Horticulture and Forestry Society of Transylvania

Sevindik E *et al.* (2023)
Notulae Scientia Biologicae
Volume 15, Issue 1, Article number 11377
DOI:10.15835/nsb15111377
Research Article

Notulae Scientia Biologicae

Chemical composition of *Vitex agnus-castus* L. flowers collected from populations distributed in Aydin, Türkiye

Emre SEVİNDİK[1]*, Deniz KARAKOYUN[1], İbrahim M. GÜLDERE[1], Fatih BORHAN[1], Elif APAYDIN[2], Emre KABİL[3]

[1]*Aydın Adnan Menderes University, Faculty Agriculture, Department of Agricultural Biotechnology, South Campus, Cakmar, Aydin, Türkiye; ph.d-emre@hotmail.com (*corresponding author); denizkrkyn98@gmail.com; mguldere00@gmail.com; fatihborhan986@gmail.com*

[2]*Giresun University, Center Research Laboratory Application and Research Center, Giresun, Türkiye; eliferenapaydin@gmail.com*

[3]*Yalova University, Armutlu Vocational School, Food Processing Division, 77500 Yalova, Türkiye; emre.kabil@yalova.edu.tr*

Abstract

Essential oils (EOs) are compounds that are biosynthesized autonomously by aromatic plants as their secondary metabolites. *Vitex agnus-castus* plant leaves, flowers and fruits are of pharmacological importance. In this study, the chemical composition determination of the essential oils of the *Vitex agnus-castus* flowers with different colors (white, pink, purple) growing in Aydin ecological conditions was carried out with the extraction using Clevenger hydro-distillation apparatus and then the essential oil composition was determined by Gas Chromatography-Mass Spectrometer (GC-MS). As a result of the study, 'Çakmar' pink-flowered population had the main component (-)-allospathulenol (14.59%), 'Çakmar' purple-flowered and 'Koçarli' purple-flowered populations had the main component pyrrolo (3,2,1-jk) carbazole (14.42% and 14.68%, respectively), while 'Çakmar' white flowered, 'Koçarli' white flowered and 'Koçarli' pink flowered populations had the main component caryophyllene (15.54%, 12.64%, and 19.05 respectively).

Keywords: GC-MS; essential oils; *Vitex agnus-castus*; Türkiye

Introduction

All over the world, various plants have been used for various reasons. Especially, medicinal and aromatic plants are grown for use in preventing diseases, as flavoring agents in incense, cosmetics, preserving food and improving the taste of many types of food (Toplan *et al*., 2022; Yilmaz *et al*., 2022). In addition, many studies reporting medicinal plants with important biological activities such as antioxidant, antimicrobial, antiviral, and antiproliferative activities have been revealed (Zhang *et al*., 2014; Suleman *et al*., 2021; Gecer, 2022). *Vitex* is one of the largest genera of the Lamiaceae family (formerly belonging to the Verbenaceae family), and consists of 217 species. Some of the known and studied *Vitex* species are *Vitex negundo Vitex agnus-castus, Vitex trifolia, Vitex rotundifolia, Vitex cymosa* and *Vitex peduncularis* (Souto *et al*., 2020; Kamal *et al*., 2022). The *Vitex* genus is represented by two species (*V. agnus-castus* and *V. pseudo-negundo* (Hausskn. Ex Bornm.) Hand.-Mazz) in

Received: 09 Nov 2022. Received in revised form: 10 Feb 2023. Accepted: 07 Mar 2023. Published online: 22 Mar 2023.
From Volume 13, Issue 1, 2021, Notulae Scientia Biologicae journal uses article numbers in place of the traditional method of continuous pagination through the volume. The journal will continue to appear quarterly, as before, with four annual numbers.

the flora of Türkiye (Eryiğit *et al.*, 2015). *Vitex agnus-castus* is defined as vitex, agnos and lygos by ancient literature (Kolancı, 2017). In Turkish, is known as 'hayıt, ayd, hayed, beşparmak grass, and bitter ayit' (Kavaz *et al.,* 2022). It spreads especially in the Eastern Black Sea, Marmara, Aegean, Mediterranean, and partially in the Southeastern Anatolia region of Türkiye (Fakir *et al.,* 2014). When this plant is looked at from an aesthetic point of view; the length of its spike-shaped flowers, its plump flower structure, its rich colour range from white-light pink to purple, its sustained blooming, and the striking appearance of its large seeds on the spike formed after its flowers, increase the variety of usage areas in herbal landscaping (Girmen and Karagüzel, 2005). *Vitex agnus-castus* is rich in numerous bioactive substances it is a well-known herbal plant (Zhelev *et al.*, 2022). *V. agnus castus* fruits, flowers and leaves contain phenolic acids and derivatives, flavonoids, tannins, iridoids and diterpenoids (Sarikurkcu *et al.*, 2009; Săvulescu *et al.*, 2019; Bakr *et al.*, 2020). Since ancient times, local flowers and fruits have been applied in various cultures (Özderin, 2021). Traditionally, chasteberry extract has been used to treat many gynecological conditions, including menstrual disorders, premenstrual syndrome (PMS), corpus luteum insufficiency, infertility, acne, menopause, impaired lactation, and various gynecological problems (Stojković *et al.*, 2011; Ogaly *et al.*, 2021). In this study, essential oil content of different colored (white, pink, purple) *V. agnus-castus* flowers grown in Aydın ecological conditions was determined.

Materials and Methods

Collection of plant samples and extraction of essential oils

For the essential oil extraction process, approximately 500 grams of *V. agnus-castus* flower samples were collected from different regions of Aydın, Türkiye, six populations with white, purple, and pink flowers in three different colors. The collected flower samples were kept with their moisture evaporated in an oven at 35 °C for 24 hours, then distilled for about 4 hours by hydro-distillation method in the Clevenger apparatus to extract the essential oil, and kept at +4 °C for chromatographic analysis.

Chromatographic analysis by GC-MS

The qualitative analysis of the essential oil obtained from the plant sample was dedected by Gas Chromatography-Mass Spectrometry (GC-MS) analysis system. Helium was used as the carrier gas and separation was performed with an HP-5MS capillary column coated with 5% phenyl-methylpolysiloxane (30.0 m x 250µm x 0.25 µm). GC-MS temperature program was applied from 50 °C to 80 °C ramped with 5 °C/min waiting for 2 minutes, 80 °C to 100 °C ramped with 2 °C/min waiting for 1 minute, 100 °C to 150 °C ramped with 2 °C/min waiting for 1 minute, 150 °C to 240 °C ramped with 2 °C/min waiting for 1 minute and finally from 240 °C to 270 °C ramped with 2 °C/min waiting for 7 minutes (Rambla *et al.*, 2015; Apaydın, 2018). The volatile compounds which dedected were identified with Wiley and NIST mass spectrometry libraries.

Results and Discussion

Essential oils (EOs) which are biosynthesized by aromatic plants as their secondary metabolites and represented by a strong odor are natural, volatile and complex mixtures of lipophilic compounds, often including terpenes, phenol-derived aromatic compounds and aliphatic compounds (Bakkali *et al.*, 2008; Santos *et al.*, 2016; Marić *et al.*, 2021). There have been numerous studies to determine the chemical composition of essential oils obtained from chasteberry (Moudachirou *et al.*, 1998; Senatore *et al.*, 2003; Sarikurkcu *et al.*, 2009; Stojković *et al.*, 2011; Duymuş *et al.*, 2014; Fakir *et al.*, 2014; Gulsoy Toplan *et al.*, 2015; Ulukanlı *et al.*, 2015; Eryiğit *et al.*, 2015; Tin *et al.*, 2017; Zhelev *et al.*, 2022 etc.). In our study, essential oil composition of *V.*

agnus-castus flowers analyzed (components with a total ratio of ≥2%) is shown in Table 1, while GC-MS chromatogram images are shown in Figures 1, 2, 3, 4, 5 and 6. As a result of the study, 'Çakmar' pink-flowered population had the main component (-)-allospathulenol (14.59%), 'Çakmar' purple-flowered and 'Koçarlı' purple-flowered populations had pyrrolo (3,2,1-jk)carbazole (14.42% and 14.68% respectively), while 'Çakmar' white flowered, 'Koçarlı' white flowered and 'Koçarlı' pink flowered populations had the main component of caryophyllene (15.54%, 12.64%, and 19.05 respectively). PCA (Principal Component Analysis) (simca 14.1) was used to determine the effect of flower varieties on volatile compounds.

Table 1. Composition of the essential oil from *Vitex agnus-castus* flowers of different populations

Çakmar pink flowers			Çakmar purple flowers			Çakmar white flowers		
RT	**Component**	**%**	**RT**	**Component**	**%**	**RT**	**Component**	**%**
7.423	α-pinene	2.45	21.516	cyclohexene	3.24	10.530	1.8-cineole	2.22
8.539	sabinene	2.99	24.446	trans β-farnesene	4.63	21.499	α-terpinyl propionate	4.90
15.108	cyclopentasiloxane	2.05	25.556	bicyclogermacrene	6.08	23.490	**caryophyllene**	15.54
21.591	1-p-menthen-8-yl acetate	6.19	27.839	spathulenol	6.11	24.423	trans-β-farnesene	4.66
23.554	caryophyllene	5.53	27.965	caryophyllene oxide	4.28	27.782	spathulenol	6.36
24.480	trans β-farnesene	4.35	28.480	ledol	2.37	27.925	caryophyllene oxide	5.85
28.051	**(-)-allospathulenol**	14.59	29.418	delta.-cadinene	4.08	29.390	delta.-cadinene	5.57
28.120	caryophyllene oxide	3.71	34.866	guaia-3,9-diene	2.07	36.187	n-(m-fluorophenyl)-maleımıde	4.68
28.675	ledol	2.56	36.250	n-(m-fluorophenyl)-maleımıde	13.70	36.977	pyrrolo(3,2,1-jk) carbazole	11.46
29.447	. α-cadinol	2.57	36.685	1-(3-hexyl)-2,5-dimethylbenzene	3.57	38.688	α-selinene	4.29
36.279	4(1h)-pteridinone	6.54	37.040	**pyrrolo(3,2,1-jk) carbazole**	14.42	39.346	sigmosceptrellin-b	2.34
37.103	pyrrolo(3,2,1-jk) carbazole	10.77	38.728	bakkenolıde-a-dıol	6.28			
38.763	cycloheptane	4.67						
39.386	kolavelool	2.29						
Koçarlı purple flowers			**Koçarlı white flowers**			**Koçarlı pink flowers**		
RT	**Component**	**%**	**RT**	**Component**	**%**	**RT**	**component**	**%**
8.493	sabinene	3.49	9.987	β-phellandrene	2.12	6.811	α-pinene	3.00
10.513	1.8-cineole	3.79	25.179	(+)-2-carene	6.10	8.058	sabinene	4.24
21.505	4-terpinenyl ester of isobutanoicacid	5.63	28.915	**caryophyllene**	19.05	9.998	β-phellandrene	2.19
23.485	caryophyllene	7.47	32.468	bicyclogermacrene	6.19	15.360	cyclopentasiloxane	5.32
24.423	trans-.β.-farnesene	4.08	39.129	(+)-epi-bicyclosesquiphellandrene	2.54	25.110	(+)-2-carene	3.34
25.522	bicyclogermacrene	5.23	45.486	2-methyl-6-propylpyridine-3-carboxylic acid	3.02	28.829	**caryophyllene**	12.64
27.811	spathulenol	7.25	48.810	(z)-β-caryophyllene	3.32	30.563	trans-. β-farnesene	5.38
27.942	caryophyllene oxide	4.23	50.407	1,2,4-trıazolo(3,4-c)(1,2,4)-benzotrıazın-1(5h)-one	2.98	32.463	bicyclogermacrene	4.50
29.396	α-cadinol	3.53	51.437	β-isomethylıonone	4.96	45.520	2h-1,4-benzothiazine	3.04
36.222	n-(m-fluorophenyl)-maleımıde	13.15	53.685	levopimaradiene	2.38	48.822	(z)-β-caryophyllene	3.08
36.674	1-(3-hexyl)-2,5-dimethylbenzene	3.54	55.682	cycloheptane	2.60	50.464	1,2,4-trıazolo(3,4-c)(1,2,4)-benzotrıazın-1(5h)-one	3.49
37.006	**pyrrolo(3,2,1-jk) carbazole**	14.68				51.431	β-ısomethylıonone	3.74
38.711	bakkenolıde-a-diol	6.72				52.879	3-fluoro-5,7-dimethylquinol-2(1h) one	3.67

39.358	sigmosceptrellin-b	2.62				55.654	methylpropyleyne	7.73
						56.604	kolavelool	3.57
						68.706	4,4'-dimethyl-2,2',5,5'-tetramethoxy-1,1'-biphenyl	2.02

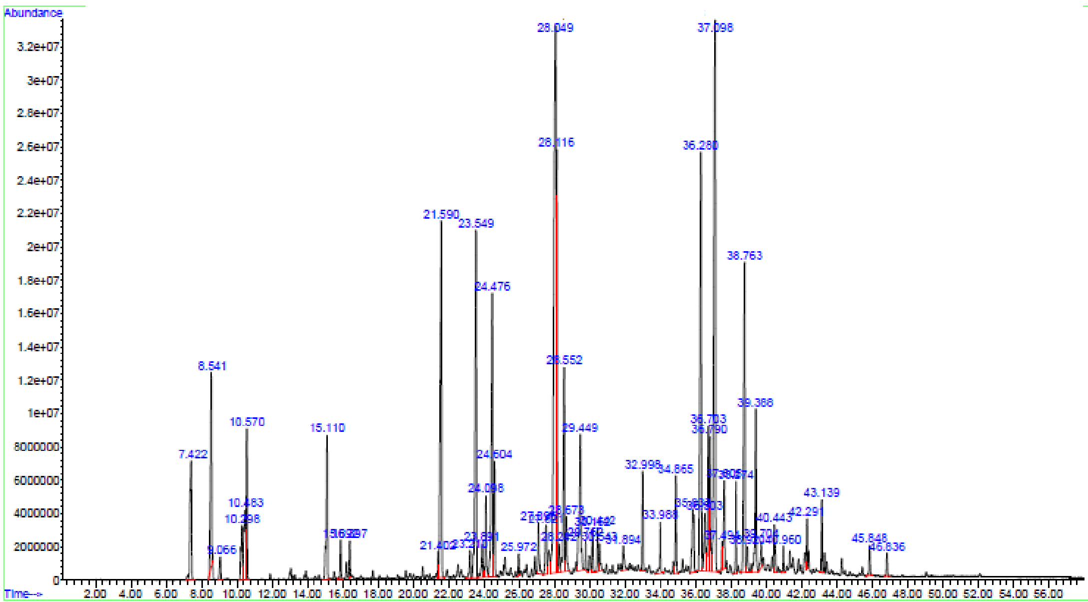

Figure 1. Gas chromatogram of the essential oil of 'Çakmar' pink flowers

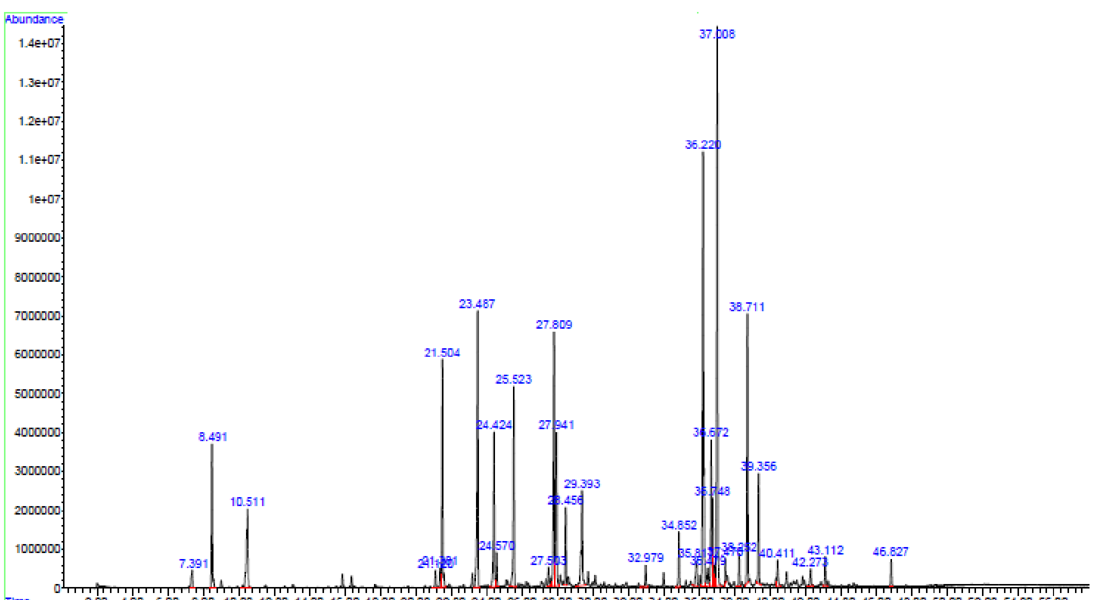

Figure 2. Gas chromatogram of the essential oil of 'Koçarlı' purple flowers

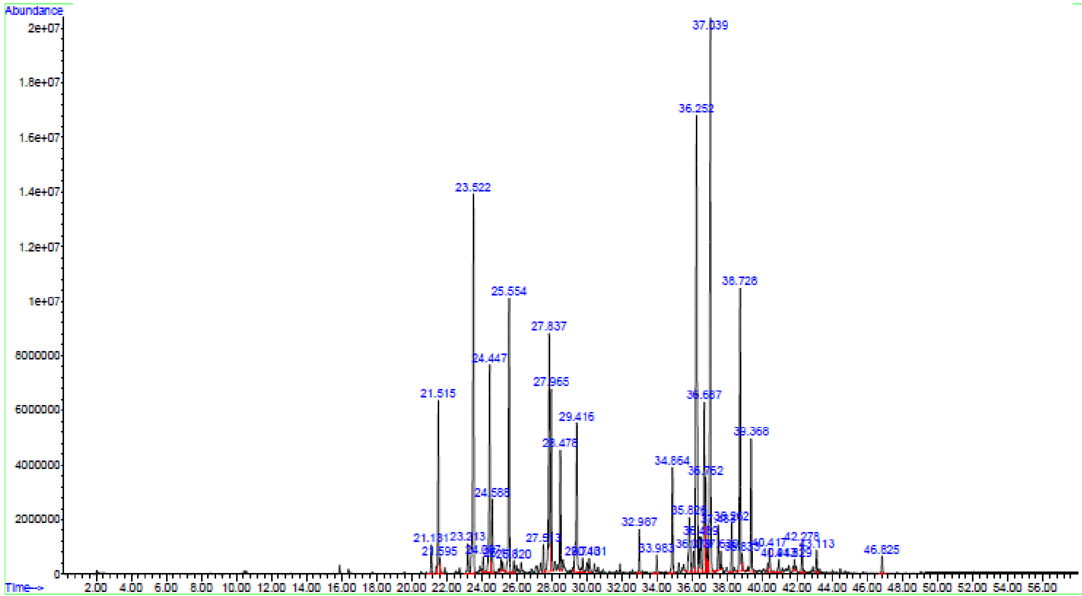

Figure 3. Gas chromatogram of the essential oil of 'Çakmar' purple flowers

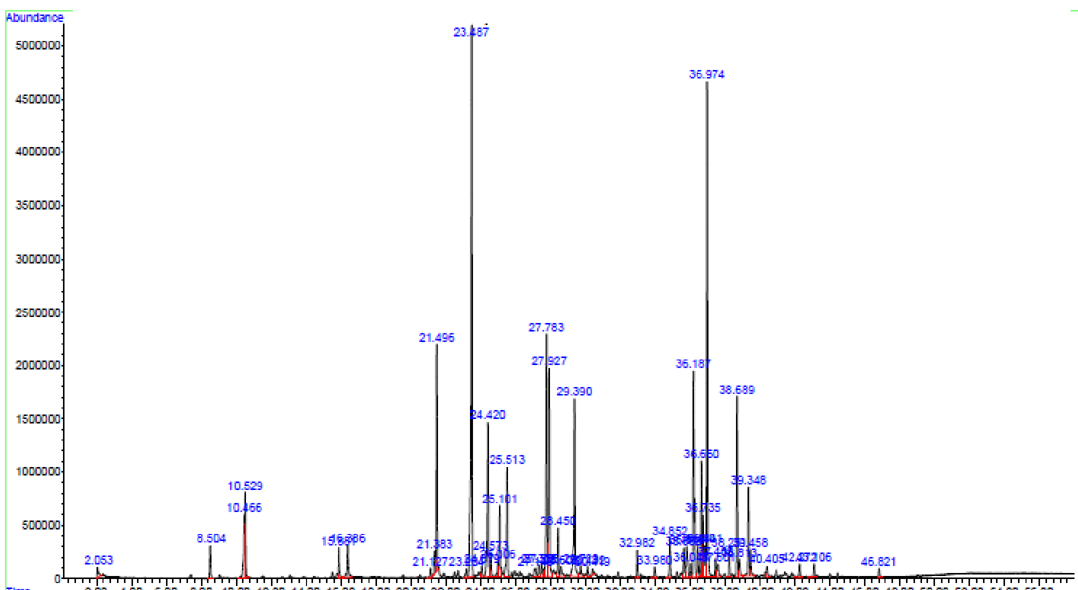

Figure 4. Gas chromatogram of the essential oil of 'Çakmar' white flowers

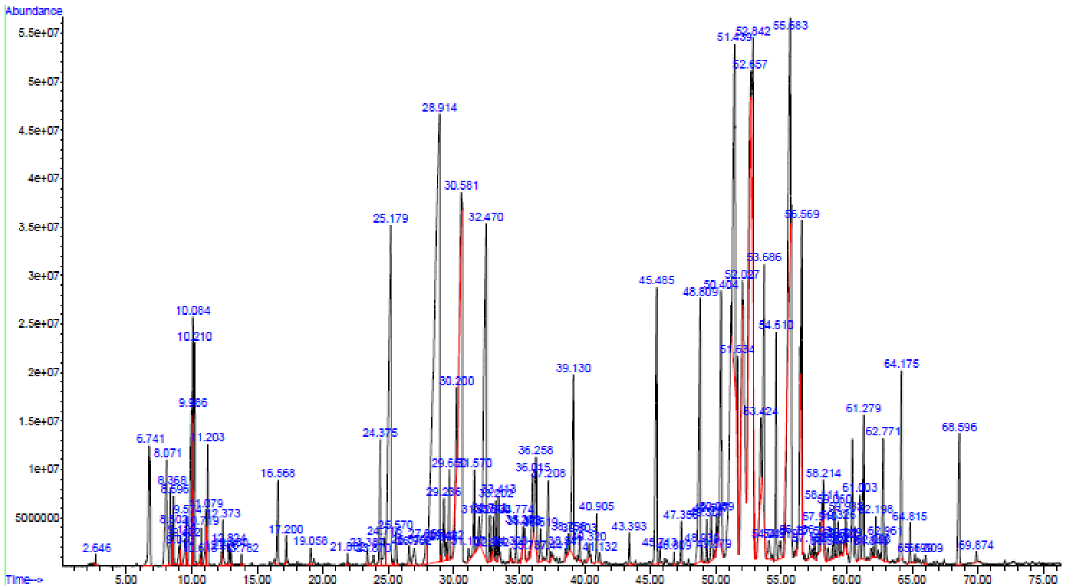

Figure 5. Gas chromatogram of the essential oil of 'Koçarlı' white flowers

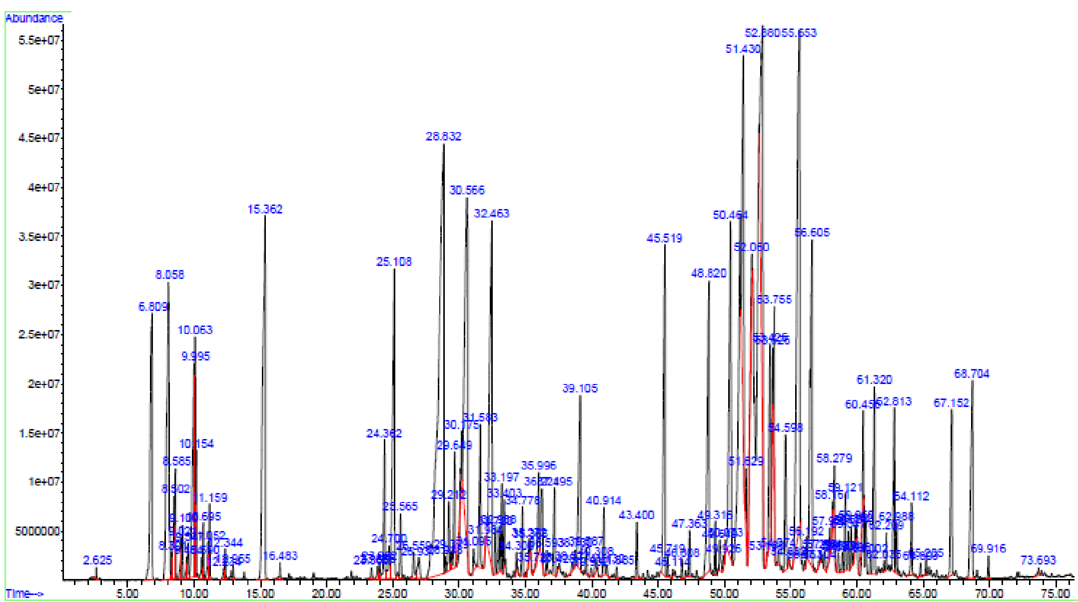

Figure 6. Gas chromatogram of the essential oil of 'Koçarlı' pink flowers

The biplot diagram for the first and second components shows the correlation of the studied flowers based on the volatile compounds detected. According to the data obtained, the first and second components (PC1 and PC2) explained 59.7% of the total variance. Except for 'Çakmar' purple flower, 'Çakmar' and 'Koçarlı' flower populations were collected in two different groups according to PC1 (Figure 7).

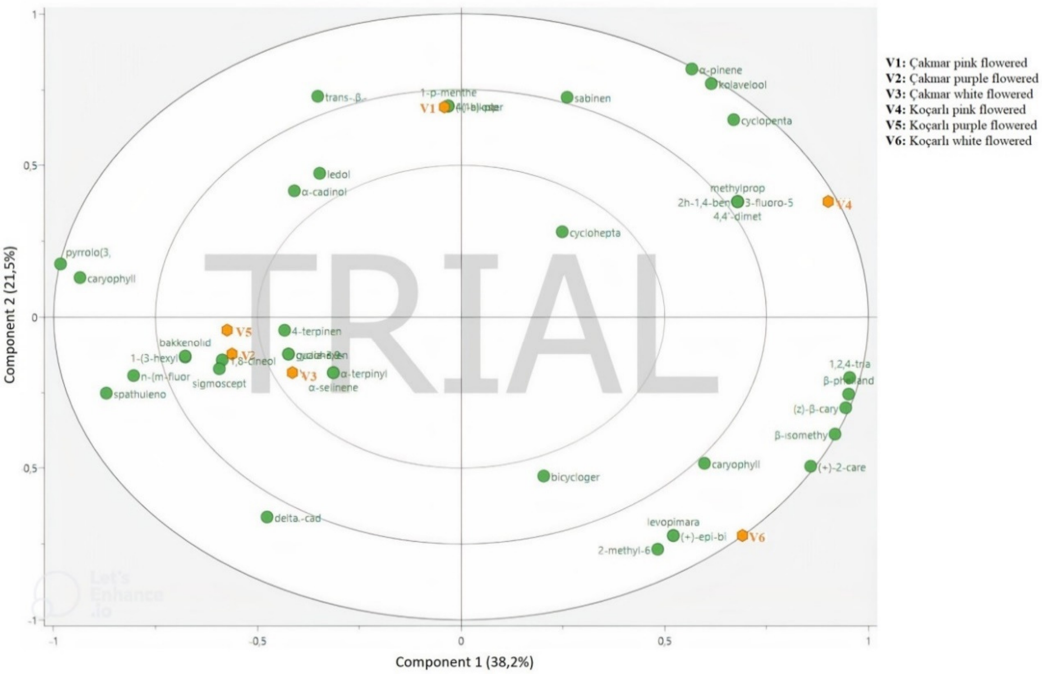

Figure 7. Biplot of the first two principal components

In chasteberry fruits collected from Aydın,Türkiye, Tin *et al.* (2017) determined 1.8 cineole (8.24%) as the main component. Gulsoy Toplan *et al*. (2015) examined the essential oils of *V. agnus-castus* fruits collected from Zonguldak, Edirne, Balıkesir, Muğla, Antalya and the main components were determined as β-caryophyllene (11.7%), bicyclogermacrene (22.1%), 1.8-cineole (17.3%), 1.8-cineole (13.2%), sabinene and bicyclogermacrene (12.1%), respectively. In the essential oils of the fruits of the chasteberry plant collected from Izmir/Turkey, Eryiğit *et al. (*2015) determined trans-caryophyllene (19.17%) as the main component. Duymuş *et al.* (2014) determined sabinene (22.7%) and 1.8-cineole (22.4%) as the main components of fruits and the fruitless herbs, respectively, of *V. agnus-castus* collected from İzmir, Türkiye. Fakir *et al.* (2014) determined essential oil content of *V. agnus castus* collected from Isparta, Türkiye during the flowering period and the main component was α-pinene (26.99), while the main component was 1.8 cineole (28.34%) during the fruit ripening period. Ulukan *et al.* (2015) determined the main component as 1.8-cineole (24.38%) from essential oils of chasteberry leaves collected from Osmaniye, Türkiye. Sarikurkcu *et al.* (2009) identified 1.8-cineole (24.98%) as the main component of chasteberry fruits from Manisa, Türkiye. Senatore *et al.* (2003) determined 1.8-cineol (21.6%) as the most abundant in the essential oil obtained from the white flowered fruit of *Vitex agnus-castus* collected from İçel, Türkiye, and caryophyllene (30.9%) as the most in essential oil obtained from the fruits of the purple flowered ones. In Montenegro, Stojkovic *et al*. (2011) found the main component as sabinene (17.8%) in immature chasteberry fruits, 1.8-cineole (16.3%) in mature fruits, and 1.8-cineol (22.0%) in leaves. Bakr *et al*. (2020) have determined 1.8 cineole (44.98 %) as the most abundant component in leaves of *V. agnus-castus* collected from the city of Giza, Egypt. Zhelev *et al.* (2022) identified 1.8-cineole (16.9–18.8%) as the main component in chasteberry fruits collected from South-Central Bulgaria and North-East Bulgaria. Moudachirou *et al.* (1998) determined 1.8-cineole (22.6%) as the main component in the essential oil content of the leaves of *Vitex agnus-castus* collected from Benin. In the past, in some studies of essential oils on the fruits, leaves and flowers of the *Vitex agnus-castus,* 1.8 cineole, α-pinene, caryophyllene, trans-caryophyllene, β-caryophyllene, sabinene and bicyclogermacrene were determined as main components.

When we compare our study with previous ones, the results are not consistent. The reason for this could be that the geographical and environmental conditions in which the samples distributed were different, confirming that the essential oil composition and content of the plants could be different (Sevindik *et al.,* 2016). In our study, for 'Çakmar' white flower, 'Koçar' white flower and 'Koçarlı' pink flower populations, the main component was determined as caryophyllene. Sesquiterpenoids are an extremely large group of secondary metabolites found in plants. Among them, the caryophyllene or β-caryophyllene group is the most common in nature. In the last few years, β-caryophyllene has represented an important topic of study (Francomano *et al.*, 2019; Gyrdymova and Rubtsova, 2021). In the past, the antimicrobial effect of β-caryophyllene has been tested against some human pathogens (Dahham *et al.*, 2015).

Conclusions

In this study, we evaluated the chemical composition of essential oils obtained from white, pink and purple chasteberry flowers. As a result, we found (-)-allospathulenol, pyrrolo(3,2,1-jk)carbazole and caryophyllene as main components. These findings may be a source for further antimicrobial, anti-inflammatory, anti-cancer, and antioxidant studies.

Authors' Contributions

E.S, D.K İ.M.G and F.B collected flowers samples. The experiments were performed and analyzed by E.S. E.A and E.K. E.S, E.A and E.K wrote the paper.

All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

Acknowledgements

This research was supported by the TUBITAK 2019-2/2209-A (Project no: 1919B011904175)

Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

References

Apaydın E (2018). Investigation of antioxidant and antimicrobial activity of essential oil from *Salvadora persica* (miswak). Sakarya University Journal of Science 22(3):1001-1006. *https://doi.org/10.16984/saufenbilder.332517*

Bakkali F, Averbeck S, Averbeck D, Idaomar M (2008). Biological effects of essential oils—A review. Food and Chemical Toxicology 46(2):446-475. *https://doi.org/10.1016/j.fct.2007.09.106*

Bakr RO, Zaghloul SS, Hassan RA, Sonousi A, Wasfi R, Fayed MA (2020). Antimicrobial activity of *Vitex agnus-castus* essential oil and molecular docking study of its major constituents. Journal of Essential Oil Bearing Plants 23(1):184-193. *https://doi.org/10.1080/0972060X.2020.1727368*

Dahham SS, Tabana YM, Iqbal MA, Ahamed MB, Ezzat MO, Majid AS, Majid AM (2015). The anticancer, antioxidant and antimicrobial properties of the sesquiterpene β-caryophyllene from the essential oil of *Aquilaria crassna*. Molecules 20(7):11808-11829. *https://doi.org/10.3390/molecules200711808*

Duymuş HG, Çiftçi GA, Yıldırım ŞU, Demirci B, Kırımer N (2014). The cytotoxic activity of *Vitex agnus castus* L. essential oils and their biochemical mechanisms. Industrial Crops and Products 55:33-42. *https://doi.org/10.1016/j.indcrop.2014.01.041*

Eryiğit T, Çig A, Okut N, Yıldırım B, Ekici K (2015). Evaluation of chemical composition and antimicrobial activity of *Vitex agnus castus* L. fruits' essential oils from West Anatolia, Turkey. Journal of Essential Oil Bearing Plants 18(1):208-214. *https://doi.org/10.1080/0972060X.2014.976665*

Fakir H, Erbaş S, Özen M, Dönmez IE (2014). The effects of different harvest dates on essential oil content and composition in chaste tree (*Vitex agnus-castus* L.). European Journal of Science and Technology 1(2):25-28.

Francomano F, Caruso A, Barbarossa A, Fazio A, La Torre C, Ceramella J, … Sinicropi MS (2019) β-Caryophyllene: a sesquiterpene with countless biological properties. Applied Sciences 9(24):5420. *https://doi.org/10.3390/app9245420*

Gecer EN (2022). Chemical constituents of essential oil of *Syringa vulgaris* flowers. Turkish Journal of Agriculture-Food Science and Technology 10(6):1108-1111. *https://doi.org/10.24925/turjaf.v10i6.1108-1111.5165*

Girmen B, Karagüzel O (2005). Gazipaşa (Antalya) yöresi doğal Hayıt'larının (*Vitex agnus-castus* L.) seleksiyonu-I: Seçilen tiplerin özellikleri. Akdeniz University Journal of the Faculty of Agriculture 18(3):385-396.

Gulsoy Toplan G, Kurkcuoglu M, Husnu Can Baser K, Sariyar G (2015). Composition of the essential oils from samples of *Vitex agnus-castus* L. growing in Turkey. Journal of Essential Oil Research 27(4):337-342. *https://doi.org/10.1080/10412905.2015.1025920*

Gyrdymova YV, Rubtsova SA (2021). Caryophyllene and caryophyllene oxide: a variety of chemical transformations and biological activities. Chemical Papers 1-39. *https://doi.org/10.1007/s11696-021-01865-8*

Kamal N, Mio Asni NS, Rozlan INA, Mohd Azmi MAH, Mazlan NW, Mediani A, … Edrada-Ebel RA (2022.) Traditional medicinal uses, phytochemistry, biological properties, and health applications of *Vitex* sp. Plants 11(15):1944. *https://doi.org/10.3390/plants11151944*

Kavaz A, Işık M, Dikici E, Yüksel M (2022). Anticholinergic, antioxidant, and antibacterial properties of *Vitex agnus-castus* L. seed extract: Assessment of its phenolic content by LC-MS/MS. Chemistry & Biodiversity 19:e202200143. *https://doi.org/10.1002/cbdv.202200143*

Kolancı BY (2017). Traditional uses of chaste tree (*Vitex agnus-castus* L.) in Karahayıt (Denizli). Journal of Interdisciplinary Mediterranean Studies 3:49-60. *https://doi.org/10.18367/Pha.17002*

Marić T, Friščić M, Marijanović Z, Maleš Ž, Jerković I (2021). Comparison of volatile organic compounds of *Sideritis romana* L. and *Sideritis montana* L. from Croatia. Molecules 26:5968. *https://doi.org/10.3390/molecules26195968*

Moudachirou M, Ayedoun MA, Sossou PV, Garneau FX, Gagnon H, Jean FI (1998). Chemical composition of leaf oil of *Vitex agnus-castus* L. from Benin. Journal of Essential Oil Research 10(3):343-344. *https://doi.org/10.1080/10412905.1998.9700917*

Ogaly HA, Alsherbiny MA, El Badawy SA, Abd-Elsalam RM, Li CG, Azouz AA (2021). Gastroprotective effects and metabolomic profiling of chasteberry fruits against indomethacin-induced gastric injury in rats. Journal of Functional Foods 86:104732. *https://doi.org/10.1016/j.jff.2021.104732*

Özderin S (2021). Determination of phenolic components of *Vitex agnus-castus* L. (Verbenaceae) from Muğla-Ula region in Turkey. Mustafa Kemal University Journal of Agricultural Sciences 26(3):692-699. *https://doi.org/10.37908/mkutbd.937814*

Rambla JL, López-Gresa MP, Belle's JM, Granell A (2015). Metabolomic profiling of Jose' G. Vallarino et al. plant tissue. In: Alonso JM, Stepanova AN (Eds). Plant Functional Genomics, Methods in Molecular Biology. Springer, Berlin, Heidelberg, New York, pp 221-235.

Santos DC, Ribeiro-Santos R, Ventura LAF, Melo NR, Costa B, Rojas EEG, Salgado NL (2016). Antimicrobial activity studies and characterization of cellulose acetate films containing essential oils. Italian Journal of Food Science 28(2):248-257.

Sarikurkcu C, Arisoy K, Tepe B, Cakir A, Abali G, Mete E (2009). Studies on the antioxidant activity of essential oil and different solvent extracts of *Vitex agnus castus* L. fruits from Turkey. Food and Chemical Toxicology 47(10):2479-2483. *https://doi.org/10.1016/j.fct.2009.07.005*

Săvulescu E, Georgescu MI, Luchian V, Popa V (2019). Some morphological and anatomical particularities in *Vitex agnus-castus* L. specie grown in protected space. Scientific Papers-Series B, Horticulture 63(2):233-240.

Senatore F, Napolitano F, Ozcan M (2003). Chemical composition and antibacterial activity of essential oil from fruits of *Vitex agnus-castus* L. (Verbenaceae) growing in Turkey. Journal of Essential Oil Bearing Plants 6(3):185-190. *https://doi.org/10.1080/0972-060X.2003.10643349*

Sevindik E, Abacı ZT, Yamaner C, Ayvaz M (2016). Determination of the chemical composition and antimicrobial activity of the essential oils of *Teucrium polium* and *Achillea millefolium* grown under North Anatolian ecological conditions. Biotechnology & Biotechnological Equipment 30(2):375-380. *https://doi.org/10.1080/13102818.2015.1131626*

Souto EB, Durazzo A, Nazhand A, Lucarini M, Zaccardelli M, Souto SB, … Santini A (2020). *Vitex agnus-castus* L.: main features and nutraceutical perspectives. Forests 11(7):761. *https://doi.org/10.3390/f11070761*

Stojković D, Soković M, Glamočlija J, Džamić A, Ćirić A, Ristić M, Grubišić D (2011). Chemical composition and antimicrobial activity of *Vitex agnus-castus* L. fruits and leaves essential oils. Food Chemistry 128(4):1017-1022. *https://doi.org/10.1016/j.foodchem.2011.04.007*

Suleman M, Faiz AUH, Abbas FI (2021). Antibacterial, antiparasitic and phytochemical activities of *Chenopodium album* (Bathua) plant extract. Bangladesh Journal of Botany 50(2):417-421. *https://doi.org/10.3329/bjb.v50i2.54100*

Tin B, Kurtoğlu C, Sevindik E (2017). Evaluation of chemical composition of *Vitex agnus-castus* (Verbenaceae) fruits essential oils grown in Aydın/Turkey. Turkish Journal of Life Sciences 2(2):171-174.

Toplan GG, Taşkın T, İşcan G, Göger F, Kürkçüoğlu M, Civaş A, … Başer KHC (2022). Comparative studies on essential oil and phenolic content with ın vitro antioxidant, anticholinesterase, antimicrobial activities of *Achillea biebersteinii* Afan. and *A. millefolium* subsp. *millefolium* Afan. L. growing in Eastern Turkey. Molecules 27(6):1956. *https://doi.org/10.3390/molecules27061956*

Ulukanli Z, Çenet M, Öztürk B, Bozok F, Karabörklü S, Demirci SC (2015). Chemical characterization, phytotoxic, antimicrobial and insecticidal activities of *Vitex agnus-castus'* essential oil from East Mediterranean region. Journal of Essential Oil Bearing Plants 18(6):1500-1507. *https://doi.org/10.1080/0972060X.2015.1004125*

Yilmaz A, Yilmaz H, Turan S, Celik A, Nadeem MA, Demirel F, … Arslan M (2022). Biotechnological Advancements in Coriander (*Coriandrum sativum* L.). European Journal of Science and Technology 35:203-220.

Zhang XL, Guo YS, Wang CH, Li GQ, Xu JJ, Chung HY, … Wang,GC (2014). Phenolic compounds from *Origanum vulgare* and their antioxidant and antiviral activities. Food Chemistry 152:300-306. *https://doi.org/10.1016/j.foodchem.2013.11.153*

Zhelev I, Petkova Z, Kostova I, Damyanova S, Stoyanova A, Dimitrova-Dyulgerova I, … Sayed A A (2022) Chemical composition and antimicrobial activity of essential oil of fruits from *Vitex agnus-castus* L., growing in two regions in Bulgaria. Plants 11(7):896. *https://doi.org/10.3390/plants11070896*