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Impacts of Essential Oil and Extracts Obtained from Coriander Cultivars (*Coriandrum sativum* L.) on Important Some Pathogenic Bacteria

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Abstract

In this study, the antibacterial activity of the essential oil obtained from the seeds of two coriander (*Coriandrum sativum* L.) cultivars (Gürbüz and Arslan) and extracts obtained from the seeds, leaves and stems with methanol and ethanol against seven Gram-negative (*Escherichia coli* ATCC®25922, *Pseudomonas aeruginosa* ATCC®9027, *Salmonella typhimurium* ATCC®14028, *Serratia marcescens* ATCC®13880, *Proteus vulgaris* ATCC®6380, *Enterobacter cloacae* ATCC®13047, and *Klebsiella pneumoniae* ATCC®4352), and one Gram-positive bacteria (*Staphylococcus aureus* ATCC®6538) were evaluated. Summer sowing was carried out for the supply of herbal materials and the plants were grown in Yozgat / TURKEY climatic conditions. Linalool (average 74%) has been noted as the main component in essential oils, and γ-terpinene, geraniol and camphor have been identified as other important components. It has been determined that essential oils exhibit varying levels of activity against *S. aureus, E. coli, S. tyhimurium, S. marcescens, P. vulgaris*, and *E. cloacae* bacteria in this study. Especially, the essential oil obtained from Arslan cultivar exhibited strong activity against *P.aeruginosa* and *S.aureus* bacteria.

Key Words: Clevenger, Fruit, GC/MS, Kirby-Bauer Method, Linalool, Methanol

1. Introduction

Coriander (*Coriandrum sativum* L.) is an economically important spice and essential oil plant from the Apiaceae (Umbelliferae) family. It is an annual herbaceous structure. Light or dark green leaves are segmented and usually 3-lobed. The flowers are white or light pink in the form of umbrellas at the ends of the branches and bloom in June-July. The fruits are light yellow-brown, spherical schizocarp with a diameter of 2-4 mm. 1000 fruit weight varies between 5-18 g (Diederichsen and Hammer, 2003; Yeung and Bowra, 2011). The leaves, stem, flowers and fruits of the plant contain high levels of essential oil. The amount and chemical composition of the essential oil differ according to the organs of the plant (Mandal and Mandal, 2015).

The predominant component in the essential oil obtained from coriander fruits is linalool. In some essential oils, the linalool content can reach up to 80%. The essential oil contains "α-pinene, ɣ-terpinene, camphor, geranial acetate, geraniol, borneol, citronellol, thymol,

β-caryophyllene and caryophyllene oxide", although at lower concentrations than this component (Zekovića et al., 2011; Vasconcelos Dos Santos et al., 2019; Satyal and Setzer, 2020; Al-Khayri et al. 2023).

Coriander has essential oil that exhibits broad biological activity (antifungal, antibacterial, antioxidant, antibacterial, antidiabetic, antidepressant etc.) (Gkogka et al., 2013; Al-Khayri et al. 2023). Studies have shown that coriander essential oil has determined the inhibitory efficacy against *Bacillus subtilis, Candida albicans, Enterococcus faecalis, Enterococcus faecium, Klebsiella pneumoniae, Listeria innocua, Pseudomonas aeruginosa, Salmonella enteritidis, Salmonella infantis*, and *Salmonella kentucky*. (Serban et al., 2011; Niamah and Alali 2016; Ozkinali et al., 2017; Rizk et al., 2022; Al-Khayri et al., 2023). In this study, it was aimed to determine to what extent essential oils and extracts of coriander cultivars grown in cultural conditions inhibit the growth of important pathogenic bacteria.

2. Material and Methods

2.1. Plant Material

Two coriander cultivars (cv. Arslan-large fruited and cv. Gürbüz- small fruited) registered by Ankara University/TURKEY were used as plant material.

2.2. Production area

Production of plant material to be used in analysis was carried out in Yozgat Bozok University, Research and Application Area (Yozgat/TURKIYE; Locality: 39° 45' 08" N, 34° 48' 11" E, Altitude:1267 m). The precipitation, temperature and humidity values of the vegetation period of the production area, and soil properties are given in Figure 1 and Table 1, respectively.

Table 1. The soil analysis results of the production area (Yakupoglu, 2018)

Clay	Silt	Sand	pH	Salt	$CaCO_3$	Organic matter	Total N
(g kg^{-1})				(%)			
476	138	386	7.09[1]	0.178[2]	7.15[3]	2.49[4]	0.15[5]
P	K	Ca	Mg	Fe	Cu	Zn	Mn
(µg g^{-1})							
78[6]	728[6]	7060[6]	5604[7]	8.08[6]	2.84[5]	0.62[8]	4.07[8]

1 Neutral, 2 Slightly salty, 3 Medium calcareous, 4 Medium, 5 Enough, 6 Much, 7 Excessive, 8 Little

The semi-arid continental climate of the Central Anatolia Region is dominant in the Yozgat Province. Summers are hot and dry, as it is closed to sea influence; winters are cold and rainy. Temperature differences between day and night, and summer and winter are high. The total precipitation, the average temperature and the average relative humidity were 177 mm, 18.74 C, and 45.24%, respectively in the production area during the vegetation (Figure 1). The production area with medium level of organic matter has a heavy structured soil (Table 1).

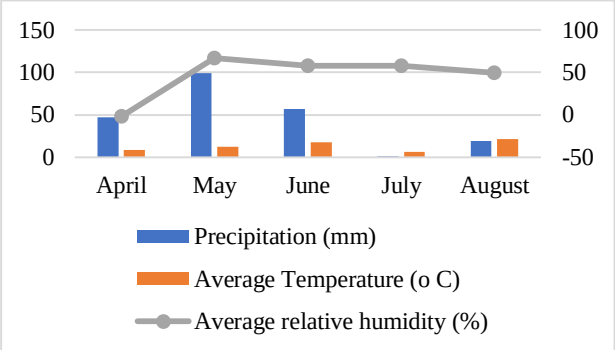

Figure 1. Climate data recorded during vegetation

2.3. Production practices

The seeds of the coriander cultivars were 30 cm between rows and 3 m in row length, 1 g of seeds were planted in rows. Sowing was made on April 21, 2017, with 30 rows of each variety. Weed control has been done when necessary. Any irrigation and fertilization have not been done. Plants were harvested in two different periods.

Period 1: Fresh plant harvesting: All above ground parts of plants were collected when the plants were in full flowering stage. (5 July 2017, 12:00)

Period 2: Dried plant harvesting: During the seed ripening period, all plant parts were harvested (12 August 2017, 11:00). The harvested fresh plants (Period 1) were dried in the shade. Plants in Period 1 were divided into three parts as flower, stem and leaf; Plants in Period 2 were divided into two parts as seed and stem (Figure 2).

Figure 2. Development stages of coriander and its fruits

2.4. Preparation of extracts

The dried plant parts (flower, green stem, green leaf, seed and dry stem) were ground separately with a laboratory type blender. The dry matter of 1 g from the flowers, 2 g from the green stem and leaf, and 4 g from the dry stem was used. Two different solvents (methanol and ethanol, 1/10 w / v) were used in the study. The samples mixed with the solvent were first incubated in the oven (Elekto-mag M 5040p) at 40 ° C for 24 hours. Then, the solvents were removed from the extracts filtered through Whatman No 1 filter paper with the help of a rotary evaporator, and then it was left in the oven for another 24 hours to ensure complete drying. The dried extracts were dissolved in 2 ml of methanol and stored at +4 ° C until analyzed (Zakaria et al., 2019).

2.5. Essential oil extraction

100 g of the ground seeds of the coriander varieties were weighed and after they were placed in 2 L balloon flasks, 750 mL of water was added to them. It was subjected to water distillation in Clevenger device for 3 hours. Essential oil values (%, v/w) were calculated as volume on dry matter. The essential oils obtained as a result of distillation were kept at +4 C in dark glass bottles until analyzed (Baj et al., 2015).

2.6. Determination of the chemical composition of essential oil

Chemical component determination of essential oils ob tained as a result of the research was made by Shimadzu, QP2010 ULTRA Gas Chromatography-Mass Spectrometer (GC / MS) at Yozgat Bozok University, Science and Technology Application and Research Center. Separation of the components was made on an Rxi-5ms capillary column with a length of 30 m, an inner diameter of 0.25 mm, and a film thickness of 0.25 µm. The split rate was set to 10, the flow rate was set to 1.10 mL/min. In the analysis, a temperature program that ends at 70°C for 1 minute, with an increase of 20°C/min to 180°C, 1 minute at 180°C, and 280°C with an increase of 10°C/min was applied. Helium was used as the carrier gas, and the injector temperature was kept at 250°C. Substances exiting the column were screened in the mass range of

50-550 (m/z) (70eV). The transfer temperature was set to 250°C and the ion source temperature to 200°C. Identification of components was done using FFNSC 1.2 library search software and literature data (Babushak et al., 2011).

2.7. Antibacterial activity test

In the study, three different medium was prepared, as below:
1:Tryptic Soy Agar (TSA, a general purpose growth medium for a wide variety of microorganisms),
2:Tryptic Soy Broth (TSB, a high nutrient-containing bacteria and fungus growth medium,) and
3:Muller-Hinton Agar (MHA, having international validity in antimicrobial susceptibility tests). The contents of the medium are given in Table 2. While preparing the medium, 40 g TSA, 30 g TSB and 38 g MHA were weighed on a precision scale and mixed with 1L distilled water, then autoclaved at 121 °C for 15 minutes to sterilize the media. Medium were stored at + 4C until analysis.

Disk diffusion technique (Kirby-Bauer method) was used to evaluate the antimicrobial activity (Prescott et al., 1990). In the tests, 7 Gram-negative (*Escherichia coli* ATCC®25922, *Pseudomonas aeruginosa* ATCC®9027, *Salmonella typhimurium* ATCC®14028, *Serratia marcescens* ATCC®13880, *Proteus vulgaris* ATCC®6380, *Enterobacter cloacae,* ATCC®13047, and *Klebsiella pneumoniae* ATCC®4352), and 1 Gram-positive bacteria (*Staphylococcus aureus* ATCC®6538) were used. These pathogenic organisms were selected for the study considering their clinical and pharmaceutical importance (Table 3). Bacteria were transferred to test tubes containing 2 ml TSB and incubated in an oven at 37 ° C for 3 hours, and at the end of 3 hours, each microorganism was spread on TSA containing medium and inoculated.

Table 2. TSA, TSB and MHA contents

Tryptic Soy Agar (TSA)	
Typical Formula	**gL^{-1}**
Pancreatic Digest of Casein	15.0
Piapiac Digest of Soybean Meal	5.0
Sodium chloride	5.0
Agar (gelatin)	15.0
pH =7.3 ± 0.2	
Tryptic Soy Broth (TSB)	
Typical Formula	**gL^{-1}**
Pancreatic Digest of Casein	17.0
Soybean Meal Piapiac Digest	3.0
Sodium chloride	5.0
Dipotassium Phosphate	2.5
Glucose	2.5
pH =7.3 ± 0.2	
Mueller-Hınton Agar (MHA)	
Typical Formula	**gL^{-1}**
Beef, dried infusion	300.0
Casein hydrolysate	17.5
Starch	1.5
Agar	17.0
pH=7.3 ± 0.1	

It was left in the oven at 37 ° C for another 2 days. At the end of the two days, 4-5 loops bacteria were taken from pure cultures, transferred to medium containing 20 ml TSB and incubated at 37 ° C until the morning. 0.5Mc Farland (McF) unit bacteria were put into tubes containing 2 ml TSB with the help of a densitometer. Then, 100 µl of the obtained suspension was taken and spread in Petri dishes containing MHA and the medium were prepared for antibacterial test. 5 separate antibiotic discs "Erythromycin (15µg), Ampicillin (10 µg), Carpenicillin (100µg), Tetracycline (30µg), Chloramphenicol (30µg)" were used for controls. All stages were carried out in a laminar flow sterile cabin. Filter papers to be used in the study were cut in 0.22 µm shape and autoclaved for 15 minutes at 121 ° C and sterilized. With the help of a densitometer, 0.5Mc Farland (McF) unit was set from the bacteria, 100 µl was drawn with a pipette, transferred to the medium containing MHA and spread on the media with an iron loop and waited for 30 minutes. Sterile discs were dipped in extracts (5 mL) and essential oils (2 mL), and the excess water was removed on sterile blotting paper and placed in petri dishes. The trial was set

up in 2 replications. Petri dishes were kept in the oven at 37 ° C for 24 hours, and then, the diameters of the inhibition zones around the discs were measured in mm with the help of a digital caliper. (Figure 3).

Table 3. The effects of bacteria used in the research on human health (WHO, 2001; Hogg 2005)

Pathogen	Diseases
Escherichia coli	Urinary tract infection, Chronic renal failure, Stomachache, Diarrhea, Vomiting, Dysentery, Meningitis, Liver abscess
Pseudomonas aeruginosa	Eye disease, External and middle ear infection, Burn and wound infections, Meningitis, Bronchitis, Cramp, Nausea, Epidemic diarrhea, Death in infants
Salmonella typhimurium	Fever, Nausea, Headache, Diarrhea, Tuberculosis, Meningitis
Serratia marcescens	Urinary tract, upper respiratory tract and wound infections, Meningitis
Proteus vulgaris	Urinary tract and wound infections, Meningitis Diarrhea, Sepsis (organ failure)
Enterobacter cloacae	Urinary tract infection, Fever, Shortness of breath, Cough
Klebsiella pneumoniae	Sudden fever, Wound infections, Shortness of breath, Bronchitis, Heart disease
Staphylococcus aureus	Meningitis, Vomiting, Fatigue, Inflamed wounds, Sweating, Skin and Organ infections

All tests and analyzes performed in the study were carried out with 3 repetitions, and the mean of the values was given with the standard deviation (mean ± SD). Antibacterial activity results were evaluated according to the criteria reported by Davis and Stout (1971) (Table 4).

Table 4. The criteria for evaluating antibacterial activity

Inhibition zone diameter (mm)	Evaluation
<5	Weak
5-10	Moderate
10-19	Strong
>20	Very strong

3. Results and Discussion

3.1. Extract yield

Flowers, leaves and stems were harvested during the flowering period, and seeds and stem were harvested at full maturity. The values obtained from the extracts prepared by using ethanol (E) and methanol (M) of these plant samples are given in Table 5.

Table 5. Extract amount and yield of plant samples

Fresh Plant Organs				
Cv.	Plant Organ	Solvent[1]	Extract Amount (g)	Extract Yield (%)
Arslan	Flower	E	0.027±0.0022	2.54±0.20
		M	0.080±0.0046	7.63±0.18
	Leaf	E	0.037±0.0035	1.77±0.15
		M	0.083±0.0075	5.67±0.38
	Stem	E	0.017±0.0012	0.80±0.06
		M	0.045±0.0009	2.23±0.07
Gürbüz	Flower	E	0.021±0.0004	2.02±0.07
		M	0.077±0.0030	7.37±0.31
	Leaf	E	0.021±0.0010	1.05±0.05
		M	0.088±0.0092	4.31±0.46
	Stem	E	0.018±0.0014	0.86±0.07
		M	0.053±0.0040	2.60±0.23
Dry Plant Organs				
Cv.	Plant Organ	Solvent	Extract Amount (g)	Extract Yield (%)
Arslan	Seed	E	0.029±0.0029	1.42±0.13
		M	0.038±0.0031	1.87±0.19
	Stem	E	0.026±0.0052	0.32±0.26
		M	0.017±0.0049	0.82±0.25
Gürbüz	Seed	E	0.061±0.0264	2.99±1,29
		M	0.042±0.0046	2.03±0.25
	Stem	E	0.038±0.0030	0.19±0.14
		M	0.011±0.0022	0.52±0.97

The extract yields of the fresh plant parts obtained from the flowering period were higher than the seed and stem obtained from the full maturity period. In general, it was observed that the yields of extracts prepared using methanol were higher than those prepared with ethanol. Palmieri et al.

(2020) reported that the yields of extracts prepared using different traditional and non-traditional methods in coriander fruits varied between 0.57-2.36% (w / w). Jangra et al. (2018), who prepared extracts from coriander leaves using acetone, ethanol and water, obtained extract yields (g 100 g-1) of 2.22-2.45, 2.59-3.35, and 1.99-2.4, respectively, and they had emphasized that higher yields were obtained from extracts prepared with ethanol. It is stated that in general, extraction yield is lower in seeds and higher in stems and leaves (Palmieri et al. 2020). According to the literature findings, we can say that the yields of herbal extracts vary according to the organ of the plant, the solvent and method used.

3.2. The chemical compositions and content of essential oil

Mean values belong to the ratio and chemical composition of light yellow-colored essential oils obtained from coriander varieties are presented in Table 6. The fruit essential oil ratio of cv. Arslan (large-fruited) and cv. Gürbüz (small-fruited) were recorded as 0.31% (v/w) and 0.42% (v/w), respectively. Beyzi et al. (2017) worked with the same cultivars, essential oil contents of cultivars detected 0.30% in cv. Arslan and 0.33% in cv. Gürbüz. Generally, the essential oil content of small-fruited varieties (0.8-1.8%, v/w) is higher than the varieties with large-fruited (0.1-0.35%, v/w) (Burdock and Carabin, 2009). Similar results were obtained in our study, but the essential oil content of the small-fruited cultivar was found to be lower than the values stated in the literature. In a study conducted in Bangladesh, fruit essential oil was found to be 0.42% (Bhuiyan et al., 2009). In other studies, the essential oil content of coriander fruits was reported as 0.39% by Ravi et al (2006), 0.35% by Msaada et al. (2007), and 0.23% by Mansori et al. (2018). Although coriander fruits contain 0.2-1.5% essential oil, in some genotypes this rate is up to 2.6% (Ebrahimi et al., 2010). However, it is also possible to come across genotypes containing essential oil higher than 2.6%. For example, the essential oil yields obtained by hydro distillation method from fruits belonging to coriander genotypes originating from different countries have taken values in the range of 0.1-5.2 % (Orav et al., 2011). It is observed that there are differences in the essential oil content of coriander fruits grown in different geographies.

Table 6. Chemical composition and content of fruit essential oils of coriander cultivars (%)

Compound	RT[1]	cv. Arslan	cv. Gürbüz	EPS[2]
α-pinene	3.760	1.03	1.67	3-7
Camphene	3.909	0.11	0.15	
Sabinene	4.093	0.13	0.13	
β-Pinene	4.152	0.23	0.31	
β-Myrcene	4.182	0.21	0.26	
Ortho-Cymene	4.537	0.73	0.67	
Limonene	4.578	1.43	1.45	1.5-5
p-cymene				0.5-4
γ-Terpinene	**4.831**	**8.11**	**6.94**	1.5-8
Trans-sabinenehydrate	4.930	0.01	0.02	
Linalool	**5.203**	**73.52**	**74.38**	65-78
Citronellal	5.615	-	0.02	
Camphor	**5.667**	**3.67**	**4.22**	3-6
1-Borneol	5.836	0.14	0.22	
Terpinen-4-ol	5.911	0.19	0.18	
α-Terpineol	6.013	0.21	0.25	0.1-1.5
Myrtenol	6.074	0.27	0.29	
Geraniol	**6.444**	**6.11**	**8.45**	0.5-3
Cis-myrtanol	6.615	-	0.01	
Caryophyllene	8.109	0.21	0.31	
Bicyclogermacrene	8.833	-	0.06	
Geranyl acetate	-	-	-	0.5-4
TOTAL		**96.31**	**99.99**	
Essential oil content (%)		**0.31 ±0.025**	**0.42 ±0.03**	**min. 0.3**

[1]RT: Retention Time; [2]EPS: European Pharmacopoeia Standards (Gebarowska et al., 2019).

In the cv. Arslan, 17 components representing 96.31% of the oil and in the cv. Gürbüz, 20 components representing 99.99% of the oil were detected. It was observed that the main component is linalool in both essential oils. Also, γ-terpinene, geraniol and camphor were determined as other important components in essential oils (Table 5). Considering the literature data and our study results, linalool was determined as the component

with the highest value in the essential oil obtained from coriander fruits. Overall, it was reported that the linalool content in the essential oils obtained from coriander fruits ranged from 37.3% to 87.5% (de Figueiredo et al.2004; Msaada et al., 2007; Bhuiyan et al., 2009; Ebrahimi et al., 2010). γ-terpinene, α-pinene, p-cymene, camphor, and geranyl acetate were determined as the other characteristic components of the essential oil (Orav et al., 2011; Zekovića et al., 2011; Vasconcelos Dos Santos et al. 2019; Satyal and Setzer, 2020; Al-Khayri et al. 2023). Micića et al. (2019) stated that they detected α-pinene (7.31%), geranyl acetate (5.76%), γ-terpinene (5.59%), camphor (4.245), p-cymene (3.83%), and limonene (1.60%) in addition to linalool (64.04%) in the essential oil of coriander fruits. When we compare the data obtained from our study with EP standards; α-pinene and limonene values are low, geraniol and γ- terpinene values are very high, and essential oil content, linalool and camphor values are among the limit values. On the other hand, geranyl acetate and p-cymene were not detected in the essential oil samples we studied (Table 6).

Although some of the findings we obtained from our study are compatible with the literature data, there are differences. In this context, cultural conditions are an important factor (Mandal and Mandal, 2015). Within the scope of the study, coriander varieties were grown in arid conditions and no additional irrigation was done. The literature data indicate that the essential oil content and composition may differ depending on the climatic conditions of the region, the growing conditions of the plant, cultural practices (sowing time, harvest time etc.) and the genotype of the plant (Gebarowska et al., 2019; Delibaltova 2020).

3.3. Antibacterial activity

Inhibition zone diameters (mm), which are the indicators of the activity of the research materials against one Gram-positive and seven Gram-negative bacteria, are given in Table 7. The antibacterial activity of essential oils obtained from Arslan and Gürbüz cultivars was similar. While none of the antibiotic discs in the study showed any effect against *S. aureus*, the only Gram-positive bacteria included in the study, essential oils were effective. When evaluated the antibacterial activity according to the criteria reported by Davis and Stout (1971), EO (essential oil) Arslan was strong and EO-Gürbüz was medium. The CB-100 antibiotic used as a control showed the highest activity against *E. coli* bacteria. A moderate activity recorded in essential oils was similar to that of the C-30 and TE-30 antibiotics. The essential oil of both varieties showed no activity against *P. aeruginosa* bacteria. In most studies examining the effect of essential oils against pathogens, it is revealed that the effect of essential oils against Gram-positive bacteria is more than Gram-negative bacteria. The cell wall of Gram-negative bacteria is surrounded by lipopolysaccharides, which prevents the antibacterial effect. The outer membrane surface of Gram-negative bacteria such as *P. aeruginosa* is rich in hydrophilic and lipopolysaccharide molecules. Therefore, they show a very different internal resistance to essential oils (Dorman and Deans, 2000; Esen et al., 2007; Turker and Usta, 2008).

The highest activity against *S. tyhimurium* bacteria was observed with antibiotic discs. However, the activity exhibited by essential oils was close to E-15. M-10 and E-15 control antibiotics were ineffective against *S. marcescens* bacteria. C-30 and CB-100 antibiotics exhibited the highest activity against this bacterium. It was noted that the activity (moderate) exhibited by essential oils was close to the TE-30 control disc. TE-30, C-30 and CB-100 control discs, respectively, exhibited the highest activity against *P. vulgaris* bacteria.

Table 7. Antibacterial activity of essential oils and extracts from coriander varieties against tested bacteria

Mean inhibition zone diameters (mm±SD)				
Material	**1[1]**	**2**	**3**	**4**
EO-A	11.34±0.29(S)	9.99±0.34 (M)	-	8.36±0.23 (M)
EO-G	10.23±0.72 (M)	9.56±0.55 (M)	-	7.30±0.06 (M)
Fruit (Ethanol-G)	-	7.08±0.94 (M)	-	-
C (30 µg)	-	10.73±0.00 (M)	23.92±2.03 (VS)	22.80±2.26 (VS)
TE-(30 µg)	-	8.64±1.02 (M)	22.14±0.43 (VS)	20.09±1.02 (VS)
AM-(10 µg)	-	-	13.46±0.00 (S)	17.13±4.18 (S)
CB-(100 µg)	-	22.16±0.00 (VS)	21.38±0.02 (VS)	10.44±1.68 (M)
E-(15 µg)	-	-	8.97±0.05 (M)	9.29±0.20 (M)
	5	**6**	**7**	**8**
EO-A	9.17±0.21 (M)	9.24±0.36 (M)	11.43±0.07 (S)	-
EO-G	10.79±0.22 (M)	9.48±0.68 (M)	10.52±0.00 (M)	-
Fruit (Ethanol-G)	-	-	-	-
C (30 µg)	23.41±0.40 (VS)	22.25±0.69 (VS)	24.67±0.71 (VS)	29.65±1.37 (VS)
TE-(30 µg)	11.58±0.00 (S)	22.26±1.19 (VS)	16.53±0.00 (S)	22.52±4.09 (VS)
AM-(10 µg)	-	-	21.32±0.04 (VS)	-
CB-(100 µg)	25.51±1.42 (S)	19.64±0.57 (S)	31.93±0.21 (VS)	-
E-(15 µg)	-	-	-	18.43±0.06 (S)

[1]1: *S. aureus*, 2: *E. coli*, 3: *P. aeruginosa*, 4: *S. tyhimurium*, 5: *S. marcescens*, 6: *P. vulgaris*, 7: *E.cloacae*, 8: *K. pneumoniae*
EO: Essential oil, A: cv. Arslan, G: cv. Gürbüz, C: Chloramphenicol, TE:Tetracycline, AM:Ampicillin, CB:Carbenicillin , E:Erythromycin, M: Moderate, S: Strong, VS: Very Strong

AM-10 and E-15 antibiotics were ineffective against the bacterium in question. The inhibition zone diameter recorded for these bacteria, in the essential oils was lower than that of in the controls, with an average of 9.36 mm. CB-100 showed the highest activity against *E. cloacae* bacteria with an inhibition zone diameter of 31.93. C-30 (24.67 mm, VS), AM-10 (21.32 mm, VS) and TE-30 (16.53 mm, VS) followed respectively. E-15 had no activity against this bacterium. EO-Arslan and EO-Gürbüz showed strong and moderate activity, respectively, against this bacterium. Essential oils and AM-10 and CB-100 antibiotics were ineffective against *K. pneumoniae* bacteria. C-30 exhibited the highest activity, followed by TE-30 and E-15, respectively (Table 7).

It is known that essential oils obtained from different organs of coriander (such as fruits and leaves) inhibit microorganisms in a wide spectrum (Bhuiyan et al., 2009; Begnami et al., 2010; Mandal and Mandal, 2015; Beyzi et al., 2017; Al-Khayri et al., 2023). Coriander essential oil has been observed to be effective against both Gram-positive and Gram-negative bacteria (*E. coli, Salmonella* spp., *S. aureus*, *S. typhimurium*, *K. pneumoniae*, *P. aeruginosa, E. cloacae*) (Delaquis et al., 2002; Asgarpanah and Kazemivash, 2012; Dima et al., 2015; Mandal and Mandal, 2015; Rezaei et al., 2016). In our study, essential oils were ineffective against *K. pneumoniae* and *P. aeruginosa* bacteria.

In the study we carried out, only the extract prepared with ethanol from the fruits of the cv. Gürbüz showed moderate activity against *E. coli* bacteria. However, this activity was lower than both essential oils and control antibiotics (Table 7). None of the other extracts exhibited antibacterial activity against tested microorganisms. In the studies conducted also, it has been stated that the coriander aqueous extract had no antimicrobial activity (Sahib et al., 2013).

It has been reported that the antimicrobial activity of coriander essential oil is due to active ingredients such as linalool, α-pinene, β-pinene, p-cymene and ɣ-terpinene (Dorman and Deans, 2000; Koutsoudaki et al., 2005; Xianfei et al., 2007). In addition, it was determined that the antimicrobial activity of coriander essential oil is not only related to the linalool amount of the essential oil, but also the interaction of other components in the essential oil is important on the antimicrobial activity (Begnami et al., 2010).

Although the amount of linalool (63% and 66%) in coriander fruit essential oils obtained by two different methods is similar, it was determined that the essential oil with higher ɣ-terpinene, α-pinene and p-cymene contents exhibited a stronger activity against *S. aureus* bacteria (Sourmaghi et al., 2015). In our study, since the essential oil composition of the cultivars was similar, their activity against the tested bacteria was also found similar (Table 5 and Table 7).

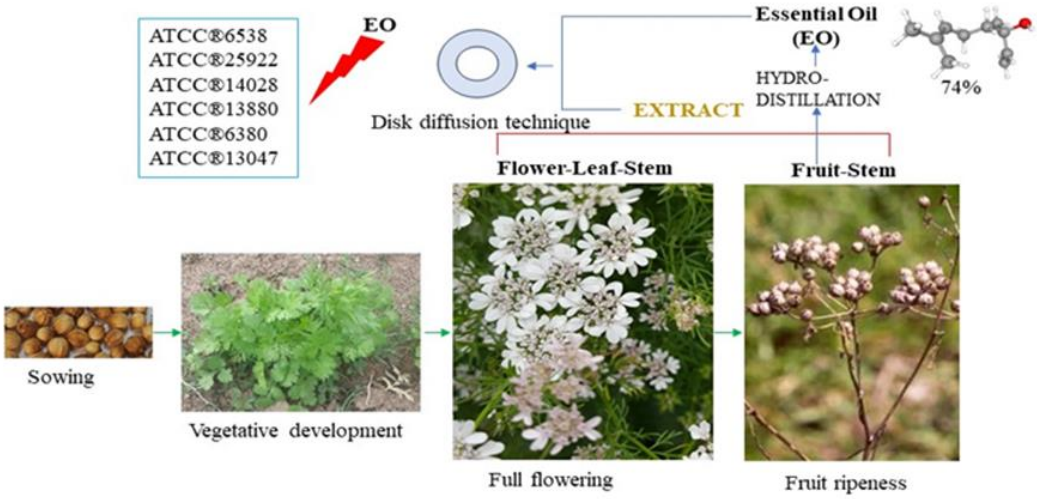

Figure 3. Procedures in this research

4. Conclusion

In this study, the antimicrobial activities of essential oils obtained from the seeds of two coriander varieties grown under semi-arid culture conditions and extracts obtained from different parts against pathogenic bacteria that threaten human health were evaluated (Figure 3). All but one of the extracts (Fruit /Ethanol-Gürbüz) showed no activity against test microorganisms. It has been determined that essential oils exhibit varying levels of activity against *S. aureus, E. coli*, *S. tyhimurium, S. marcescens, P. vulgaris*, and *E. cloacae* bacteria. In line with the findings, these essential oils may inhibit the growth of different bacteria. Therefore, more research with different bacteria is needed to better explain the healthcare use of these essential oil samples.

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Author Contribution

This article was produced from a graduate test.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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