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A comparative study of the chemical composition of oil–bearing *Rosa damascena* Mill. cultivated in Bulgaria and in Japan

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The oil-bearing rose, *Rosa damascena* Mill., is an emblematic species of high economic importance for Bulgaria, a crop whose cultivation is largely determined by meteorological and environmental factors. We report the first successful cultivation of *R. damascena* Mill. in Japan, where no prior data on its growth exist. This study aimed to compare the yield and chromatographic profiles of rose oils produced in Bulgaria and Japan. The essential oil yield, calculated on a dry weight basis, was determined to be 0.191% (w/w) for the Bulgarian rose oil and 0.07 % (w/w) for the Japanese rose oil. Gas chromatography with flame ionization detection (GC–FID) analysis identified the main aroma components—the monoterpene alcohols, which represent more than 65% of the total 20 identified substances for the Bulgarian oil and only 26% for the Japanese oil. The results are presented as relative percentage as follows: geraniol (22.48/7.05), citronellol (39.18/17.91), and nerol (4.46/1.5), followed by the stearoptene fraction: nonadecane (14.89/26.31), nonadecene (0.83/7.38), heneicosane (4.12/8.36) and heptadecane (2.14/5.29) for Bulgarian and Japanese rose oil, respectively. A remarkable feature is the inverse deviation of the Japanese oil's composition: its aromatic compounds are sub-standard, while its stearoptene fractions are substantially higher than the upper limit defined by the standard. Statistical evaluation using a paired binomial proportion test confirmed that Bulgarian rose oil is by 58.3% superior in eleoptene composition. These findings confirm the first successful cultivation of *R. damascena* Mill. in Japan, highlighting significant yield and compositional disparities against traditional Bulgarian rose oil production.

Keywords: rose oil, GC–FID, paired binomial proportion test

INTRODUCTION

Bulgarian rose oil, produced from *R. damascena* Mill., is globally recognized as the highest quality and ultimate standard in the market [1]. Regarded as "liquid gold", its exceptional value stems from low distillation yield, lack of substitutes [2], and cultivation restricted to specific climate and soil conditions. The chemical complexity of Bulgarian rose oil, with its more than 300 identified constituents, represents a remarkable example of nature's biochemical diversity. This complex mixture of terpene alcohols, hydrocarbons, phenolic compounds, and trace components creates a unique phytochemical profile that has defied complete synthetic replication and continues to reveal new therapeutic applications through scientific investigation. The oil's complex composition underpins both its exquisite fragrance and its diverse biological activities, which collectively explain the enduring value of Bulgarian rose oil in perfumery, cosmetics, and complementary medicine [3–6]. The cultivation of *R. damascena* Mill. in Bulgaria is closely associated with the unique soil and climatic conditions of the Rose Valley. Among the climatic factors, air temperature and annual precipitation play the most significant roles in influencing the growth and development of this oil-bearing rose [7]. Bulgaria and Turkey dominate global rose oil production, collectively accounting for approximately 70% of the world's supply [8]. Limited production also occurs in several other countries, including Iran, India, Egypt, Morocco, France, Afghanistan, Saudi Arabia, and China. The primary species cultivated in Bulgaria, Turkey, and Iran is *R. damascena*, whereas *Rosa centifolia* L. is prevalent in Morocco, Egypt, and France. Dobreva *et al.* [9] revealed that the chemical composition of rose oil from Saudi Arabia ranges widely depending on the local traditions of growing and processing oil-bearing rose. The distillation technology and rigor of process control are critical determinants of oil quality, alongside the influence of the specific growing micro-region.

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No published data exist on the essential oil of *R. damascena* Mill. cultivated in Japan. Therefore, we aimed to study and compare the rose oil obtained from Bulgarian-origin *R. damascena* Mill. cultivated in Japan with the one produced in Bulgaria. For this reason, we were particularly interested in growing *R. damascena* Mill. on two private fields - of Mr. Shimazaki in Kazanlak, Bulgaria, and of Mr. Yosuke in Yamagata, Japan.

EXPERIMENTAL

Plant material

Rooted stem cuttings of *R. damascena* Mill. (supplied by the Institute of Roses and Aromatic Plants, Agricultural Academy, Kazanlak, Bulgaria) were planted in two private rose fields: one in Kazanlak, Bulgaria (42°31′35.8″N, 25°19′39.5″E) and another in Yamagata, Japan (38°32′03.3″N, 140°23′37.5″E; Japanese Rose Valley). After five years of growth, rose blossoms were harvested during the flowering period (May–June 2024).

Rose oil production

The rose oils were obtained through the classical Bulgarian water steam distillation method in a 0.5 m^3 industrial still of the fresh flowers, as described by Dobreva and co–workers [1].

The rose oil from Japan was obtained in a small distilling equipment – laboratory module with the volume of the still 0.1 m^3. The water cooler has a volume of 0.62 m^3 and the florentine vessel has a volume of 0.007 m^3. Briefly, 8 kg of fresh rose flowers were added to 50 L of water and boiled under high pressure steam 0.5 – 0.7 MPa. The first 10 L of the distillate were kept as a final product and the next 5 L were put back to the tank for second distillation. The duration of one cycle was about 90 – 120 min. The yield of both essential oils was calculated on a dry weight basis - Y_{dw} (%), using the following formula: Y_{dw} (%) = $(V_{oil} \times \rho_{oil}/ W_{dry}) \times 100$, where: V_{oil} - volume of the obtained essential oil (ml); ρ - density of the essential oil (g/ml); W_{dry} - dry mass of the plant material, calculated as $W_{fresh} \times (1 - MC)$, W_{fresh} –mass of the fresh flowers; MC - moisture content (%) = $[(W_{fresh} - W_{dry}) / W_{fresh}] \times 100$, expressed as a decimal (0.85 for 85%).

The essential oil yield, calculated on a dry weight basis, was determined to be 0.191% (w/w) for the Bulgarian rose oil and 0.07% (w/w) for the Japanese rose oil. Rose oils were stored in a refrigerator at 4°C in the dark, in non-transparent containers.

To measure the density of rose oils a pycnometer acc. to Gay-Lussac, volume 1 ml, was used. The study of refractive index was conducted on cutting oil refractometer PAL-102S.

Gas chromatographic (GC–FID) analysis

The GC analysis of both essential oils was performed on an Agilent 7820A GC–FID system.

Standard calibration mixture of n–alkanes C_8–C_{27} in hexane ≥ 98% (Honeywell, Riedel–de Haën TM) was used for quantification of major and minor components. The GC system was equipped with the non–polar capillary column EconoCapTM ECTM–5 (30 m × 0.32 mm × 0.25 μm film of 5% phenyl, 95% methylpolysiloxane). The split ratio was 1:10, the inlet temperature – 250°C, and the FID temperature was set from 60˚C to 300˚C through a controlled program. Synthetic air (mixture of nitrogen (N_2) – 80% and oxygen (O_2) – 20%) was used as a carrier gas and hydrogen (99.999%) for the FID. Data were processed using Agilent chromatography data systems (CDS) software – Open Lab CDS – Agilent RapidControl.NET.

The identification of the compounds was performed using retention times and authentic references. The quantification of the main compounds was carried out by peak area without correction factor.

Statistical analysis

We firstly made a test for normality – Shapiro–Wilkson – for every single parameter of the climate features for the two locations, Kazanlak, Bulgaria, and Yamagata, Japan, followed by a Fisher test (F–test) for the variance of all pairs of parameters of the climate for the two locations. Then we proceeded with the t–test to prove the significant difference between the parameters of climate of the two locations at the 99.999 level of confidence.

Hypothesis test was used to compare paired binomial proportion, based on differences in the relative percentage concentrations (calculated by peak area without correction factor) of aroma compounds of the studied rose oils obtained from *R. damascena* Mill. produced in Kazanlak – Bulgaria, and in Yamagata Japan, by two similar methods of distillation: classical Bulgarian technology and traditional Bulgarian technology.

All analyses were performed using R–4.4.1 (R Core Development team 2024, Copyright © 2021–2025 R Core Team) and RStudio version 2024.09.0–375.

RESULTS AND DISSCUSION

Influence of climate and environmental conditions

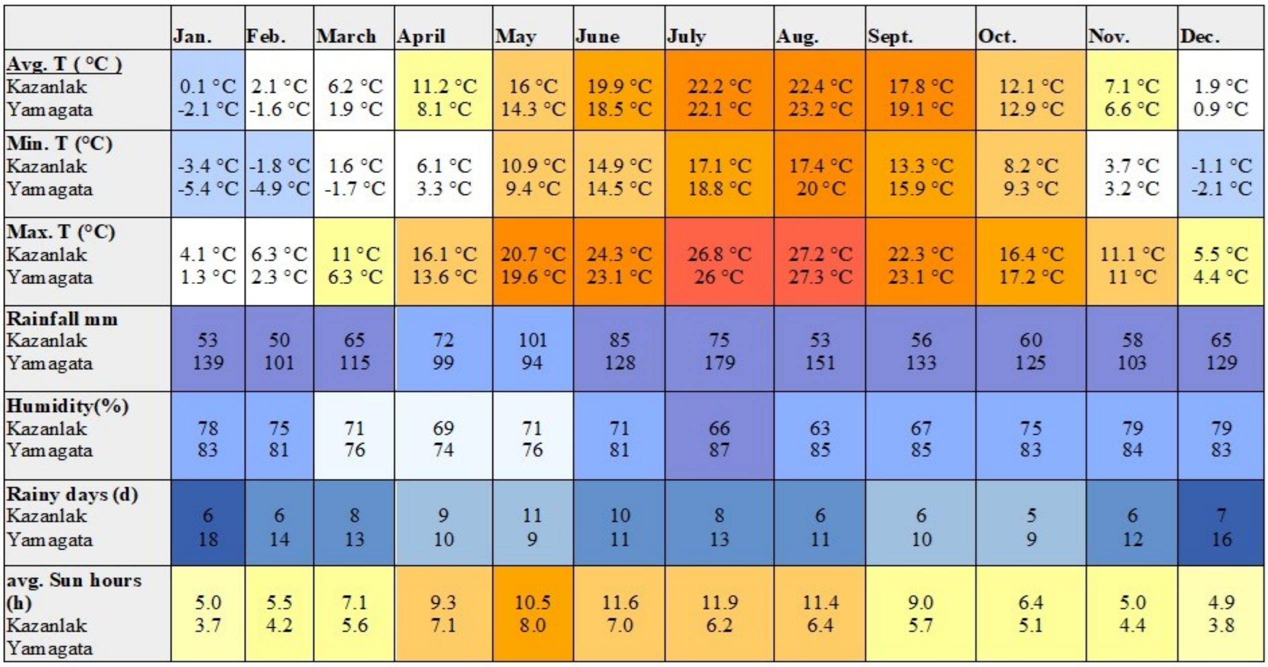
The most dynamic climate components that have a direct impact on the development of the oil–bearing rose are the air temperature and annual precipitation amounts. For example, the Kazanlak oil–bearing rose withstands low temperatures in winter down to minus 28.0°C. After the start of sap flow, depending on the degree of development, it freezes at temperatures from minus 5 to minus 10°C. Frosts occur in autumn–winter and winter–spring [7].

R. damascena Mill. flowers from early May to early June in Rose Valley of Bulgaria. Exact flowering time depends upon prevailing temperature in the locality The total period of of the flowering is about 25 – 35 days, the major part of the yield (about 75%) being obtained within 15 days of peak flowering period.

Yamagata City, known as Japanese Rose Valley, is located in the Tohoku region of northern Honshu, Japan. It has a humid continental climate, closely bordering on humid subtropical climate with large seasonal temperature differences, with warm to hot (and often humid) summers and cold (sometimes severely cold) winters. Precipitation is significant throughout the year, and is heaviest from July to September.

The climate characteristics of the regions where oil—bearing *R. damascena* Mill. was grown: Kazanlak (Bulgaria) and Yamagata (Japan) are summarized in Table 1.

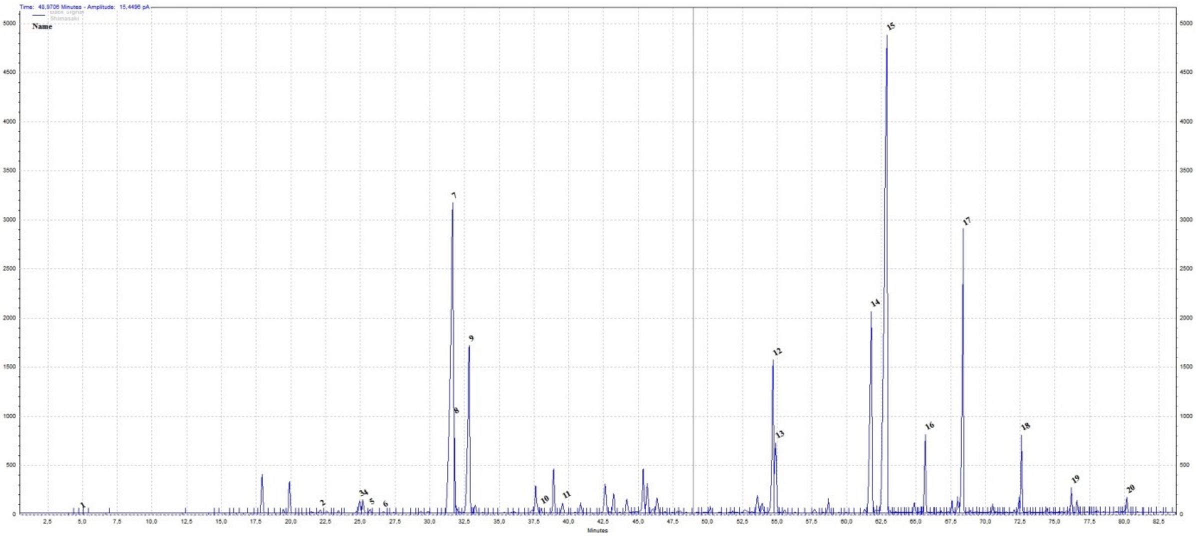
Table 1. Climatic characteristics (weather by month/weather averages) in Kazanlak, Bulgaria, and Yamagata, Japan [10].



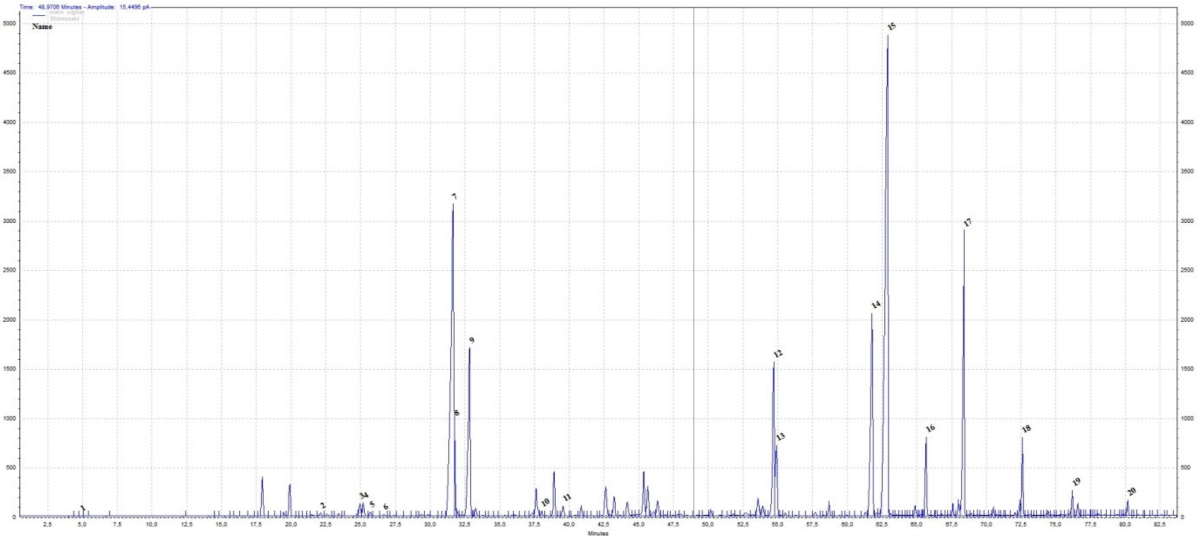
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Avg. T (°C) Kazanlak Yamagata	0.1 °C -2.1 °C	2.1 °C -1.6 °C	6.2 °C 1.9 °C	11.2 °C 8.1 °C	16 °C 14.3 °C	19.9 °C 18.5 °C	22.2 °C 22.1 °C	22.4 °C 23.2 °C	17.8 °C 19.1 °C	12.1 °C 12.9 °C	7.1 °C 6.6 °C	1.9 °C 0.9 °C
Min. T (°C) Kazanlak Yamagata	-3.4 °C -5.4 °C	-1.8 °C -4.9 °C	1.6 °C -1.7 °C	6.1 °C 3.3 °C	10.9 °C 9.4 °C	14.9 °C 14.5 °C	17.1 °C 18.8 °C	17.4 °C 20 °C	13.3 °C 15.9 °C	8.2 °C 9.3 °C	3.7 °C 3.2 °C	-1.1 °C -2.1 °C
Max. T (°C) Kazanlak Yamagata	4.1 °C 1.3 °C	6.3 °C 2.3 °C	11 °C 6.3 °C	16.1 °C 13.6 °C	20.7 °C 19.6 °C	24.3 °C 23.1 °C	26.8 °C 26 °C	27.2 °C 27.3 °C	22.3 °C 23.1 °C	16.4 °C 17.2 °C	11.1 °C 11 °C	5.5 °C 4.4 °C
Rainfall mm Kazanlak Yamagata	53 139	50 101	65 115	72 99	101 94	85 128	75 179	53 151	56 133	60 125	58 103	65 129
Humidity(%) Kazanlak Yamagata	78 83	75 81	71 76	69 74	71 76	71 81	66 87	63 85	67 85	75 83	79 84	79 83
Rainy days (d) Kazanlak Yamagata	6 18	6 14	8 13	9 10	11 9	10 11	8 13	6 11	6 10	5 9	6 12	7 16
avg. Sun hours (h) Kazanlak Yamagata	5.0 3.7	5.5 4.2	7.1 5.6	9.3 7.1	10.5 8.0	11.6 7.0	11.9 6.2	11.4 6.4	9.0 5.7	6.4 5.1	5.0 4.4	4.9 3.8

Table 2. Physicochemical properties of *R. damascena* Mill. rose oil from Bulgaria (BG) and Japan (JPN).

Characteristics	**Requirements / ISO 9842:2024 test method**	**BG rose oil**	**JPN rose oil**
Appearance	Liquid or more or less crystallized / –	Liquid or more or less crystallized	Liquid or more or less crystallized
Color	Light yellow / –	Colorless to pale yellow liquid	Colorless to pale yellow liquid
Odor	Floral, rosy / –	Fresh, floral rose odor	Light scent of roses
Relative density at 25 °C	0.8480 to 0.8800 /ISO 279	0.864	0.889
Refractive index at 25°C	1.450 to 1.468 /ISO 280	1.463	1.451
Freezing point	Range from + 16°C to 23.5°C /ISO 1041	16	19



(A) Chromatographic profile of *R. damascena* Mill. essential oil from Bulgaria



(B) Chromatographic profile of *R. damascena* Mill. essential oil from Japan

Fig. 1. Chromatographic profile of *R. damascena* Mill. essential oil from (A) Bulgaria (BG) and (B) Japan (JPN): x–axis – retention time (RT) – minutes; y–axis – picoamperes (pA). Sequence number by retention time of identified compounds: 1 – ethanol; 2 – limonene; 3 – linalool; 4 – phenylethanol; 5 – *cis*–rose oxide; 6 – *trans*–rose oxide; 7 – citronellol; 8 – nerol; 9 – geraniol; 10 – eugenol; 11 – methyl eugenol; 12 – heptadecane; 13 – farnesol; 14 – nonadecene; 15 – nonadecane; 16 – eicosane; 17 – heneicosane; 18 – tricosane; 19 – pentacosane; 20 – heptacosane.

Sharpio–Wilxon test showed that every single parameter of the climate for the two locations is with normal distribution (p–value > 0.05). The results from the F–test showed that all pairs are with equal variance for the two locations, (p–value > 0.05). The results of the independent t–test for all pairs of parameters of the climate showed a significant difference at a confidence level of 99.999 for humidity, rainy days and mm rainfall. There is no significant difference between the temperatures in Kazanlak and Yamagata at a confidence level of 99.999.

These findings underscore the distinct climatic regimes of the two regions, with Yamagata's consistently higher humidity and precipitation levels contrasting sharply with Kazanlak's more variable and temperate conditions. Such differences may have implications for agricultural practices, particularly in crops sensitive to moisture, such as *Rosa damascena* Mill.

Soil characteristics

R. damascena Mill. in Bulgaria grows well on silty clay loam to sandy loam soils. It withstands a wide range of soil pH conditions from 6 to 8. Irrigation is necessary in the rose plantation at a frequency of 12–15 days during peak periods.

Yamagata is located in a valley that is surrounded to the east by the Ohu Mountains and to the west by the Echigo Mountains. Yamagata's soil is brown forest soil with a lower humus horizon.

Rose oil characteristics

The traditional method of rose oil production in Bulgaria involves water steam distillation of rose flowers, followed by cohobation of the resulting distillate.

The marked difference in dry weight yield – 0.191% (w/w) for Bulgarian oil *versus* 0.07% (w/w) for Japanese oil – reflects the influence of processing technology, environmental conditions, and seasonal factors. Table 2 displays the physicochemical properties of *R. damascena* Mill. rose oil from Bulgaria (BG) and Japan (JPN).

GC–FID analyses of rose oil. Comparison of the chemical compositions of rose oils from Bulgaria and Japan

The rose oils from the private field of Mr. Takeshi Shimazaki in Bulgaria and those obtained from the field of Mr. Sato Yosuke in Japan were chemically characterized and the chromatographic profiles were compared. The results of both chromatograms are displayed on Table 3.

The compositions of Bulgarian and Japanese rose oils differed significantly. The main aroma components of rose oil – monoterpene alcohols, constituted over 65% of total 20 identified substances in the Bulgarian oil, but only 26% in the Japanese oil.

This aligns with previous studies. Dobreva and co-workers [12] demonstrated that oxygenated monoterpenes are the primary aroma substances in *R. damascena* Mill. essential oil, comprising 70% of all identified components. According to Topalov [13], these are L-citronellol, geraniol, and nerol, which together form the eleopten portion of the rose oil.

A direct comparison of the relative percentages for these key compounds and the major stearoptenes for Bulgarian and Japanese rose oils is as follows: geraniol (22.48 *vs*. 7.05), citronellol (39.18 *vs*. 17.91), and nerol (4.46 *vs*. 1.5), followed by the stearopten fraction: nonadecane (14.89 *vs*. 26.31), nonadecene (0.83 *vs*. 7.38), heneicosane (4.12 *vs*. 8.36) and heptadecane (2.14 *vs*. 5.29).

These compositional deviations indicate that the Japanese rose oil does not comply with the international ISO 9842 standard [11], whereas the Bulgarian oil aligns with it. It should be noted that this work represents the first successful cultivation and chemical characterization of *Rosa damascena* Mill. in Japan. A striking feature of the Japanese oil is its inverse deviation: its aroma compounds are sub-standard, while its stearoptene fractions are supra-standard.

We compared our results with those obtained earlier by Dobreva and Nedeltcheva-Antonova [14], who studied the chemical profiles of *R. damascena* Mill. cultivated in China, as well as their data for seven *R. damascena* Mill. essential oil samples collected from three main rose production micro-regions: Al-Taif, Al-Shafa, and Al-Hada in Saudi Arabia [9].

The data for Chinese oil revealed a total amount of the main terpene alcohols citronellol, nerol, geraniol on average of 52.35 %. The quality of rose oil is predominantly determined by the content and ratio of its main constituents [15]. Furthermore, Ohhloff [16] emphasized that minor components are also critical for defining its unique flavor and fragrance.

A comparative summary of the compositional data for the Bulgarian (BG), Japanese (JPN), Chinese (CHN), and Saudi Arabian (SA) rose oils (in relative %) is presented below: citronellol (39.18 / 17.91 / 36.69 / 19.64 – 28.13), nerol (4.46 / 1.5 / 5.94 / 7.02 – 14.27), geraniol (22.48 / 7.05/ 7.64 /18.29 – 27.23), followed by the stearopten fraction: heptadecane (2.14 / 5.29 / 1.67 / 1.46 – 3.25), nonadecene (0.83 / 7.38 /4.28 / 2.47 – 4.94), nonadecane (14.89 / 26.31 / 11.08 / 6.72 – 16.52), heneicosane (4.12 / 8.36 / 6.71 / 1.33 – 4.16).

This comparison reveals a remarkable singularity. Both the eleopten and stearopten profiles of the Chinese *R. damascena* Mill. oil are close to the Bulgarian benchmark, excluding geraniol, which is sub-standard. The SA oil is also close to the Bulgarian one, although, both CHN and SA oils do not meet the standard. In contrast, the Japanese oil exhibits inverse deviation: its aroma compounds are sub-standard, while its stearoptene fractions are supra-standard.

These findings place a new standpoint within the existing global spectrum of rose oil compositions. The observed variability is likely attributable to specific geographical conditions and processing methods. Comparative studies are needed to define the specific scenarios and applications where one oil may be more advantageous than the other.

Employing advanced chromatographic techniques, e.g., high-resolution mass spectrometry (HRMS), or enantio-multidimensional gas chromatography (MDGC) would be highly valuable to elucidate the complete profile of trace compounds, which could provide further insight into the oil's origin and subtle bioactivities [17].

Table 3. Retention time, relative percentage and retention index for 20 rose oil compounds from Bulgaria and Japan analyzed on a non–polar column EconoCapTM ECTM–5 with GC–FID. RVs–reference values of the main rose oil compounds described in the International Standard ISO 9842:2024 [11]. Relative % – area percentage – the amount of each compound in a mixture, calculated by the ratio of the area of the component to the total area; $\mathrm{RI_{Cal}}$ depicts the calculated RI values, while $\mathrm{RI_{Lit}}$ are the ones obtained from literature (NIST database).

Sequence number by retention time (№)	Compound (RVs– ISO 9842:2024)	Primary Functional Group	Chemical Family / Sub–Class	Retention Time (RT) BG	Relative % BG	$\mathrm{RI_{Cal}/RI_{Lit}}$ BG	Retention Time (RT) JPN	Relative % JPN	$\mathrm{RI_{Cal}/RI_{Lit}}$ JPN
1	Ethanol (≤ 3.0 %)	Alcohol	Primary Alcohol	4.94	0.46	NA	4.84	0.00	NA
2	Limonene	Hydrocarbon (Alkene)	Monoterpene Hydrocarbon	21.81	0.02	1027/1020	22.11	0.12	1023/1020
3	Linalool	Alcohol	Monoterpene Alcohol	25.14	0.38	1105/1100	24.94	0.39	1098/1100
4	Phenylethanol (≤ 2.5 %)	Alcohol	Aromatic Alcohol	25.39	0.73	1096/1073	25.18	0.46	1092/1073
5	*Cis*–rose oxide	Ether	Cyclic Ether (Pyran)	25.9	0.10	1106/1097	25.69	0.12	1104/1097
6	*Trans*–rose oxide	Ether	Cyclic Ether (Pyran)	26.8	0.05	1110/1079	26.64	0.06	1102/1079
7	Citronellol (20.0–34.0 %)	Alcohol	Monoterpene Alcohol	31.9	39.18	1158/1150	31.65	17.91	1155/1150
8	Nerol (5.0–12.0 %)	Alcohol	Monoterpene Alcohol	32.02	4.46	1231/1220	31.75	1.50	1234/1220
9	Geraniol (14.0–22.0 %)	Alcohol	Monoterpene Alcohol	33.15	22.48	1234/1245	32.84	7.05	1233/1245
10	Eugenol	Alcohol (Phenolic)	Allylphenol, Phenylpropanoid	37.9	1.08	1361/1350	37.62	1.02	1359/1350
11	Methyl eugenol (0.8–3.0 %)	Ether (Methoxy)	Phenylpropanoid	39.7	0.57	1369/1368	39.55	0.32	1367/1368
12	Heptadecane (1.0–2.5 %)	Hydrocarbon (Alkane)	n–Alkane (Saturated)	54.7	2.14	1705/1700	54.71	5.29	1702/1700
13	Farnesol	Alcohol	Sesquiterpene Alcohol	54.39	0.55	1672/1667	54.89	2.26	1668/1667
14	Nonadecene (1.5–4.0 %)	Hydrocarbon (Alkene)	n–Alkene (Unsaturated)	61.74	0.83	1877/1875	61.78	7.38	1879/1875
15	Nonadecane (8.0–15.0 %)	Hydrocarbon (Alkane)	n–Alkane (Saturated)	62.81	14.89	1903/1900	62.9	26.31	1902/1900
16	Eicosane	Hydrocarbon (Alkane)	n–Alkane (Saturated)	65.74	1.79	1998/2000	65.67	1.83	2002/2000
17	Heneicosane (3.0–5.5 %)	Hydrocarbon (Alkane)	n–Alkane (Saturated)	68.38	4.12	2105/2100	68.39	8.36	2101/2100
18	Tricosane	Hydrocarbon (Alkane)	n–Alkane (Saturated)	72.64	0.29	2308/2300	72.59	1.52	2305/2300
19	Pentacosane	Hydrocarbon (Alkane)	n–Alkane (Saturated)	76.24	0.08	2513/2500	76.19	0.49	2509/2500
20	Heptacosane	Hydrocarbon (Alkane)	n–Alkane (Saturated)	80.26	0.07	2711/2700	80.18	0.38	2708/2700

Statistical analysis

Main advantage of using a hypothesis test for paired binomial proportion compared to the other statistical tests is the control for within–sample variability, which is the difference in mixture concentrations due to sample handling. Other is the disadvantage of independent tests (e.g., chi–square) assuming unrelated groups, increasing false positives if pairs are correlated.

We used a hypothesis test for paired binomial proportion test to compare the relative percentage concentrations of compounds of rose oil produced by classical technology (industrial with cohobation and semi-industrial distillation) from *R. damascena* Mill. grown in Bulgaria, and those obtained from the same roses grown in Japan. We included the following components (Table 2, column 1 – sequence number by retention time: RT 1 – ethanol; RT 4 – phenylethyl alcohol, RT 7–citronellol, RT 8–nerol, RT 9– geraniol, RT 10–eugenol, RT 11 – methyl eugenol. On the other hand, only five of these components in Japanese rose oil, RT 2 – limonene, RT 3 – linalol, RT 4 – *cis*–rose oxide, RT 5 – *trans*–rose oxide, RT 13 – farnesol, have higher percentage concentrations than those in Bulgarian rose oil, as can be seen from the graph in Fig. 2 illustrating these differences. Using this approach, we calculated that there are seven "superior" for the 12 trails, corresponding to the main identified eleopten components for Bulgarian rose oil. It was estimated for this sample that the Bulgarian rose oil can be assessed as 58.3%, with a p–value = 0.7744 which is greater than 0.05, so we reject the null hypothesis with 95% significance level, there is significant difference between the two oils. The Bulgarian rose oil is superior to Japanese oil when calculating probability of superiority based on the difference between relative concentrations.

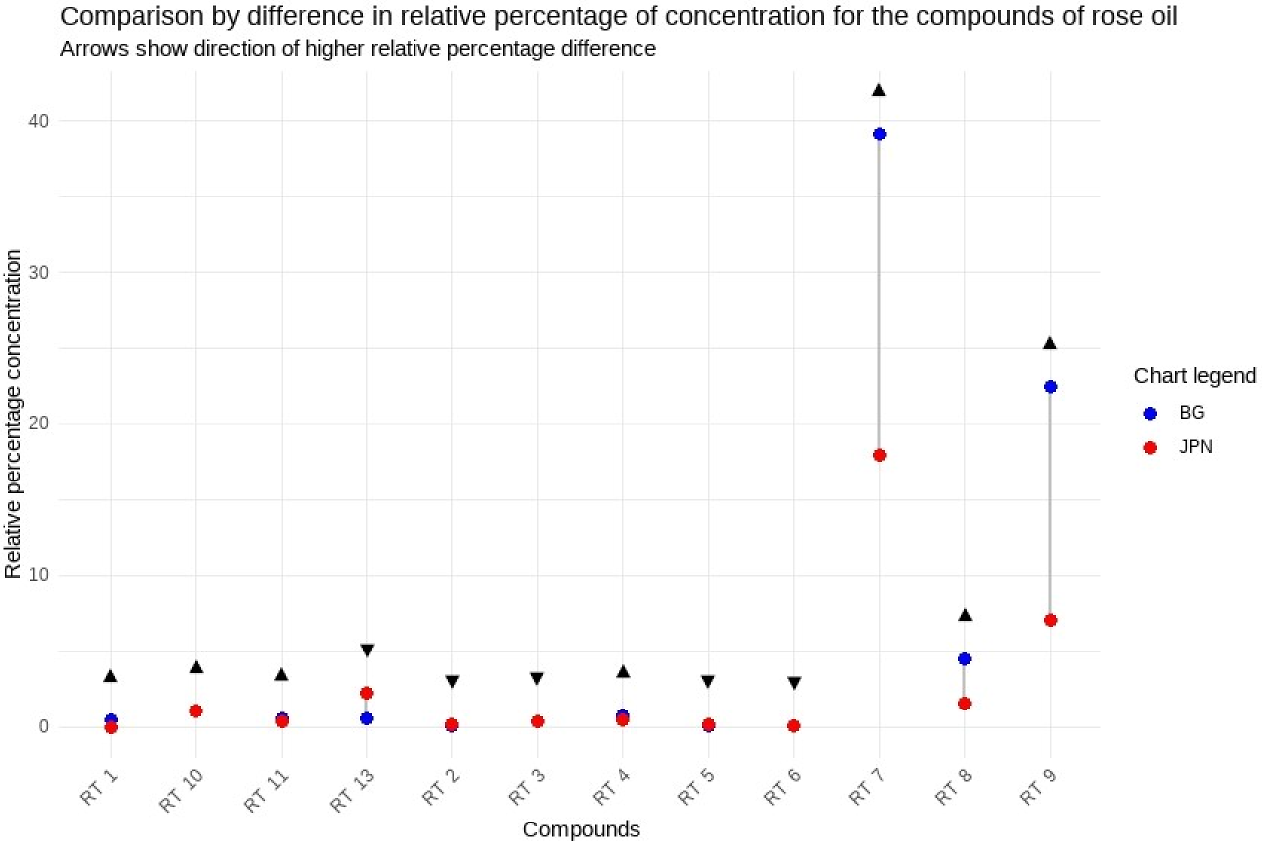


Fig. 2. Graph depicting the binomial test comparing the percentage differences in relative percentage concentrations of components from the eleopten group for rose oils from Bulgaria and Japan.

As easily noticeable from Fig. 2, there are large differences in percentage concentrations of compounds, in which Bulgarian oil significantly exceeds Japanese oil (seven "superior" against five): RT 7 (citronellol) – 21.27%; RT 9 (geraniol) – 15.43%; RT 8 (nerol) –2.96%; RT 11 (methyl eugenol) – 0.25%; RT 10 (eugenol) – 0.06%.

CONCLUSION

R. damascena Mill. of Bulgarian origin cultivated in Japan produced rose oil displaying markedly different chemical composition compared to oil distilled in Bulgaria. GC–FID analysis combined with a paired binomial proportion test (95% confidence) showed Bulgarian rose oil to be superior by 58.3% in eleoptene content. These differences can be primarily attributed to environmental conditions, as Yamagata is characterized by persistently high humidity and rainfall, in contrast to the more moderate climate of Kazanlak. Such climatic disparities, together with soil variability and production technology, strongly influence the growth of *R. damascena* Mill. and the quality of the essential oil. Consequently, Japanese rose oil does not fully meet international standard requirements, underlining the critical role of local ecological factors in rose oil production.

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