9%), Linalool (0.6, 0.8%)	Turkey	[33]**
23	α-Pinene (0.80%), Linalool (0.53%), Citronellol acetate (0.70%), Heptadecane (0.90%), Germacrene-D (0.45%), Geranyl acetate (2.00%), Citronellol (35.23%), Nerol (10.26), Geraniol (22.19%), Nonadecane (13.85%), 9-Nonadecane (2.79%), Phenylethyl alcohol (2.30%), Methyl eugenol (1.97%), Heneicosane (4.85%), Eugenol (1.18%)	Turkey	[34]

*-Indicates the references wherein rose flowers were collected from multiple regions within same country, **-Indicates the references in which first oil and second oil composition were determined.

IV. Conclusion

Rose essential oil is an important industrial product for different applications [24]. The variations in the amount/percentages of compounds identified and detected depend on variation of many factors such as the altitude and geographic conditions, soil composition, harvesting and storage conditions, distillation methods, genetic variations, time of collection, stages of plant growth and maturity at the time of collection. Therefore finding the methods for increasing the oil yield and decreasing the expense of oil production are important issues for the future [24].The climate of the zone plays an important role at the essential oil level production [10]. The best rose essential oil is the oil with the high amounts of monoterpenes [24]. Hence depending upon the variation of concentration of different constituents of the rose oil from the different locations of world the applications of rose oil can be varied. For Turkey harvesting of Rosa damascena in the first week is favorable as it yields high amount of monoterpenes alcohols. The method of extraction also plays as important step while determining the chemical composition of rose essential oil. As per this study, extraction of rose oil from rose flowers by hydrodistillation using Clevenger's apparatus is most commonly and widely method. The yield of the rose oil obtained by this method was found to be (0.1 – 0.2%). Hence this can be concluded to be used while determining the rose oil chemical composition.

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