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Research Article

Phytochemical profiling, molecular docking and ADMET prediction of essential oil of *Ocimum basilicum*

Yunus Başar[1*], **Mesut Gök**[2], **Ramazan Erenler**[1,3], **İbrahim Demirtaş**[1,4]

[1]Research Laboratory Practice and Research Center, Igdir University, 7600, Igdir, Turkiye
[2]Science and Technology Application and Research Center, 56210, Siirt University, Siirt, Türkiye
[3]Department of Chemistry, Faculty of Arts and Sciences, Tokat Gaziosmanpasa University, 60240 Tokat, Türkiye
[4]Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Ondokuz Mayıs University, 55000 Samsun, Türkiye

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Abstract: Essential oils are widely used in pharmacology, cosmetics, and food industries, and they also have biological activities such as antioxidant, anti-inflammatory, anti-rheumatic, and antimicrobial. *Ocimum basilicum* (basil) plant has a rich content of essential oils. Hence, the stem, leaf, and flower parts of the *O. basilicum* were analyzed freshly on the RSH/GC-MS device to determine the essential oil content. As a result of the analysis, *α*-elemene, linalool, and eucalyptol were detected as the main components. It was observed that the highest linalool content was in the flower part at 47.85%, and the eucalyptol content was in the leaf part at 44.00%. Additionally, it was determined that the *α*-elemene content was highest in the flower part with 12.49%. According to the analysis results, high amounts of linalool, eucalyptol, and *α*-elemene were detected. The inhibitory properties of these compounds against the DNA gyrase enzyme were investigated by molecular docking. MolDock score (-78.72, -47.50, -88.86) and binding energy (2.9, 4.6, 4.0 kcal/mol) of linalool, eucalyptol, and *α*-elemene compounds were determined respectively. According to the ADME/T properties of the molecules examined; The *α*-elemene did not show any toxic effects. As a result, the eucalyptol compound may be used as an inhibitor against the DNA gyrase enzyme. In addition, it can contribute to the economy by obtaining essential oils from the non-consumable flowers and stem parts of the basil plant and increasing its usability in industries such as cleaning, cosmetics, etc.

1. INTRODUCTION

Plants have been exploited for medicinal purposes and food since ancient times. Moreover, they reveal significant biological activity due to their possessing of secondary metabolites (Erenler, *et al.*, 2023; Hadjra *et al.*, 2023; Khodja *et al.*, 2023). Furthermore, plants play an important role in regulating ecosystems and are thus known to influence biological processes. From the past to the present, aromatic and medicinal plants have been widely used to sweeten meals and make them more delicious (Yaglioglu *et al.*, 2022; Zerrouki *et al.*, 2022). Today, developing technology has made it possible for aromatic and fragrant plants to be used not only in the

*CONTACT: Yunus BAŞAR ybasar7631@hotmail.com Research Laboratory Practice and Research Center, Igdir University, 7600, Igdir, Turkiye

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kitchen, but also in cosmetics, the pharmaceutical industry, food additives, and many other areas (Topçu *et al.*, 1999). *Ocimum* includes more than 30 species based on their morphology, color of flowers, growth habits, chemical composition, and characteristics of their leaves and stems (Nusret *et al.*, 2020). It grows widely in Asia, America, and Africa. *Ocimum basilicum* (OB) in traditional medicine; It has been reported that it is used as a flavoring agent, deodorizer in oral and dental health, against bacterial skin infections in wounds, cough, headache, dewormer, diarrhea, and cancer treatment (Ahmed *et al.*, 2019).

Essential oils are important secondary metabolites used in many fields including pharmaceuticals, cosmetics, and spices (Boulechfar *et al.*, 2022; Erenler, *et al.*, 2023). Essential oils have been reported to display a large variety of biological activities (Karan *et al.*, 2018a; Karan *et al.*, 2018b). Volatile components are molecules that generally contain terpenes, aldehyde, and alcohol groups. The presence of these chemical groups in different proportions in different parts of the plants affects the odors, tastes, and therapeutic properties of the plants (Bayir *et al.*, 2014; Kaya *et al.*, 2014; Türkmen *et al.*, 2014). The main essential oil components of the basil plant have been reported to contain α-pinene, β-pinene, methyl cavicol, 1,8 cineole, L-linalool, and o-cymene (Purushothaman *et al.*, 2018). GC, GC-MS, and Headspace GC-MS are effectively used to determine the compounds in plants. The OB, which grows widely in Türkiye, is consumed as a spice due to its intense pleasant smell and flavoring properties (Telci *et al.*, 2006).

At harvest, the flower and stem parts are usually thrown away. By comparing the non-edible parts of OB with the edible parts, it is hoped to increase their use in pharmacology, perfumery, cosmetics, aromatherapy, and the food industry and to provide new economic benefits to those working in agriculture. For this purpose, the stem, leaf, and flower parts of OB were analyzed separately by RSH/GC-MS in our previous study (Gök & Başar, 2023). In this study, the interactions of the main components detected in the RSH/GC-MS analysis with the antibacterial enzyme (DNA gyrase) were determined by molecular docking. In addition, the pharmacokinetic properties (ADME/T) of these main components were investigated. Therefore, they are expected to provide information about the inhibitory properties and pharmacokinetic properties of these molecules.

2. MATERIAL and METHODS

2.1. Plant and Sample Preparation

OB was freshly collected in Siirt (Siirt University Kezer Campus) at coordinates of 37°57'56''N 41°51'01''E. The plant was divided into stem, leaf, and flower parts. 0.5 g samples of the stem, leaf, and flower were added to a 25 mL headspace bottle without drying and then placed in the chamber of the RSH/GC-MS device for analysis.

2.2. RSH/GC-MS Analysis

The sample vial was heated at 130 °C for 30 min in the triplus RSH oven. It was delivered to GC/MS with an injection volume of 2.5 mL from the heated vial. The analysis was carried out by ISQ mass spectroscopy (Thermo Fisher Scientific, Austin, TX) and trace 1310 gas chromatography. The process was held at an initial temperature of 80 °C for 2 minutes, then heated to 240 °C by increasing 4 °C/min and held at 240 °C for 25 minutes. The ion source and detector temperature were set at 250 °C and the sample injection volume was set at 1.5 mL. Helium (1.2 mL/min) was used as carrier gas. Thermo TG-WAXMS with GC column (60 m × 0.25 mm ID × 0.25 µm) was used for sensitive separation. The mass spectral scan range was set to 55–300 (Amu) (Gök & Başar, 2023). Components were identified by scanning the NIST demo, Wiley7, Wiley9, redlip, mainlip, and WinRI libraries (Benguedouar *et al.*, 2022).

2.3. Molecular Docking Application

3D structures and minimum energy of the linalool, eucalyptol, and α-elemene were carried out in the ChemDraw software. The 3D protein structure of DNA gyrase (PDB ID: 1KZN) was selected from the protein data bank (RCSB PDB: Homepage). The search area of the enzyme was determined as coordinates X: 19.07, Y: 29.61, Z: 34.87, and the rasidus was determined as 29.00 Å, and the molecules interacted in this area. Linalool, eucalyptol, and α-elemene with enzyme interactions were determined using the Molegro Virtual Docker (MVD) program (Başar *et al.*, 2023). The 2D and 3D images of the interactions were taken with the BIOVIA Discovery Studio Visualizer program. Also, The AutoDock Vina program was used to calculate the binding affinities (Yenigün *et al.*, 2024; Başar *et al.*, 2024a).

2.4. ADME/T Application

In the RSH/GC-MS analysis, ADME/T calculations were utilized for prediction in pharmacokinetics to investigate the absorption, distribution, role in metabolism, excretion from the body, and whether there are toxic effects of the most common components in the body. These parameters are SwissADME (https://www.swissadme.ch/), Molinsiparation (https://www.molinspiration.com), Molsoft (https://molsoft.com/mprop/), Peo (https://www.organic-chemistry.org/prog/peo/) and pKCSM (https://biosig.lab.uq.edu.au/pkcsm/prediction) programs. ADME/T utilizes *in silico* techniques to better understand and predict how drugs will affect the body. It can optimize clinical use, reduce unwanted side effects, focus research on development, and improve alternative treatments (Pires *et al.*, 2015; Başar *et al.*, 2024b; Ipek *et al.*, 2024).

3. RESULTS

In our study, the essential oil content of the OB plant, which we had previously presented as a report, was determined by RSH-GC/MS (Gök & Başar, 2023). As a result of the analysis, the interactions of the molecules determined as the main constituent with the enzyme DNA gyrase, which is known as an antibacterial enzyme, were determined by molecular docking application, and the binding energies were calculated using Autodock vina. In addition, the parkinetic properties of the molecules were calculated using the online application ADME/T.

The volatile components of the body, leaf, and flower of the OB were presented. The stem part included linalool (32.68%), eucalyptol (21.44%), and α-elemene (3.17%), and the leaf part contained the eucalyptol (44.00%), linalool (40.34%) and α-elemene (2.48%). The flower consisted of linalool (47.85%), eucalyptol (24.16%), and α-elemene (12.49%) (Figure 1 and Table 1) (Gök & Başar, 2023).

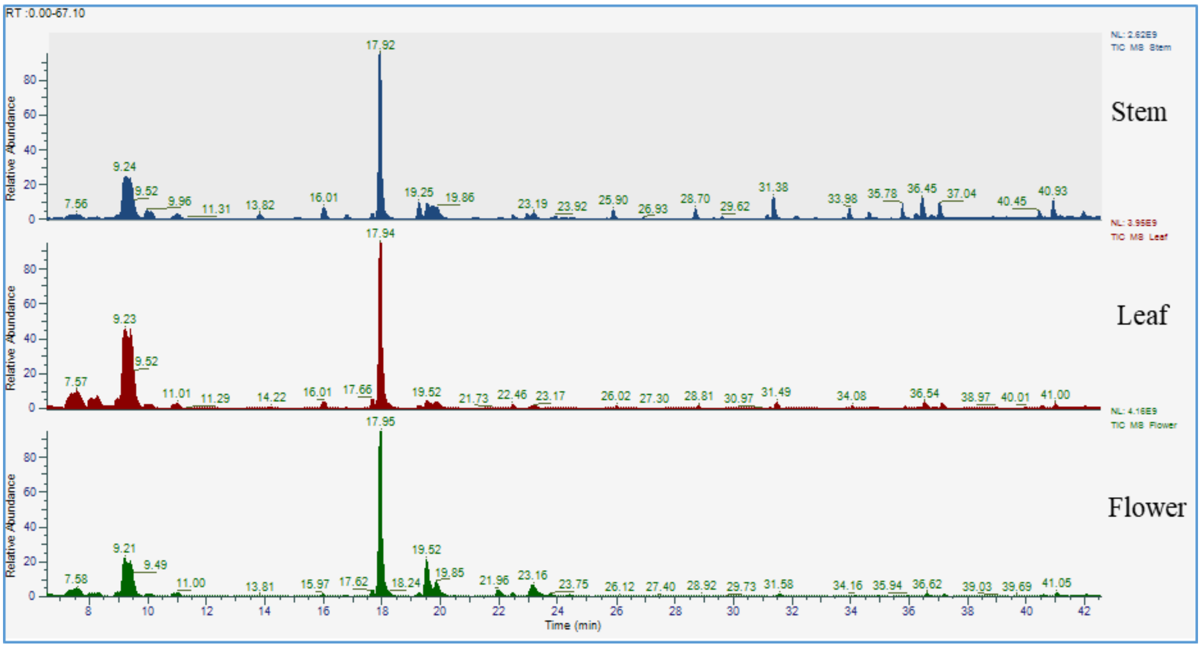


Figure 1. RSH/GC-MS chromatograms of the body, leaf and flower of OB (Gök & Başar, 2023).

Table 1. Results of volatile components of OB (Gök & Başar, 2023).

No	Compound	RT	RI[a]	RI[b]	Body%	Leaf %	Flower %
1	Eucalyptol	9.24	1211	1237	21.44	44.00	24.16
2	*β*-Ocimene	9.96	1254	1268	2.16	-	-
3	1,3,6-Octatriene,3,7-dimethyl-(E)-	10.10	1258	1273	1.46	-	-
4	*α* -Terpinolene	10.87	1294	1304	-	0.83	-
5	1,5,5-Trimethyl-6-methylene-cyclohexene	11.01	1338	1309	2.15	1.49	1.18
6	Nonanal	13.81	1408	1411	1.24	-	-
7	Fenchyl acetate	16.01	1482	1482	3.05	2.00	-
8	Decanal	16.79	1505	1508	1.13	-	-
9	Camphor	17.67	1531	1539		1.88	1.62
10	Linalool	17.92	1547	1547	32.68	40.34	47.85
11	Bornyl acetate	19.26	1591	1591	3.03	-	-
12	*α*-Elemene	19.55	1605	1601	3.17	2.48	12.49
13	Calarene	19.71	1610	1607	2.69	-	-
14	Caryophyllene	19.85	1614	1612	2.22	2.09	4.37
15	*α*-Humulene	21.95	1681	1685	-	-	2.58
16	L-*α*-Terpineol	22.46	1690	1702	-	0.96	0.92
17	Dodecanal	22.96	1718	1721	1.13	-	-
18	Valencene	23.19	1728	1729	1.54	-	4.84
19	Tridecanal	25.90	1822	1827	1.97	-	-
20	Tetradecanal	28.70	1933	1933	1.99	-	-
21	Pentadecanal	31.38	2041	2041	4.33	1.47	-
22	Hexadecanal	33.98	2137	2147	1.69	-	-
23	cis-11-Hexadecenal	34.64	2159	2175	1.07	-	-
24	2-Heptadecanone	36.23	2243	2245	1.18	-	-
25	Heptadecanal	36.45	2247	2254	3.86	1.42	-

RT: Retention time**, RI[a]:** Covarx index literature (Cadwallader & Xu, 1994; Adams, 2007), **RI[b]:** Covarx index experimental results

3.1. Molecular Docking

DNA gyrase is a bacterial enzyme that functions to reduce the molecular tension created by winding during DNA replication. It belongs to the topoisomerases class of enzymes that control the topological transitions of DNA (Reece & Maxwell, 1991). OB essential oils are known to show high antibacterial activity (Al Abbasy *et al.*, 2015). The linalool, eucalyptol, and *α*-elemene were determined to be high concentrations in OB essential oil. Therefore, the interactions of corresponding compounds with the DNA gyrase enzyme were investigated (Figure 2).

Linalool consisted of one conventional hydrogen bond with residues VAL43 and seven alkyl interactions with amino acids such as VAL43, VAL71, VAL167, VAL120, ILE78 within DNA gyrase (Figure 2 and Table 2). The interactions of the linalool molecule with DNA gyrase were calculated as -78.72 (MolDock score), and binding energy was detected as -2.90 kcal/mol. The eucalyptol molecule contained one carbon-hydrogen bond with residues THR165 and ten alkyl interactions with amino acids, VAL43, ALA47, ILE78, VAL71, VAL167, VAL120 in DNA gyrase (Figure 2 and Table 2). The MolDock score of the interaction of the eucalyptol with DNA gyrase was calculated as -47.50, and the binding energies were calculated as -4.60

kcal/mol.

The thirteen alkyl interactions of α-elemene with amino acids such as VAL43, ALA47, ILE78, VAL71, VAL167, VAL120, within DNA gyrase were observed (Figure 2 and Table 2). The MolDock score of the interactions of the α-element molecule with DNA gyrase was calculated as -88.86, and the binding energies were calculated as -4.00 kcal/mol. According to a molecular docking study; eucalyptol may be used as an inhibitor against the DNA gyrase enzyme. The accuracy of these studies can be checked in an *in vitro* environment.

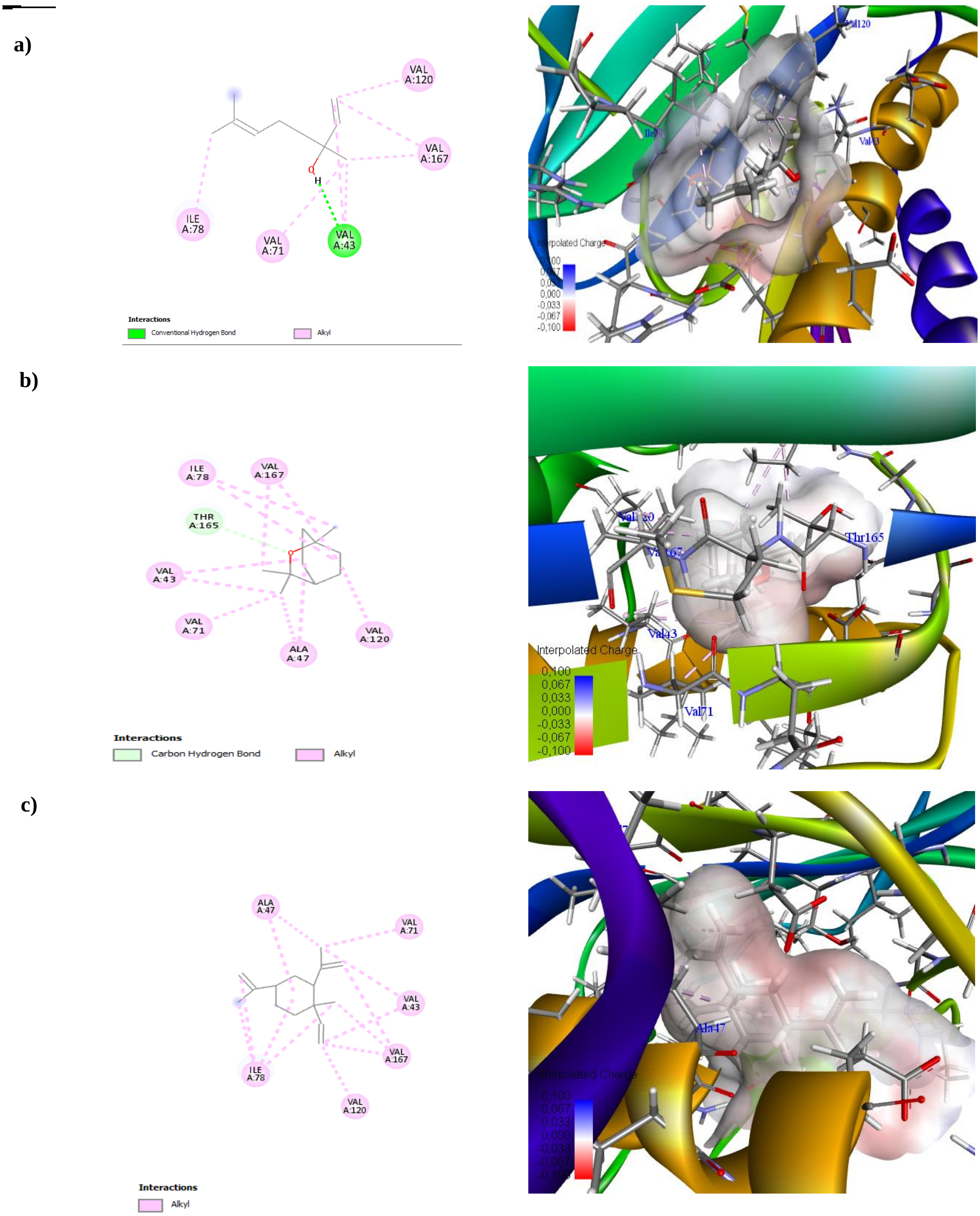


Figure 2. 2D images and 3D interpolated load view of a) linalool b) eucalyptol c) α-elemene with DNA gyrase interaction.

Table 2. DNA gyrase-compounds interaction categories, species and molecular docking distance.

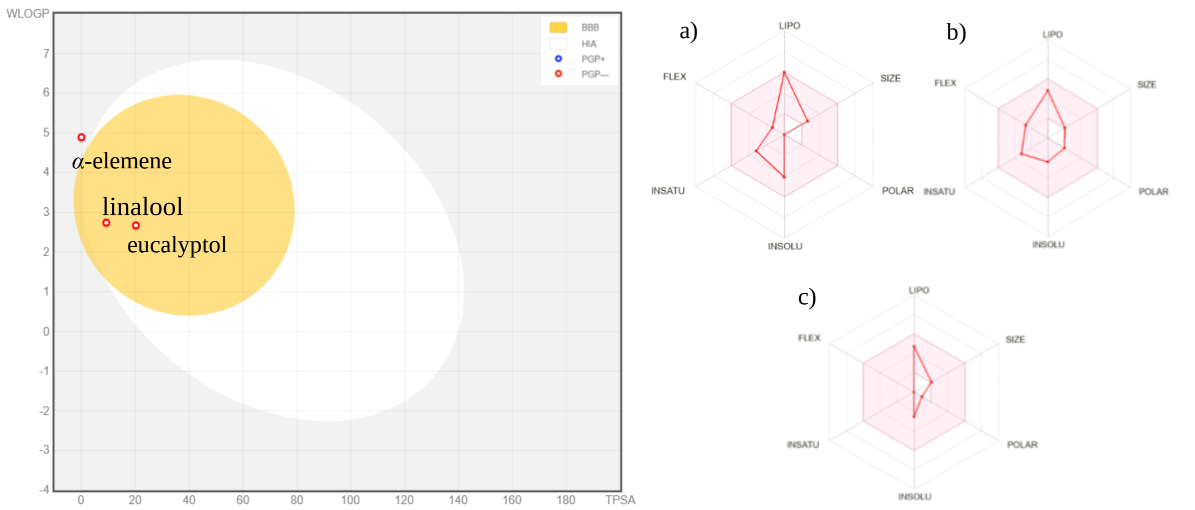
Conpound Name	Aminoacid Names	Distance	Bond Types
Linalool	VAL43	1.183206	Hydrogen Bond (Conventional)
	VAL43	4.54811	Hydophobic (Alkyl)
	VAL71	4.29064	Hydophobic (Alkyl)
	VAL167	3.91122	Hydophobic (Alkyl)
	VAL43	4.91913	Hydophobic (Alkyl)
	VAL120	3.95533	Hydophobic (Alkyl)
	VAL167	4.00937	Hydophobic (Alkyl)
	ILE78	4.73652	Hydophobic (Alkyl)
Eucalyptol	THR165	2.3919	Hydrogen Bond (Carbon)
	VAL43	5.34605	Hydophobic (Alkyl)
	ALA47	4.44641	Hydophobic (Alkyl)
	ALA47	3.4129	Hydophobic (Alkyl)
	ILE78	5.16506	Hydophobic (Alkyl)
	VAL120	5.10748	Hydophobic (Alkyl)
	VAL167	4.71775	Hydophobic (Alkyl)
	ILE78	4.91334	Hydophobic (Alkyl)
	VAL167	4.0741	Hydophobic (Alkyl)
	VAL43	5.34768	Hydophobic (Alkyl)
	VAL71	3.94457	Hydophobic (Alkyl)
α-Elemene	ALA47	5.4813	Hydophobic (Alkyl)
	ALA47	2.91057	Hydophobic (Alkyl)
	ILE78	5.0842	Hydophobic (Alkyl)
	ILE78	4.79639	Hydophobic (Alkyl)
	VAL167	4.45664	Hydophobic (Alkyl)
	VAL43	3.48572	Hydophobic (Alkyl)
	VAL120	3.33498	Hydophobic (Alkyl)
	VAL167	3.87033	Hydophobic (Alkyl)
	ILE78	5.16772	Hydophobic (Alkyl)
	ILE78	4.81986	Hydophobic (Alkyl)
	VAL43	5.21836	Hydophobic (Alkyl)
	VAL71	4.07398	Hydophobic (Alkyl)
	VAL167	4.66851	Hydophobic (Alkyl)

3.1. ADME/T Results

The evaluation of ADME/T properties (absorption, distribution, metabolism, excretion, and toxicity) is considered an important step in drug development. Thus, a substance, which may be a drug, is absorbed and distributed in the body within a certain period to ensure effective metabolism (Bruna *et al.*, 2022). ADME/T evaluation can be completed after estimating the physicochemical properties and following Lipinski's "rule of five"(Ye *et al.*, 2018). Lipinski's "rule of five" states that the compound has a molecular weight ≤ 500, logP ≤ 5, number of hydrogen bond donors ≤ 5, and number of hydrogen bond acceptors ≤ 10. In biological systems, the LogP value is taken into account in the distribution of molecules between phases (oil, water) (Znati *et al.*, 2019).

Analysis of the boiled egg plot (Figure 3) shows that eucalyptol and linalool have high gastrointestinal absorption (GIa) and blood-brain barrier permeability (BBBp). In contrast, the α-elemene compound has low GIa and BBBp. P-glycoprotein (P-gp) is a membrane protein that removes compounds from cells. Drug-like compounds should not be P-gp substrates. According to the predictions in this regard, the investigated compounds fulfilled this condition. According to the bioavailability radar table of the ingredients, they exhibited better scores than the standard references used (Figure 3). The fact that the molecules are in the pink region indicates high bioavailability and similarity to the drug (Znati *et al.*, 2019). In addition, cytochrome P450 (CYP), derived from pharmacokinetically related proteins, can be excreted via the kidneys following the polarization of oxidized molecules and may play a role in the oxidative metabolism of compounds.That is, the studied components did not appear to interact with CYP isozymes (Table 3) (Bruna *et al.*, 2022). In addition, bioavailability values of 0.55 indicate that they have more drug-like properties and high usability as drugs (Table 3).

The bioactivity values of the compounds that were detected in large quantities to identify biological targets are shown in Table 3: Ligand of a G protein-coupled receptor (GPCR), ligand of a nuclear receptor, kinase, protease enzyme inhibitor and modulator of an ion channel. In addition, the bioactivity values of these molecules are grouped as active, moderately active, or inactive.



The pink zone is the suitable physicochemical space for oral bioavailability. LIPO (lipophilicity), POLAR (polarity), INSOLU (insolubility), INSATU (insaturation), FLEX (flexibility). The gastrointestinal tract is illustrated by the white of a boiled egg, the blood-brain barrier by the yolk, and chemicals expected to be P-glycoprotein substrates are represented by the blue dot.

Figure 3. Boiled egg graph and bioavailability radar graph of the main components of RSH/GC-MS analysis of OB, α-elemene (a), eucalyptol (b), linalool (c).

If the bioactivity score value is greater than 0.00, the molecule is assumed to be active; if the score value is between -0.50 and 0.00, it is assumed to be moderately active; if the score value is less than -0.50, the molecule is assumed to be inactive (Znati *et al.*, 2019).The compounds eucalyptol and linalool were found to be significantly bioactive as modulators of ion channels, and only the elemental compound was predicted to have a moderate effect. On the other hand, eucalyptol was postulated to be an excellent nuclear receptor ligand and a moderate general enzyme inhibitor. In protease inhibition, only the α-elemene compound was found to be moderately inhibitory, while the compounds eucalyptol and linalool were found to be strongly inhibitory (Table 3).

Determining the toxicity of chemical compounds is of utmost medical importance (Srivastava, 2021). It is also an in-silico approach to predict the risks of particular toxicity such as mutagenicity, tumor formation, irritation, and reproductive efficacy. No risk of tumorigenicity, reproductive toxicity, irritation, and mutagenicity was predicted for the elemental compound (Table 3).

Table 3. Pharmacokinetic properties of the main components of OB plant RSH/GC-MS analysis.

Name	MW (g/mol)	logP	GIa	BBB_p	nHA	nHD	nRB	P-gp	IA (Human) %	CL_{tot} (Log mL/min/kg)	VD_{ss} (Human) Log L/kg
α-Elemene	204.36	4.89	Low	0.77	0.00	0.00	2.00	No	96.83	1.39	0.58
Eucalyptol	154.25	2.74	High	0.37	1.00	0.00	0.00	No	96.50	1.01	0.50
Linalool	154.25	2.67	High	0.61	1.00	1.00	4.00	No	93.65	0.45	0.11

Name	GPCR ligand	Kinase inhibitor	Ion channel modulator	Nuclear receptor ligand	Protease inhibitor	Enzyme inhibitor	Oral Acute Toxicity (LD_{50})	CYP substrate
α-Elemene	-0.55	-0.86	-0.14	0.49	-0.64	0.26	1.60	-
Eucalyptol	-0.93	0.01	-1.60	-1.07	-0.90	-0.15	2.01	-
Linalol	-0.73	0.07	-1.26	-0.06	-0.94	0.07	1.80	-

Name	Mutagenicity	Irritation	Tumorigenicity	Reproductive	Bioavailability Score
α-Elemene	LR	LR	LR	LR	0.55
Eucalyptol	HR	LR	LR	HR	0.55
Linalol	HR	LR	HR	LR	0.55

MW: Molecular weight, **LogP:** logarithmic ratio of partition coefficient, **CYP:** human cytochrome P450, **VDss:** volume of distribution, **CLtot:** total clearance (hepatic and renal clearance), Number of hydrogen bond acceptors, Number of hydrogen bond donors, Number of rotatable bonds, GIa: Gastrointestinal absorption, **BBBp:** Blood-brain barrier permeant, **P-gp:** P-glycoprotein substrate, **IA:** Intestinal absorption, **LR:** Low risk, **MR:** Medium risk, **HR:** Higher risk.

4. DISCUSSION and CONCLUSION

Linalool was determined as the first main component in the stem (32.68%) and flower (47.85%) and the second main component in the leaf (40.34%). The second main component, eucalyptol molecule, was found in the leaf (44.00%), stem (21.44%), and flower (24.16%). According to the results, it was observed that 44% eucalyptol was found in the leaf parts, which are mostly consumed as spices, and linalool and α-elemene were high in the flower and stem parts. The main component of OB essential oils was reported as linalool (31.6-69.87%) (Hussain *et al.*, 2008). GC-MS analysis of OB revealed linalool (44.18%), 1,8-cineole (13.65%), eugenol (8.59%), methyl cinnamate (4.26%), iso-caryophyllene (3.10%) and α-cubebene (4.97%) as the main constituents of the essential oil (Ismail, 2006). The main constituents of OB were reported as linalool (48.4%), 1,8-cineole (12.2%), eugenol (6.6%), methyl cinnamate (6.2%), α-cubebene (5.7%), caryophyllene (2.5%), β-ocimene (2.1%) and α-farnesene (2.0%) (El-Soud *et al.*, 2015). GC/MS analysis of OB revealed that the main components of the essential oil are geranial (35.5%) and cis-citral (26.2%) (Barua *et al.*, 2023). Linalool has been reported as the major constituent of the essential oil of OB originating (Telci *et al.*, 2006). Linalool is not only used in perfumes, cosmetics, food, and detergents but also has anti-inflammatory, analgesic (pain-relieving), antispasmodic (muscle relaxant), DNA-protective and antimicrobial properties (Mitić-Ćulafić *et al.*, 2009). In addition to its use in the pharmaceutical industry and cosmetics, the eucalyptol compound has been reported to have anti-inflammatory, analgesic (pain-relieving), antispasmodic (muscle relaxant), antioxidant, and antimicrobial activities against chronic upper respiratory tract infections.

According to the MolDock results of linalool, eucalyptol, and α-elemene compounds, moldock scores were detected as -78.72, -47.50, -88.86 respectively, and binding energies were calculated as 2.9 kcal/mol, 4.6 kcal/mol, 4.0 kcal/mol respectively. The eucalyptol compound may be used as an inhibitor against the DNA gyrase enzyme. According to the ADME/T results of these components, it was observed that eucalyptol and linalool components passed the blood-brain barrier, while the other components did not pass through both the blood-brain barrier and the gastrointestinal system. While it was determined that the elemental compound had no toxic effects, it was noted that other components had toxic effects. It was also determined that these components did not interact with cytochrome P450 enzymes. In summary, these components can be used as medicine. But further studies should be carried out. The essential oil content extracted from flowers and stems is therefore widely used in perfumery, cosmetics, aromatherapy, and the food industry. The extraction of essential oils from the OB and their processing into products with high added value can make an economic contribution.

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Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. This research study complies with research and publishing ethics. The scientific and legal responsibility for manuscripts published in IJSM belongs to the authors.

Authorship Contribution Statement

Yunus Başar: Investigation, Software, Visualization, Formal Analysis, Design, and Writing-original draft. **Mesut Gök:** Investigation, Resources, Formal Analysis, and Literature review. **Ramazan Erenler:** Methodology and Supervision. **İbrahim Demirtaş:** Methodology, Supervision, and Validation.

Orcid

Yunus Başar https://orcid.org/0000-0002-7785-3242
Mesut Gök https://orcid.org/0000-0001-9217-8022

Ramazan Erenler https://orcid.org/0000-0002-0505-3190
İbrahim Demirtaş https://orcid.org/0000-0001-8946-647X

REFERENCES

Adams, R.P. (2007). *Identification of essential oil components by gas chromatography/mass spectrometry*: Allured publishing corporation Carol Stream, IL.

Ahmed, A.F., Attia, F.A., Liu, Z., Li, C., Wei, J., & Kang, W. (2019). Antioxidant activity and total phenolic content of essential oils and extracts of Sweet basil (*Ocimum basilicum* L.) plants. *Food Science and Human Wellness, 8*(3), 299-305. https://doi.org/10.1016/j.fshw.2019.07.004

Al Abbasy, D.W., Pathare, N., Al-Sabahi, J.N., & Khan, S.A. (2015). Chemical composition and antibacterial activity of essential oil isolated from Omani basil (*Ocimum basilicum* Linn.). *Asian Pacific Journal of Tropical Disease, 5*(8), 645-649. https://doi.org/10.1016/S2222-1808(15)60905-7

Barua, S., Dewan, K., Islam, S., Mojumder, S., … Rahman, I. M.M (2023). Chemical composition, antioxidant, and antimicrobial activities of Bangladesh-origin Jhum-cultivar basil (Ocimum basilicum L.) essential oil. *International Journal of Secondary Metabolite, 10*(4), 511-524. https://doi.org/10.21448/ijsm.1230316

Başar, Y., Yenigün, S., İpek, Y., Behçet, L., Gül, F., Özen, T., & Demirtaş, İ. (2023). DNA protection, molecular docking, enzyme inhibition and enzyme kinetic studies of 1,5,9-epideoxyloganic acid isolated from Nepeta aristata with bio-guided fractionation. *Journal of Biomolecular Structure and Dynamics, 42*(17), 9235-9248. https://doi.org/10.1080/07391102.2023.2250461

Başar, Y., Demirtaş, İ., Yenigün, S., İpek, Y., Özen, T., & Behçet, L. (2024a). Molecular docking, molecular dynamics, MM/PBSA approaches and bioactivity studies of nepetanudoside B isolated from endemic Nepeta aristata. *Journal of Biomolecular Structure and Dynamics*, 1-14. https://doi.org/10.1080/07391102.2024.2309641

Başar, Y., Yenigün, S., Gül, F., Ozen, T., Demirtas, İ., Alma, Mh, Temel, S. (2024b) Phytochemical profiling, molecular docking and ADMET prediction of crude extract of Atriplex nitens Schkuhr for the screening of antioxidant and urease inhibitory. *International Journal of Chemistry and Technology, 8(1), 60-68.* https://doi.org/10.32571/ijct.1389719

Bayir, B., Gündüz, H., Usta, T., Şahin, E., Özdemir, Z., Kayır, Ö., ... Erenler, R. (2014). Chemical Composition of Essential Oil from *Marrubium Vulgare* L. Leaves. *Journal of New Results in Science, 6*(6), 44-50.

Benguedouar, K., Betina, S.B., Erenler, R., Genc, N., Gok, M., Sebti, M., ... Barkat, M. (2022). Evaluation of the antioxidant properties and total phenolic content of a dairy product (yogurt) supplemented with *Thymus willdenowii* essential oil from Algeria. *Journal of Food Measurement and Characterization, 16*, 3568-3577. https://doi.org/10.1007/s11694-022-01455-6

Boulechfar, S., Zellagui, A., Asan-Ozusaglam, M., Bensouici, C., Erenler, R., Yildiz, İ., ... Demirtas, I. (2022). Chemical composition, antioxidant, and antimicrobial activities of two essential oils from Algerian propolis. *Zeitschrift für Naturforschung C, 77*(3-4), 105-112. https://doi.org/10.1515/znc-2021-0028

Bruna, F., Fernandez, K., Urrejola, F., Touma, J., Navarro, M., Sepulveda, B., ... Ferrando, M. (2022). Chemical composition, antioxidant, antimicrobial and antiproliferative activity of *Laureliopsis philippiana* essential oil of Chile, study *in vitro* and *in silico*. *Arabian Journal of Chemistry, 15*(12), 104271. https://doi.org/10.1016/j.arabjc.2022.104271

Cadwallader, K.R., & Xu, Y. (1994). Analysis of volatile components in fresh grapefruit juice by purge and trap/gas chromatography. *Journal of Agricultural and Food Chemistry, 42*(3), 782-784. https://doi.org/10.1021/jf00039a036

El-Soud, N.H., Deabes, M., El-Kassem, L.A., & Khalil, M. (2015). Chemical composition and antifungal activity of Ocimum basilicum L. essential oil. Open Access Maced J Med Sci, 3(3), 374-379. https://doi.org/10.3889/oamjms.2015.082

Erenler, R., Carlik, U.E., & Aydin, A. (2023). Antiproliferative activity and cytotoxic effect of essential oil and water extract from *Origanum vulgare* L. *Sigma, 41*(1), 202-208. https://doi.org/10.14744/sigma.2023.00018

Gök, M., & Başar, Y. (2023, November 17-18, 2023). *Analysis of volatile components of the body, leave and flower parts of the fresh Ocimum basilicum plant growing in Siirt conditions by RSH-GC/MS*. IV. International Siirt Conference On Scientific Research, Siirt/Türkiye.

Hadjra, H., Yamina, B., Soulef, K., & Erenler, R. (2023). Evaluation of Antifungal Potential of *Mentha pulegium* Essential oil in Biological Control Against the Pathogen of Inflorescence Rot Disease of Date Palm (*Mauginiella scaettae*). *Jordan Journal of Biological Sciences, 16*(4), 665-672. https://doi.org/10.54319/jjbs/160412

Hussain, A.I., Anwar, F., Sherazi, S.T.H., & Przybylski, R. (2008). Chemical composition, antioxidant and antimicrobial activities of basil (*Ocimum basilicum*) essential oils depends on seasonal variations. *Food Chemistry, 108*(3), 986-995. https://doi.org/10.1016/j.foodchem.2007.12.010

İpek, Y., Başar, Y., Yenigün, S., Behçet, L., Özen, T., & Demirtaş, İ. (2024). *In vitro* bioactivities and *in silico* enzyme interactions of abietatrien-3β-ol by bio-guided isolation from *Nepeta italica* subsp. *italica*. *Journal of Biomolecular Structure and Dynamics*, 1–24. https://doi.org/10.1080/07391102.2024.2322626

Ismail, M. (2006). Central properties and chemical composition of ocimum basilicum. essential oil. *Pharmaceutical Biology*, *44*(8), 619–626. https://doi.org/10.1080/13880200600897544.

Karan, T., Simsek, S., Yildiz, I., & Erenler, R. (2018a). Chemical composition and insecticidal activity of *Origanum syriacum* L. essential oil against *Sitophilus oryzae* and *Rhyzopertha dominica*. *International Journal of Secondary Metabolite, 5*(2), 87-93. https://doi.org/10.21448/ijsm.404114

Karan, T., Yildiz, I., Aydin, A., & Erenler, R. (2018b). Inhibition of various cancer cells proliferation of bornyl acetate and essential oil from *Inula graveolens* (Linnaeus) Desf. *Records of Natural Products, 12*(3), 273-283.

Kaya, G., Karakaya, R., Tilgel, E., Sandikci, M., Yucel, E., Cicek, G., ... Guzel, A. (2014). Essential Oil Constituents of *Thuja orientalis* Berries. *Journal of New Results in Science, 7*(7), 1-6.

Khodja, E.A.T., Abd El Hamid Khabtane, R.A., Benouchenne, D., Bensaad, M.S., Bensouici, C., & Erenler, R. (2023). *In vitro* assessment of antioxidant, neuroprotective, anti-urease and anti-tyrosinase capacities of *Tamarix africana* leaves extracts. *Journal of Traditional Chinese Medicine*, *43*(2), 252. https://doi.org/10.19852/j.cnki.jtcm.20230105.003

Mitić-Ćulafić, D., Žegura, B., Nikolić, B., Vuković-Gačić, B., Knežević-Vukčević, J., & Filipič, M. (2009). Protective effect of linalool, myrcene and eucalyptol against t-butyl hydroperoxide induced genotoxicity in bacteria and cultured human cells. *Food and Chemical Toxicology*, *47*(1), 260-266. https://doi.org/10.1016/j.fct.2008.11.015

Nusret, G., Elmastaş, M., Telci, İ.S., & Erenler, R. (2020). Quantitative analysis of phenolic compounds of commercial basil cultivars (*Ocimum basilicum* L.) by LC-TOF-MS and their antioxidant effects. *International Journal of Chemistry and Technology*, *4*(2), 179-184.

Pires, D.E., Blundell, T.L., & Ascher, D.B. (2015). pkCSM: predicting small-molecule pharmacokinetic and toxicity properties using graph-based signatures. *Journal of Medicinal Chemistry, 58*(9), 4066-4072. https://doi.org/10.1021/acs.jmedchem.5b00104

Purushothaman, B., Srinivasan, R.P., Suganthi, P., Ranganathan, B., Gimbun, J., & Shanmugam, K. (2018). A comprehensive review on *Ocimum basilicum*. *Journal of Natural Remedies*, 71-85. https://doi.org/10.18311/jnr/2018/21324

Reece, R.J., & Maxwell, A. (1991). DNA gyrase: structure and function. *Critical Reviews in Biochemistry and Molecular Biology, 26*(3-4), 335-375. https://doi.org/10.3109/10409239109114072

Srivastava, R. (2021). Theoretical studies on the molecular properties, toxicity, and biological efficacy of 21 new chemical entities. *ACS Omega, 6*(38), 24891-24901. https://doi.org/10.1021/acsomega.1c03736

Telci, I., Bayram, E., Yılmaz, G., & Avcı, B. (2006). Variability in essential oil composition of Turkish basils (*Ocimum basilicum* L.). *Biochemical Systematics and Ecology, 34*(6), 489-497. https://doi.org/10.1016/j.bse.2006.01.009

Topçu, G., Erenler, R., Çakmak, O., Johansson, C.B., Çelik, C., Chai, H.-B., & Pezzuto, J.M. (1999). Diterpenes from the berries of *Juniperus excelsa*. *Phytochemistry, 50*(7), 1195-1199. https://doi.org/10.1016/S0031-9422(98)00675-X

Türkmen, N., Öz, A., Sönmez, A., Erol, T., Gülümser, D., Yurdakul, B., ... Erenler, R. (2014). Chemical Composition of Essential Oil from *Rosmarinus Officinalis* L. Leaves. *Journal of New Results in Science, 6*(6), 27-31.

Yaglioglu, A.S., Gurbuz, D.G., Dolarslan, M., & Demirtas, I. (2022). First determination of anticancer, cytotoxic, and *in silico* ADME evaluation of secondary metabolites of endemic *Astragalus leucothrix* Freyn & Bornm. *Turkish Journal of Chemistry*, *46*(1), 169-183. https://doi.org/10.3906/kim-2104-23

Ye, Z., Yang, Y., Li, X., Cao, D., & Ouyang, D. (2018). An integrated transfer learning and multitask learning approach for pharmacokinetic parameter prediction. *Molecular Pharmaceutics, 16*(2), 533-541. https://doi.org/10.1021/acs.molpharmaceut.8b00816

Yenigün, S., Başar, Y., İpek, Y., Behçet, L., Özen, T., & Demirtaş, İ. (2024). Determination of antioxidant, DNA protection, enzyme inhibition potential and molecular docking studies of a biomarker ursolic acid in *Nepeta* species. *Journal of Biomolecular Structure and Dynamics*, *42*(11), 5799-5816. https://doi.org/10.1080/07391102.2023.2229440

Zerrouki, S., Mezhoud, S., Sahin Yaglioglu, A., Bensouici, C., Nuri Atalar, M., Demirtas, I., ... Mekkiou, R. (2022). Antioxidant, anticancer activities, and HPLC-DAD analyses of the medicinal halophyte *Limoniastrum guyonianum* Dur. extracts. *Journal of Research in Pharmacy, 26*(3), 598-608. https://doi.org/10.29228/jrp.157

Znati, M., Bordes, C., Forquet, V., Lanteri, P., Jannet, H.B., & Bouajila, J. (2019). Synthesis, molecular properties, anti-inflammatory and anticancer activities of novel 3-hydroxyflavone derivatives. *Bioorganic Chemistry, 89*, 103009. https://doi.org/10.1016/j.bioorg.2019.103009