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Biochemical parameters of cedar (Mezla) honey

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Abstract

This study was conducted to determine the characteristics of cedar honey, which is an important honeydew honey produced on the Mediterranean coast of Turkey. The geographical classification of the honey was determined by applying carbon isotope, honey colour, aromatic compound, antioxidant activity, antibacterial minimum inhibitory concentration values, and physicochemical analyses to 16 samples collected from four regions. The investigation encompassed measurements of $\delta^{13}C$ values for both protein and raw honey, obtaining the respective isotopic compositions of -25.48% and -26.67%. Diastase activity (17.9 DN), electrical conductivity (1.52 mS/cm), hydroxymethylfurfural (2.54 mg/kg), moisture (17.5%), pH (4.96), proline (347 mg/kg), free acidity (35 meq/kg), fructose (35.5 g/100 g), glucose (29.7 g/100 g), and sucrose (0.58 g/100 g) were determined. The L*, a*, and b* values were measured as 43.76 ± 4.52, 3.48 ± 1.82, and 49.31± 8.39, respectively. The total phenolic content (TP), DPPH, and FRAP were determined as 68.43 mg/100g GAE, 30.529 mg/ml, and 0.00422 ppm AAE, respectively. Antibacterial activity against *Escherichia coli, Bacillus cereus*, and *Klebsiella pneumoniae* displayed minimum inhibitory effects of 70%, 80%, and 80%, respectively. All samples exhibited cedar honey (honeydew) properties and all physicochemical parameters met the criteria set by regulatory standards for honeydew.

Keywords: antimicrobial activity, antioxidant activity, aromatic component, cedar honey, chemical parameters

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Introduction

Honey is a natural sweet substance produced by honey bees (*Apis mellifera* L.) from the nectar of flowers or secretions of living parts of plants. Honey comes in various types, each with its own unique flavour, aroma, and colour. Honey can be categorized into two main groups depending on its origin: flower or secretion. While flower honey is sourced from the flowers of plants, honeydew honey is produced when bees collect secretions from insects that inhabit the plants. Examples of secretion honey include varieties like pine, cedar, fir, and oak. Honeydew honey is predominantly collected by bees from the pine tree branches. This type of honey colours tends to have a darker colour, often ranging from amber to dark brown (Kolayli *et al*, 2018; Özkök *et al*, 2019; Uçurum *et al*., 2023). Honeydew honey aroma is often strong and reminiscent of the pine forest and has a slight medicinal value. The taste of flower honey can range from mild and floral to bold and fruity, depending on the plants involved. Unlike honeydew honey, the aroma of blossom honey is often sweet and floral, reflecting the variety of flowers from which the nectar was collected. Both honeydew and blossom honeys offer unique characteristics, and their specific flavours can vary depending on factors, such as the region, climate, and the types of plants available to the bees (Gül & Pehlivan, 2018).

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Honeydew honey often possesses a unique aroma and flavour profile that sets it apart from floral varieties. Honey contains a variety of volatile compounds that contribute to its aroma. These include aldehydes, ketones, alcohols, esters, and sulphur-containing compounds. These compounds can vary depending on factors such as the botanical sources of the honeydew, the region where it is produced, and the processing methods. The aromatic profile of honeydew honey is complex and can exhibit a wide range of flavours and aromas, including fruity, floral, woody, earthy, and caramelized notes. The aromatic compounds present in honeydew honey contribute to its characteristic scent and taste. The presence of aromatic compounds not only contributes to the sensory characteristics of honeydew honey but also reflects its unique composition and potential health benefits. The specific composition of volatile compounds in honeydew honey can vary depending on its botanical and geographical origins (Sahinler *et al*., 2004; Gül & Pehlivan, 2008).

Colour evaluation exhibits a notable level of subjectivity, prompting the need for more objective approaches to evaluating honey colour. One such widely-adopted method in the food industry involves the use of visual comparison instruments, which gauge the colour of honey samples against glass filters, offering assessments on an mm/Pfund scale. To address this challenge more effectively, instrumental techniques utilizing spectrophotometers or colourimeters have gained prevalence due to their efficiency in providing readily-comparable results in both research and routine analysis settings. Of these techniques, the tristimulus CIE (Commission Internationale de l'Eclairage, International Commission on Illumination), characterized by L^*, a^*, and b or L^*, C_{ab}, and $h°_{ab}$ chromaticity coordinates, has emerged as the most frequently used. Designed to align with human visual perception, CIE L* a* b employs Cartesian coordinates to define colour within a colour space, whereas CIE L* C_{ab} h°_{ab} adopts polar coordinates. These systems describe colour through three key attributes: lightness (L*), which indicates proximity to black or white; hue (h*), representing the perceived colour (e.g., yellow, red, blue, or green); and chroma (C*), reflecting colour saturation, vividness, or purity. Higher chroma values signify richer and more vibrant colours, whereas lower values denote duller and more muted shades. Numerous studies have explored honey colour using the CIE L* a* b* system, emphasizing its widespread application and importance in colour analysis (Bertoncelj *et al*., 2007; González-Paramás *et al*., 2007; Gámbaro *et al*., 2007; Juszczak *et al*., 2009; Kadar *et al*., 2011; Kamboj & Nanda, 2013; Rodríguez *et al*., 2012; Zhou *et al*., 2013).

Taurus fir, *Abies cilicica* (Antoine et Kotschy) Carrière, is endemic to Turkey. It is the largest native forest in the world and is naturally distributed in southern Turkey (Aytar *et al*., 2012; Figure 1). Cedar honey is produced by collecting the secretions of some aphids on the Taurus fir trees and turning them into honey by honey bees. Cedar honey is a waste product in dense liquid form as a result of sap-sucking of host plants by insect species such as aphids, scale insects, and *Hemiptera* (order dependent). Because the sugar content is high in phloem, these insect species obtain food necessary for their development from the host plants.

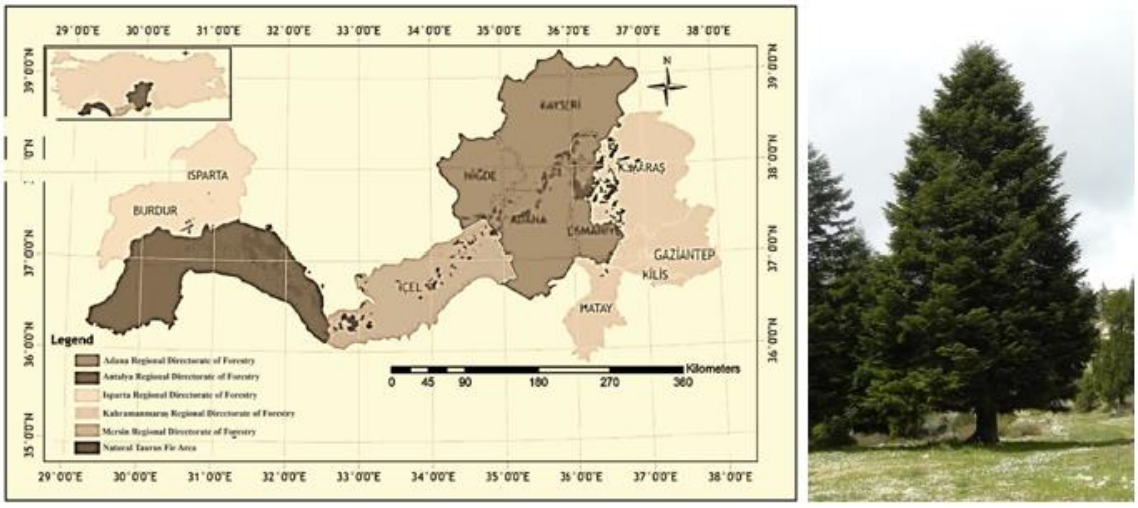

Figure 1 Taurus fir (*Abies cilicica* spp.) areas in Turkey (Aytar *et al*., 2012)

The species that are damaged by the sucking of the phloem by insects secrete honeydew (Figure 2), which is a nutritional source for insects, such as ants, bees, and flies. As such, this contributes to ecological balance (Oğuzoğlu & Avci, 2019). *Cinara cedri* Mimeur 1936 (Mimeur, 1936), a species that produces secretion honey, is an aphid species belonging to the order Hemiptera, family

Aphididae. It was first seen by Mimeur in Morocco in 1935 and was described in 1936. Due to the use of *Cedrus libani* for wood and as an ornamental plant, *C. cedri* and *C. libani* have been distributed to different parts of the world (Binazzi *et al*., 2015; Görür *et al*., 2019). The secretion honey from these species has a high phenolic content and high antifungal and antioxidant capacities (Gül & Pehlivan, 2018). Cedar honey, which is also called Mezla honey, has an aromatic taste and a honeydew scent originating from the cedar trees. Unlike other secretion honey, cedar honey has a transparent colour, high viscosity, and does not crystallize.

Figure 2 Taurus fir (*Abies Cilicia* spp.) and the secretion on the branches caused by insects

Material and Methods

Unless otherwise noted, all reagents and chemicals used were analytical grade from Sigma Chemical Company (St. Louis, MO, USA). A Shimadzu UV-1208 model ultraviolet-visible (UV-VIS) spectrophotometer (UV-1280 Multipurpose UV-VIS, Shimadzu) was used for absorbance measurements.

Honey samples were collected from 16 beekeepers in four locations spread out across the Adana province (Figure 3). The collected samples were labelled according to the information given by the beekeepers and stored under appropriate conditions (e.g. room temperature, 20–25 °C; away from direct sunlight) throughout the study. All honey were produced under controlled conditions with no sugar-feeding or adulteration. All organic solvents were of gas chromatography-grade quality; solid chemicals were Merck and Sigma-Aldrich quality.

Figure 3 Honey samples were collected from 16 beekeepers in four locations spread out across the Adana province, Turkey

The moisture, ash content, diastase, hydroxymethylfurfural (HMF), free acidity, fructose, glucose, sucrose, viscosity, electrical conductivity, and proline content of honey were measured using the methods of the International Honey Commission (IHC, 1999). The spectrophotometric method was used to determine the quantitative of the proline content in honey samples. This method is based on the colour reaction of proline with ninhydrin reagent; absorbance was read at 510 nm and the results were expressed in mg/kg. Optical rotation measurements were conducted with a polarimeter (Kruss P 3000, Germany) following the precipitation of honey proteins with Carrez's reagent. The filtrate solution was then introduced into the polarimeter, and the angular results were recorded based on a 200 mmol scale (Junk, 1973). A viscometer (DV-II Viscometer No. MO3-165-E = 211; UK) was used to measure the viscosity of honey samples. The measurement range of the device was 1000–a range of 40–60% at 20–25 °C.

Sugar profiles were determined by injecting samples into vials under the same device conditions (AOAC, 1977). Sugar fractions of the honey samples were measured using chromatographic methods with a refractive index detector (HPLC-RID) (Shimatzu 10A, Japan). high-performance liquid chromatography (HPLC) analyses of the sugar profiles were carried out on Shodex NH_2P-50 4 E column (5 µm, 250 × 4.6 mm).

The official AOAC method was employed to determine the carbon isotopes in the honey samples (AOAC, 2005). The principle of this analytical method is based on the determination of the $^{13}C/^{12}C$ ratio of the C atom in CO_2 from the combustion of raw honey; the precipitated protein was determined using elemental analyser–isotope spectrometry (EA–IRMS) (Thermo Fisher P2000; elemental analyser-isotope ratio mass spectrometry). The C4% sugar was calculated according to the following equation (White, 1992):

$$C4\ (\%)\ \text{sugar} = [\delta^{13}C\ \text{protein} - \delta^{13}C\ \text{honey}] \times 100 / \delta^{13}C\ \text{protein} \quad (1)$$

Aromatic compounds of the honey samples were tested using the method of Sánchez-Palomo *et al*. (2005). Honey samples were heated to 40 °C and kept at this temperature for 40 min using a 65-µm polydimethylsiloxane/divinylbenzene fibre. The solid phase micro-extraction (SPME) syringe with a 65- µm PDMS/DVB fibre was used for collecting the volatile compounds from the headspace of the honey samples. The SPME fibre was injected into the gas chromatography–mass spectrometry (GC-MS) to perform the analysis. The GC-MS parameters of the method used in this study research were: injection temperature, 250 °C; pressure, 49.7 kPa; column flow rate, 1.00 mL/min[2]; 240 °C; waiting time at last temperature, 10 min; and split ratio, 1/10.

The L^*, a^*, and b and L^*, C^*_{ab}, and $h°_{ab}$ coordinates were determined using a UV-VIS spectrophotometer (Varian series, Cary 50 Scan, Leini, TO, Italy). The colour of the honeys was measured in terms of (L) for darkness/lightness (0 black and 100 white), a (−a greenness, +a redness), and b (−b blueness, +b yellowness). The transmittance of the whole visible spectrum (200–1000 nm) was measured at a wavelength interval of 5 nm, using D65 illuminated at a 10° observation angle. CIE L*, a*, b*, L*, C^*_{ab}, $h°_{ab}$ colour space uses coordinates and was measured from a* and b* from the CIE XYZ tristimulus values. C_{ab} and h° values were obtained using the following formulae (Tuberoso *et al*., 2014):

$$C^*_{ab} = (a^{*2}+b^{*2})^{1/2} \quad (2)$$

$$h°_{ab} = \text{arc tan}(b/a) \quad (3)$$

The Folin–Ciocalteu method was used to determine the total phenolic content (TPC) (Singleton *et al*., 1999; Yorulmaz & Konuskan, 2017) with some modifications. In summary, each honey sample (1 g) was dissolved in 5 ml of methanol and then filtered through Whatman No. 1 filter paper. Subsequently, a 40-µl aliquot of this solution was mixed with 2.4 ml of distilled water and 200 µl of undiluted Folin–Ciocalteu reagent, followed by the addition of 0.6 ml of 20% sodium carbonate (Na_2CO_3). After incubating in the darkness at 25 °C for 2 h, the absorbance of the resulting mixture was measured at 760 nm against a methanol blank using a UV-VIS spectrophotometer (Hitachi U-1900, Japan). All measurements were performed in triplicate. Gallic acid standards ranging from 0 to 1000 mg/L were used to establish a calibration curve. The total phenolic content was quantified and expressed as milligrams of gallic acid equivalents (GAE) per kilogram of honey.

The DPPH (1,1-diphenyl-2-picrylhydrazyl) radical scavenging activity of honey samples was determined as described by Brand-Williams *et al*. (1995) with some modifications. In brief, each honey sample (1 g) was dissolved in 5 ml of methanol and then filtered through Whatman No. 1 filter paper. Following this, a 0.1-ml portion of each honey sample (concentration range: 12.5–200 mg/ml), together

with butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) in methanol, was added to 2.9 ml of a 6×10^5 M methanolic solution of DPPH. The resulting mixtures were vigorously shaken and left at 25 °C in darkness for 60 min. Subsequently, the absorbance of the solutions was measured at 517 nm using a spectrophotometer (Hitachi U-1900, Japan) against a methanol blank. All measurements were conducted in triplicate. The radical scavenging activity was quantified as %DPPH inhibition, calculated using linear regression analysis.

The ferric reduction antioxidant power (FRAP) assay is a spectrophotometric technique used to assess the antioxidant capacity of a substance by measuring its ability to reduce a ferric–tripyridyltriazine complex to its ferrous form, characterized by an intense blue colour absorbance at 593 nm. The ferric-reducing power of honey samples was determined following a method based on Oyaizu's protocol (1986), with slight adjustments (Oyaizu, 1986; Khiati, 2014). This method relies on the capacity of antioxidants to reduce a ferric 2,4,6-tripyridyl-triazine complex to its coloured ferrous form (Fe^{2+}–TPTZ) (Ahmed *et al*., 2014). The FRAP reagent was prepared by combining 2.5 mL of a 10 mM TPTZ solution in 40 mM HCl, 2.5 mL of 20 mM $FeCl_3$, and 25 mL of 0.3 M acetate buffer at pH 3.6, prepared fresh daily and warmed to 37 °C before use. Honey (1 g) was dissolved in a 10 mL n-hexane–acetone mixture (6:4) and filtered through the Whatman No. 4 filter paper. A 200-µL aliquot of the honey solution was mixed with 1.8 mL of the FRAP reagent and the absorbance of the resulting mixture was measured spectrophotometrically at 593 nm after 10 min of incubation. Trolox was used for calibration and the results were expressed as milligrams of Trolox equivalent (TE) per 100 g of honey.

The antioxidant activity of methanolic honey solutions was evaluated using the β-carotene linoleate model system (Amarowicz *et al*., 2004; Silva *et al*., 2013). A chloroform solution of β-carotene (0.2 mg/ml) was prepared and 2 ml of this solution were transferred into a small round-bottom flask (100 ml). After evaporating the chloroform under vacuum at 40 °C, a mixture containing 20 mg of linoleic acid, 200 mg of Tween 40, and 50 ml of distilled water was added to the flask with vigorous shaking. Aliquots of the resulting emulsion (4.8 ml) were dispensed into several tubes, each containing 0.2 ml of the honey samples. The test tubes were then immersed in a water bath at 50 °C and the absorbance of each tube was measured using a spectrophotometer (Hitachi U-1900, Japan) at 470 nm at the beginning (t = 0 min) and at 15-min intervals until the end of the experiment (t = 120 min). BHA and BHT were used as standards for comparison. The bleaching of β-carotene was calculated using the following equation:

$$\text{Rate of β-carotene bleaching} = \ln(A_0/A_t) \times 1/t \quad (4)$$

where A_0 is the initial absorbance of the emulsion at time 0; A_t is the absorbance at 120 min, and t is the time in min. The absorbances of all the sample solutions were measured at 470 nm. The antioxidant activity was described as the mean percent inhibition of β-carotene bleaching using the equation:

$$((R_{control}/R_{sample)} / \text{Rcontrol})) \times 100 \quad (5)$$

where $R_{control}$ and R_{sample} are the bleaching rates of β-carotene in the emulsion without antioxidants and with honey samples, respectively.

Antibacterial activity of the cedar honey sample (Jorgensen and Turnidge, 2003) was determined according to the microdilution broth method specified by Kang *et al*. (2008). The antibacterial effects of the samples determined as a result of the experiment were expressed with minimum inhibitory concentration (MIC) values. Four microorganisms, two gram negative (*Escherichia coli*, ATCC 25922; *Klebsiella pneumoniae*, ATCC 700603) and two gram positive (MRSA *Staphylococcus aureus*, ATCC 43300; *Bacillus cereus*, ATCC 11778), were used in the analyses.

Experiments were repeated three times and statistical analysis was performed after evaluating the normality with one-way analysis of variance with SPSS 22 software. Data were presented as means ± standard deviation unless otherwise stated.

Results and Discussion

The biochemical analyses of the collected honey samples indicated chemical compositions of the Mezla honey to be within the limits specified in both the Turkish Food CODEX and the International Food Codex (Table 1). The average fructose and glucose contents of Mezla honey were determined to be 65.2 g/100 g in total. The total amount of sugar is approximately 70% in other honey (Sahinler *et al*.,

2004; Gül & Pehlivan, 2008). The analysis of various parameters of cedar honey provides valuable insights into its composition and quality. The $\delta^{13}C$ values for proteins and the raw product indicate slight differences, with the protein fraction exhibiting a $\delta^{13}C$ of -25.48% and the raw product showing a $\delta^{13}C$ of -26.67%, suggesting distinct isotopic compositions between these components. The minimal difference of 0.55% between protein and honey indicates a relatively stable protein composition within the honey matrix. Additionally, the absence of C4 sugars suggests the absence of adulteration with high-fructose corn syrup or cane sugar, ensuring the purity of the honey sample. No difference was observed between the honey samples collected from the four regions (P >0.05).

The diastase activity of 17.9 DN indicates the enzymatic activity of diastase, an enzyme naturally present in honey, which serves as a marker for honey quality and freshness. The electrical conductivity of 1.52 mS/cm reflects the concentration of ions and dissolved solids in the honey, providing information about its mineral content. The absence of hydroxymethylfurfural (HMF) indicates minimal heat damage or processing of the honey sample. The moisture content of 17.5% and pH of 4.96 suggest the presence of water and acidity within acceptable ranges for honey, contributing to its stability and preservation. The proline content of 347.0 mg/kg is indicative of the honey's floral origin and serves as a quality parameter. The free acidity of 35 meq/kg reflects the concentration of free acids in the honey, influencing its taste and stability. The predominant sugars in cedar honey are fructose and glucose, with a ratio of 1.20, indicating a slightly higher concentration of fructose compared to glucose. The sucrose content was relatively low at 0.58 g/100 g, contributing to the honey's overall sweetness. The absence of maltose further confirms the honey's purity and natural composition. Overall, the comprehensive analysis of cedar honey highlights its natural and unadulterated qualities, making it a desirable choice for consumers seeking high-quality honey with authentic flavour and nutritional benefits.

Table 1 Biochemical properties of cedar (Mezla) honey

Parameters	Means ± standard deviation (SD)
$\delta^{13}C$ (Proteins)	-25.48 ± 0.25 %
$\delta^{13}C$ (Raw Product)	-26.67 ± 0.28 %
Difference of Protein–Honey	0.56%
% C4 Sugar	0.00%
Diastase activity	17.9 ± 1.4 DN
Electrical Conductivity	1.52 ± 0.038 mS/cm
Hydroxymethylfurfural	2.54 ± 0.74 mg/kg
Moisture	17.5 ± 0.5 %
pH	4.96 ± 0.13
Proline	347.0 ± 36.3 mg/kg
Free acidity	35 ± 4.2 meg/kg
Fructose + Glucose	65.2 g/100 g
Fructose	35.5 ± 5.60 g/100g
Glucose	29.7 ± 3.12 g/100g
Sucrose	0.58 ± 0.13 g/100 g
Maltose	Not detected
Fructose / Glucose ratio	1.20
Sulphonamide Residue	Not detected

Utilizing advanced techniques like gas chromatography–mass spectrometry, scientists have unveiled a diverse array of volatile compounds that contribute to honey's characteristic aroma, encompassing floral, fruity, woody and herbal nuances. This understanding not only enriches our perception of honey's sensory attributes but also paves the way for endeavours in quality assurance, authentication, and innovative product development. In the study, instrumental analyses were conducted on the cedar honey samples, resulting in the determination of aroma compounds (Table 2). Ethyl heptadecanoate was identified (1060.29) among the aroma compounds.

Table 2 Basic aroma compound composition of cedar (Mezla) honey

No	Detection Time	Linear Retention Index	Compound	Concentration (µg/g)
1	27.19	1426	Ethyl octanoate	132.49
2	27.62	1490	Furfural	406.95
3	29.80	1292	Octanal	27.76
4	30.77	1526	Ethyl Nonanoate	402.61
5	34.75	1542	2-Noneal	70.24
6	38.28	1546	Linalool oxide	170.62
7	39.10	1732	(E)-Pyran Linalool oxide	145.36
8	39.35	1752	Methyl salicylate	77.76
9	43.30	1922	Phenylethyl Alcohol	86.29
10	47.15	2235	Ethyl hexadecanoate	307.14
11	51.40	2349	Ethyl heptadecanoate	1060.29
12	51.67	2354	Methyl jasmonate	104.93
13	55.41	2445	Ethyl oleate	696.37
Total				3688.83

The essence of honey's aroma predominantly arises from a complex interplay of esters, aldehydes, ketones, alcohols, and volatile acids, with alcohols assuming a pivotal role among these compounds. Even though aldehydes and ketones are found in low concentrations in honey, they can be characterized by their intense odour (Tian *et al*., 2016). Alcohols are formed by the oxidative breakdown of lipids or by the catalysed reduction of aldehydes by reductase enzymes from bees and contaminant microorganisms (Moreira *et al*., 2010). This aromatic profile is largely derived from the floral sources of nectar, hence the distinctiveness of honey varieties such as cedar honey and pine honey, reflecting the aromatic essence of their respective nectar origins (Durmaz *et al*., 2020). Specific compounds, such as linalool oxide, methyl salicylate, and methyl jasmonate contribute unique aromatic notes to the honey, potentially influencing its sensory attributes and flavour characteristics. For instance, ethyl heptadecanoate, ethyl oleate, and ethyl nonanoate have higher concentrations than other aromatics (Table 2; Figure 4). The total concentration of aromatic compounds in the honey sample was calculated to be 3688.83, highlighting the complexity and richness of its aroma profile. The analysis of aroma compounds in the honey sample provides valuable information about its sensory characteristics, potential floral origins, and quality attributes, contributing to a deeper understanding of this natural product.

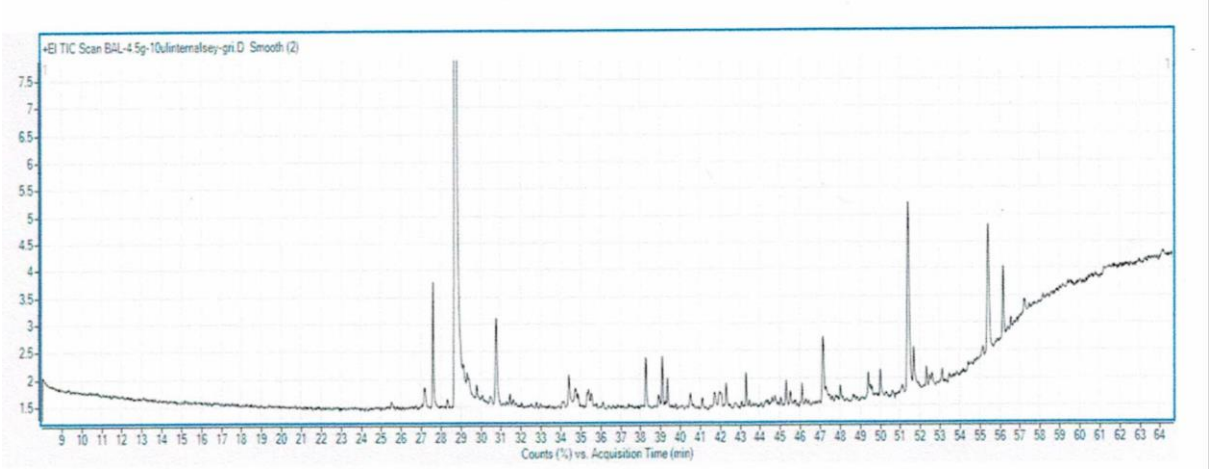

Figure 4 Chromatogram of aromatic compounds of honey samples

The colour of cedar honey, as indicated by the L_{ab}* colour space parameters, reveals distinct characteristics that contribute to its visual appeal and uniqueness. The L* value of 43.76 indicates the lightness of the honey, with higher values suggesting lighter shades. The a* value of 3.48 represents the position on the red–green axis, with positive values indicating a tendency towards red tones. The b* value of 49.31 reflects the position on the yellow–blue axis, suggesting a dominant yellow hue in the honey's colour profile. The C_{ab} value, calculated from the a* and b* values, further quantifies the colour intensity, with a higher C_{ab} value indicating a more saturated colour. Additionally, the H^*_{ab} value of 86.00 represents the hue angle within the colour space, providing insight into the dominant colour direction. Overall, these colour parameters collectively depict cedar honey as possessing a moderately light hue with a tendency towards yellow, suggesting a warm and inviting colour profile that is visually appealing (Table 3). No difference was observed between the L^*_{ab} colour space parameters of honey samples collected from the four regions (P >0.05).

Table 3 CIE L^*, a^*, b^*, C^*_{ab}, and h^o_{ab} colour characteristics of Cedar honey

Colour parameter	Cedar honey (n = 16)	
	Mean ± SD	Range
L*	43.76 ± 4.52	38.170–46.5
a*	3.48 ± 1.82	0.92–7.12
b*	49.31 ± 8.39	33.52–59.84
C^*_{ab}	49.40 ± 7.56	40.43–63.72
H^*_{ab}	86.00 ± 0.52	85.21–87.40

L* = lightness; a* = red for positive value and green for negative value; b* = yellow for positive value and blue for negative value;

The antioxidant capacity of cedar honey is evident from its values in various assays, indicating its ability to neutralize free radicals and protect against oxidative damage. The total phenolic content (TP) of cedar honey, measured at 68.43 mg/100g gallic acid equivalents (GAE), indicates the presence of phenolic compounds known for their antioxidant properties. The DPPH assay reveals a strong antioxidant activity with an inhibition concentration of 30.529 mg/ml, indicating cedar honey's effectiveness in scavenging free radicals. The FRAP assay confirmed its antioxidant potential, with a value of 0.00422 ppm of ascorbic acid equivalents (AAE), indicating its ability to reduce ferric ions. Moreover, the high β-carotene content, measured at 87.56% of the original equivalents (OE), indicates the presence of carotenoids, which are potent antioxidants known for their ability to combat oxidative stress (Table 4). No difference was observed between the honey samples collected in terms of antioxidant capacity and antibacterial activity (P >0.05). Together, these findings demonstrate the antioxidant capacity of cedar honey, suggesting its potential to promote health and help protect against various diseases associated with oxidative damage.

Table 4 Antioxidant capacity and antibacterial mean inhibitory concentration (MIC) values of cedar honey

Bioactivity of cedar honey	Name	Value
Antioxidant capacity	TP (mg/100g GAE)	68.43
	DPPH (mg/ml)	30.529
	FRAP (ppm AAE)	0.00422
	β-carotene (% OE)	87.56
Antibacterial mean inhibitory concentration (MIC)	*E. Coli* (%)	70
	B. Cereus (%)	80
	K. Pneumoniae (%)	80

The antibacterial effects of cedar honey are evident in its ability to inhibit the growth of various bacterial strains, as demonstrated by the MIC values against common pathogens. In the case of *E.coli*, cedar honey had an MIC of 70%, indicating that it can effectively suppress the growth of this bacteria

at relatively low concentrations. Similarly, against *B. cereus* and *K. pneumoniae*, cedar honey had greater efficacy, with MIC values of 80% against both strains. These findings highlight the antibacterial properties of cedar honey, suggesting its potential as a natural alternative for combating bacterial infections and promoting overall health. The ability of cedar honey to effectively inhibit the growth of these pathogenic bacteria underscores its value as a therapeutic agent and its potential application in both traditional medicine and modern healthcare practices.

Conclusion

The analysis of cedar honey reveals a profile indicative of quality and authenticity. Overall, this comprehensive analysis confirms cedar honey as a natural, unadulterated product of high quality, rich in both flavour and nutritional value. Upon examination, cedar honey has an aroma characterised by its sweetness and subtle cedar undertones, creating an inviting olfactory experience. Complementing its aroma, unlike the other honeydew honey types, the honey exhibits a light, golden colour. The analysis of cedar honey reveals concentrations of antioxidants and antifungal compounds, underscoring its potential health benefits and preservation qualities. Rich in antioxidants such as flavonoids and phenolic acids, cedar honey exhibits potential to combat oxidative stress and reduce the risk of chronic diseases. Furthermore, its antifungal properties, attributed to compounds like pinocembrin and p-coumaric acid, suggest its efficacy in inhibiting fungal growth and promoting overall wellness. The multifaceted nature of cedar honey makes it a promising natural remedy and culinary ingredient with both nutritional and therapeutic value. As a result of the statistical analysis applied to the honey samples collected for the purpose of the study, it was determined that there was no difference between the honey samples in the four regions.

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Data Availability Statement

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy.

Conflicts of Interest

The authors declare no conflicts of interest.

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