Uludag Bee Journal
Uludag Bee J.
e-ISSN: 2687-5594
ISSN 1303-0248
https://dergipark.org.tr/en/pub/uluaricilik
https://uadubj.uludag.edu.tr/

# Melissopalynological and physicochemical properties of chestnut honey produced in Zonguldak, Türkiye

**Adem TEKE**

Department of Animal Health, Ministry of Agriculture and Forestry, Zonguldak, Türkiye, Corresponding author E-mail: ademteke87@gmail.com

Received: 29.01.2026 Accepted: 08.04.2026 Published: 24.04.2026

## Abstract

This study aimed to determine the melissopalynological and physicochemical properties of chestnut honey harvested in Zonguldak Province during the 2025 production season. For this purpose, nine chestnut honey samples were utilized. Physicochemical parameters were determined by refractometry and High-Performance Liquid Chromatography (HPLC), while the botanical origin of the honey samples was verified by melissopalynological analysis under light microscopy. Melissopalynological analysis showed that *Castanea sativa* was the dominant pollen type, accounting for an average of 82.28%, which substantiates the unifloral character of the honey samples. Physicochemical analyses showed that the honey samples had an average moisture of 16.82 ± 1.42%, electrical conductivity of 1.32 ± 0.20 mS/cm, fructose content of 36.71 ± 3.21%, glucose content of 29.32 ± 2.64%, total fructose + glucose content of 66.03 ± 5.21%, and a fructose/glucose ratio of 1.26 ± 0.10. In addition, the HMF content was 2.36 ± 2.67 mg/kg, diastase activity was 29.48 ± 8.63 DN, and proline was 877.74 ± 189.58 mg/kg. All analyzed samples complied with the limits specified in the Turkish Food Codex Honey Communique and exhibited characteristics comparable to those of high-quality chestnut honeys reported in the literature. These results contribute to the literature on the physicochemical and melissopalynological characterization of chestnut honeys produced in Zonguldak and provide data for quality assessment.

**Keywords:** Chestnut honey, Honey, Honey quality, Melissopalynology, Zonguldak

## INTRODUCTION

Honey is a natural product that serves as the primary energy source for bees, formed by collecting plant nectar or botanical secretions and maturing them within honeycomb cells. Based on the nectar source, honey is classified into two categories: blossom honey and honeydew honey. While blossom honey is derived from floral nectar secretions of plants, honeydew honey originates from botanical substances or excretions of insects living on plants (Sorucu 2019, Apan et al. 2021). Honey obtained predominantly from a single floral species is termed unifloral; chestnut honey serves as a prominent example of such unifloral honeys (Chirsanova et al. 2021).

The color of chestnut honey varies from brown to black. Its flavor, which fluctuates depending on the chestnut pollen concentration, is characterized by a slightly bitter taste, unique aroma, and subtle tannic structure (Pehlivan 2023). Due to its high fructose content, it exhibits resistance to crystallization, thereby ensuring a long shelf life (Yang et al. 2012). Approximately 95% of the dry matter of honey consists of sugars. The sugar fraction of honey is primarily composed of fructose and glucose, and the fructose + glucose (%) (F+G) content, along with the fructose/glucose ratio (F/G), are important parameters for evaluating honey quality and degree of maturation. In addition, honey contains various disaccharides, such as sucrose, maltose, turanose, and isomaltose, as well as oligosaccharides such as melezitose, erlose, and raffinose, in varying concentrations (Da Silva et al. 2016). Honey also contains small amounts of proteins, amino acids, enzymes, vitamin C, B-complex vitamins, and minerals such as iron, zinc, magnesium, and copper. Furthermore, honey has a rich composition of antioxidant compounds, particularly flavonoids and phenolic acids (Bogdanov et al. 2008, Barreira et al. 2010, Simsek et al. 2021).

The physicochemical characteristics of honey significantly influence its quality. Moisture, ash content, electrical conductivity, free acidity, hydroxymethylfurfural (HMF) content, and diastase activity are the fundamental quality criteria (Bogdanov et al. 1999). Excessive moisture is a major quality defect that destabilizes honey and promotes fermentation. Such elevated levels are commonly observed in honeys harvested before full maturation (Singh and Singh 2018). The electrical conductivity of honey is associated with its mineral and acid content and serves as a critical parameter for determining botanical origin. An increase in free acidity indicates that the honey has undergone fermentation (Toy and Şahinler 2022).

HMF levels and diastase activity are indicators of freshness and processing history; HMF increases, and diastase activity is altered in honeys that are improperly stored, overheated, or adulterated with sugar (Tosi et al. 2002, Sak-Bosnar and Sakač 2012). Proline is the primary amino acid found in honey, and the International Honey Commission (IHC) recognizes proline as an indicator of honey maturity and potential sugar adulteration (Sedláčková et al. 2021). Although chestnut honey is produced in many countries worldwide, its production is heavily concentrated in Türkiye, particularly in the Black Sea, Marmara, and northern Aegean regions (Taş-Küçükaydın et al. 2023).

Zonguldak is situated in the western Black Sea region, where chestnut trees grow naturally, leading to widespread chestnut-honey production. This study aimed to characterize the melissopalynological and physicochemical properties of chestnut honeys produced in Zonguldak, evaluate their quality in accordance with the Turkish Food Codex Honey Communique (TFC-HC), and compare the results with previously reported chestnut honeys from different regions.

## MATERIALS AND METHODS

### Chestnut Honey Samples

Chestnut honey samples were selected from samples brought to the Zonguldak Beekeepers Association (ZAYBİR) facility by its members for bottling and packaging during the 2025 production season. A total of nine chestnut honey samples produced within the borders of Zonguldak province were included in this study (Figure-1) and coded as Z1–Z9. Laboratory analyses were performed at the Kastamonu University Central Research Laboratory Application and Research Center.

### Melissopalynological Analysis

Melissopalynological analyses were performed to characterize the botanical origin of honey samples according to the methods described by Sorkun (2008) and Louveaux et al. (1978). For this purpose, 10 g of honey was mixed with distilled water and a *Lycopodium spp.* tablet, stained with basic fuchsin, and centrifuged. The prepared slides were examined under a light microscope, and pollen grains were identified microscopically according to Wodehouse (1935). The proportional distributions (%) of pollen types were calculated, and the botanical origins of the honey were determined.


**Figure 1. Location of Zonguldak province in the western Black Sea region of Türkiye.**

### Physicochemical Analyses

The moisture, electrical conductivity, sugar profile (fructose, glucose, F+G, F/G ratio, sucrose, and maltose), HMF, diastase activity, and proline of the honey samples were determined. The analyses were performed based on the methodologies reported by Uzunca et al. (2023). All analyses were performed in triplicate. In this context, moisture was determined by refractometry. The sugar profile and HMF levels were analyzed by High-Performance Liquid Chromatography (HPLC) according to IHC-recommended methods. For each parameter, data were expressed as mean, standard deviation, and minimum-maximum values. The results were evaluated based on the TFC-HC (Communique No. 2020/7).

### Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics 20 software. The normality of the data distribution was evaluated using the Shapiro–Wilk test. To evaluate the impact of pollen content on the physicochemical properties, honey samples were classified into two groups based on their *Castanea sativa* pollen levels: low pollen (70–80%) and high pollen (>80%). Differences between groups were analyzed using one-way analysis of variance (ANOVA). Tukey's post hoc test was used to identify specific differences in cases of significant differences ($p < 0.05$). A one-sample t-test was applied to evaluate whether the physicochemical parameters of the samples complied with the limits specified in the TFC-HC. Pearson correlation analysis was conducted for normally distributed data, with significance levels set at $p < 0.05$ and $p < 0.01$.

## RESULTS

The results of the melissopalynological analyses are presented in Table-1. The analysis revealed that *Castanea sativa* pollen was predominant, with an average representation of 82.28 ± 5.60%. Furthermore, pollen grains belonging to the families Fabaceae, Cistaceae, Rosaceae, Ericaceae (*Rhododendron sp.*), Brassicaceae, Malvaceae, Cornaceae, Adoxaceae, Asteraceae, Ranunculaceae, Tamaricaceae, and Apiaceae were identified as secondary pollen sources. The results of the physicochemical analyses are presented in Table-2. The mean moisture of the samples was 16.82 ± 1.42%, with values ranging from 15% to 19.03%. The electrical conductivity averaged 1.32 ± 0.20 mS/cm, with a range of 1.06-1.63 mS/cm. Regarding sugar composition, the mean percentages of fructose and glucose were 36.71 ± 3.21% and 29.32 ± 2.64%, respectively, with a total of 66.03 ± 5.21%. The F/G ratio was calculated as 1.26 ± 0.10, ranging from 1.15 to 1.42.

The average maltose content was 2.80 ± 0.66%. The mean HMF concentration was 2.36 ± 2.67 mg/kg, with a maximum of 7.2 mg/kg. HMF was not detected in samples Z4, Z6, and Z9. In terms of enzymatic activity, the mean diastase activity was 29.48 ± 8.63 DN, ranging from 18.2 to 38.9 DN. Finally, the proline, an essential indicator of honey maturity and freshness, averaged 877.74±189.58 mg/kg, with minimum and maximum values of 647 mg/kg and 1172 mg/kg, respectively. Sucrose was detected only in sample Z8 at 0.16%, well below the 5% limit established by the official communique (Table-3).

The samples were categorized into two groups (low pollen: 70–80% and high pollen: >80%) to determine the effect of *Castanea sativa* pollen density on physicochemical properties. According to the one-way ANOVA results, no statistically significant differences were observed between the two groups for any of the tested parameters, including moisture, electrical conductivity, sugar profile, diastase activity, and proline content ($p > 0.05$). According to the results of the one-sample t-test applied to the honey samples, moisture, HMF, and sugar profile were significantly below the legal maximum limits, whereas quality parameters such as proline and diastase activity were significantly above the legal minimum limits ($p < 0.01$).

Correlation analysis revealed that fructose and glucose contents were positively correlated with total F+G content, whereas HMF and diastase activity were negatively correlated. Furthermore, positive correlations were identified between electrical conductivity and proline and diastase levels in the honey samples. The results of Pearson's correlation analysis are presented in Table-4.

**Table 1. Results of melissopalynological analysis of honey samples**

| Sample Number / Family (%) | Z1 | Z2 | Z3 | Z4 | Z5 | Z6 | Z7 | Z8 | Z9 |
|---|---|---|---|---|---|---|---|---|---|
| Fagaceae (*Castanea sativa*) | 76.5 | 86.5 | 72.5 | 85.5 | 85 | 85.5 | 86 | 76 | 87 |
| Fabaceae | 5 | 2.5 | 10 | 2.5 | 5 | 5.5 | 3 | 3 | 1 |
| Cistaceae | 4.5 | 2 | | 2.5 | 3 | | 3 | 1 | 4 |
| Rosaceae | 3 | | 1 | 2 | 3 | | | 2 | |
| Ericaceae (*Rhododendron sp.*) | 2 | | 3 | | 1 | 2 | | | |
| Brassicaceae | 2 | | | 2.5 | | 1 | | 10 | 1 |
| Malvaceae | 2.5 | 1.5 | 4 | 3 | 2 | 2 | 3 | 2 | 4 |
| Cornaceae | 1.5 | | | | | | 2 | | 2 |
| Adoxaceae | | 2.5 | 5.5 | | | | | 5 | |
| Asteraceae | | 1 | | 1 | | 2 | | | |
| Ranunculaceae | | 2 | 2 | | | | | | |
| Tamaricaceae | | | 1 | | | | | | |
| Apiaceae | | | | | | 1 | 1 | | |
| Others | 3 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 |

**Table 2. Results of the physicochemical analyses of honey samples**

| Sample Number | Moisture (%) | Electrical Conductivity (mS/cm) | Fructose (%) | Glucose (%) | F+G (%) | F/G Ratio | Sucrose (%) | Maltose (%) | HMF (mg/kg) | Diastase (DN) | Proline (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Z1 | 15.20±0.40 | 1.31±0.08 | 34.40±1.48 | 29.09±1.43 | 63.49 | 1.18 | ND | 3.17±0.21 | 0.25±0.04 | 38.9±2.4 | 878.3±60.2 |
| Z2 | 16.50±0.00 | 1.63±0.10 | 38.11±1.64 | 26.77±1.31 | 64.88 | 1.42 | ND | 2.76±0.18 | 0.56±0.09 | 36.4±2.3 | 1084.6±74.4 |
| Z3 | 17.06±0.44 | 1.16±0.07 | 34.92±1.50 | 30.35±1.49 | 65.27 | 1.15 | ND | 2.5±0.16 | 3.7±0.59 | 18.2±1.1 | 803.5±55.1 |
| Z4 | 18.84±0.49 | 1.06±0.06 | 38.75±1.67 | 30.85±1.51 | 69.60 | 1.26 | ND | 2.5±0.16 | ND | 23.6±1.5 | 647±44.4 |
| Z5 | 15.36±0.40 | 1.18±0.07 | 43.53±1.75 | 35.64±1.87 | 79.17 | 1.22 | ND | 3.35±0.22 | 7.2±1.15 | 21.3±1.3 | 810.5±55.6 |
| Z6 | 17.50±0.45 | 1.43±0.09 | 39.73±1.71 | 28.65±1.40 | 68.38 | 1.39 | ND | 2.60±0.17 | ND | 38±2.4 | 1092.3±74.9 |
| Z7 | 15.00±0.39 | 1.52±0.09 | 36.12±1.55 | 30.73±1.51 | 66.85 | 1.18 | ND | 2.64±0.17 | 1.32±0.21 | 36.9±2.3 | 1172±80 |
| Z8 | 19.03±0.49 | 1.53±0.09 | 33.16±1.43 | 28.79±1.41 | 61.95 | 1.15 | 0.16±0.01 | 3.83±0.25 | 1.1±0.18 | 30.6±1.9 | 831±57 |
| Z9 | 16.93±0.44 | 1.12±0.07 | 34.86±1.50 | 26.99±1.32 | 61.85 | 1.29 | ND | 1.44±0.09 | ND | 19.4±1.2 | 650±45 |
| Limits | ≤ 20% | ≥ 0.8 | | | ≥ 60% | 1-1.85 | ≤ 5% | ≤ 4% | ≤ 40 | ≥ 8 | ≥ 500 |

ND: Not detected.

**Table 3. Descriptive statistics of the analysis parameters for honey samples**

| Physicochemical properties | Mean ± SD | Median (Min - Max) | Shapiro-Wilk (p) |
|---|---|---|---|
| Moisture (%) | 16.82 ± 1.42 | 16.93 (15.00 – 19.03) | 0.386 |
| Electrical Conductivity (mS/cm) | 1.32 ± 0.20 | 1.31 (1.06 – 1.63) | 0.403 |
| Fructose (%) | 36.71 ± 3.21 | 36.12 (33.16 – 43.53) | 0.458 |
| Glucose (%) | 29.32 ± 2.64 | 29.09 (26.77 – 35.64) | 0.153 |
| F+G (%) | 66.03 ± 5.21 | 64.88 (61.85 – 79.17) | 0.055 |
| F/G Ratio | 1.26 ± 0.10 | 1.26 (1.15 – 1.42) | 0.142 |
| Maltose (%) | 2.80 ± 0.66 | 2.64 (1.44 – 3.83) | 0.545 |
| HMF (mg/kg) | 2.36 ± 2.67 | 1.21 (0.25 – 7.20) | 0.073 |
| Diastase (DN) | 29.48 ± 8.63 | 30.60 (18.20 – 38.90) | 0.079 |
| Proline (mg/kg) | 877.74 ± 189.58 | 854.65 (647.00 – 1172.00) | 0.291 |

Normality was verified via Shapiro–Wilk test (p > 0.05). Data are presented as mean ± standard deviation. n = 9

**Table 4. Pearson correlation matrix of physicochemical parameters of honey samples**

| Parameters | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 Moisture | | | | | | | | | | |
| 2 Electrical Conductivity | -0.117 | | | | | | | | | |
| 3 Fructose | -0.203 | -0.170 | | | | | | | | |
| 4 Glucose | -0.291 | -0.386 | 0.624 | | | | | | | |
| 5 F+G | -0.269 | -0.296 | 0.922** | 0.878** | | | | | | |
| 6 F/G Ratio | 0.088 | 0.260 | 0.435 | -0.433 | 0.051 | | | | | |
| 7 Maltose | 0.027 | 0.423 | 0.072 | 0.383 | 0.234 | -0.366 | | | | |
| 8 HMF | -0.178 | -0.717 | 0.763 | 0.908* | 0.896* | -0.175 | 0.064 | | | |
| 9 Diastase | -0.258 | 0.783* | -0.102 | -0.347 | -0.235 | 0.286 | 0.341 | -0.824* | | |
| 10 Proline | -0.427 | 0.829** | 0.106 | -0.145 | -0.007 | 0.308 | 0.216 | -0.495 | 0.792* | |

Pearson correlation coefficients are shown. *p < 0.05, **p < 0.01 (two-tailed). n = 9

## DISCUSSION

According to the TFC-HC, honey labeled as chestnut honey must contain at least 70% *Castanea sativa* pollen in its total pollen profile. In this study, the *Castanea sativa* pollen ratio in all analyzed honey samples exceeded the limits specified in the communique. A study by Özkök and Bayram (2021) on the melissopalynological characteristics of chestnut honeys from the Zonguldak region identified pollen from various plant taxa. That study identified *Castanea sativa* (Fagaceae) as the dominant pollen, consistent with our findings. Pollen types belonging to the families Fagaceae, Fabaceae, Cistaceae, Rosaceae, Ericaceae, Asteraceae, and Apiaceae, which were identified as secondary pollen sources in their research, were also present in the samples examined in our study.

Conversely, certain differences in pollen families were observed between the findings of Özkök and Bayram (2021) and the present study. These discrepancies may stem from the floristic structure of the apiary locations and the diversity of the surrounding vegetation. The TFC-HC establishes specific limits for parameters such as moisture, electrical conductivity, fructose, glucose, F+G, F/G ratio, maltose, HMF, diastase activity, and proline. Literature reviews of chestnut honey produced in Türkiye show that Küçük et al. (2007) reported average values for samples from the Black Sea region as 19.7 ± 1.7% for moisture, 66.8 ± 6.2% for F+G, 28.6 ± 1.9 mg/kg for HMF, and 17.7 ± 1.4 DN for diastase activity.

Kabakçı et al. (2012) reported values for samples from Ordu and Giresun as 17.46% and 16.02% for moisture, 0.84 and 1.20 mS/cm for electrical conductivity, 61.78% and 59.23% for F+G, 4.96 and 7.61 mg/kg for HMF, and 8.32 and 9.33 DN for diastase activity, respectively. Dağ (2017) reported that chestnut honey samples produced in the Black Sea Region exhibited a moisture of 18.13 ± 1.53%, a total F+G of 71.15 ± 2.26%, and F/G ratio of 1.44 ± 0.05. Furthermore, the researchers determined the HMF concentration to be 0.57 ± 0.09 mg/kg and the diastase activity to be 14.20 ± 2.87 DN. Silici (2018) determined the average parameters for chestnut honeys from different regions of Türkiye as follows: moisture 17.31 ± 0.83%, electrical conductivity 0.89 ± 0.36 mS/cm, fructose 37.09 ± 2.29%, glucose 30.41 ± 4.08%, F+G 67.50 ± 6.12%, F/G ratio 1.23 ± 0.12, maltose 1.99 ± 0.28%, HMF 22.38 ± 17.55 mg/kg, diastase activity 15.65 ± 3.60 DN, and proline 740 ± 94.44 mg/kg.

Avşar et al. (2023) reported that in their study on chestnut honeys from the Sinop region, the moisture ranged from 18.04 to 19.40%, electrical conductivity from 0.25 to 0.28 mS/cm, fructose content from 39.90 to 40.60%, glucose from 22.00 to 25.30%, F+G from 62.10 to 65.80%, F/G ratio from 1.59 to 1.76, sucrose content from 0.05 to 0.39%, maltose content from 0.05 to 0.08%, HMF content from 1.22 to 3.44 mg/kg, diastase activity from 13.42 to 20.37 DN, and proline from 702.94 to 855.49 mg/kg. Saral (2023) identified parameters for Artvin chestnut honeys as moisture 18.41 ± 0.50%, electrical conductivity 0.82 ± 0.19 mS/cm, fructose 40.30 ± 1.37%, glucose 30.41 ± 1.66%, F+G 70.71 ± 3.03%, F/G ratio 1.32 ± 0.82, diastase activity 22.79 ± 2.67 DN, and proline 1062.90 ± 112.22 mg/kg.

Yoldaş et al. (2023) reported values for Düzce chestnut honeys as moisture 18.40 ± 2.86%, electrical conductivity 1 ± 0.48 mS/cm, F+G 58.75 ± 9.80%, F/G ratio 1.40 ± 0.17, maltose 1.75 ± 0.83%, HMF 1.63 ± 0.40 mg/kg, diastase activity 15.28 ± 11.11 DN, and proline 736.80 ± 286.24 mg/kg. Uçurum et al. (2024) obtained results for Zonguldak and Bursa honeys with moisture 17.40 ± 1.20%, electrical conductivity 1.43 ± 0.33 mS/cm, fructose 35.83 ± 1.87%, glucose 26.66 ± 2.62%, F+G 66.12 ± 3.45%, F/G ratio 1.40 ± 0.15, maltose 2.73 ± 1.12%, and proline 1015.60 ± 362.89 mg/kg. The values obtained in our study for moisture 16.82 ± 1.42%, electrical conductivity 1.32 ± 0.20 mS/cm, fructose 36.71 ± 3.21%, glucose 29.32 ± 2.64%, F+G 66.03 ± 5.21%, and the F/G ratio 1.26 ± 0.10 are in alignment with previous studies on chestnut honeys from various regions of Türkiye.

The high phenolic content of chestnut honeys is closely correlated with their dark color and enhanced biological activity. These compounds contribute significantly to antioxidant capacity. Electrical conductivity is primarily related to the mineral and organic acid content of honey; however, it may also reflect, to some extent, the presence of other bioactive compounds. The relatively high electrical conductivity values obtained in this study are consistent with the literature and may indicate a rich mineral composition, which is characteristic of chestnut honey (Kolayli et al. 2020, Kanbur et al. 2021).

In our study, the positive correlation observed between fructose, glucose, and F+G confirms that the total reducing sugar amount primarily originates from these two monosaccharides. The negative correlation between HMF and diastase activity reflects qualitative changes in honey resulting from thermal processing and storage conditions. Furthermore, the positive correlation among electrical conductivity, proline, and diastase activity is a significant indicator of the botanical origin and overall quality of honey samples. In summary, the correlation analyses yielded results consistent with existing literature. Notably, the low moisture suggests that the honey is well matured with a low risk of fermentation. The observed low HMF values (2.36 ± 2.67 mg/kg) and high diastase activity (29.48 ± 8.63 DN) demonstrate that the samples were not subjected to thermal processing. This is particularly characteristic of chestnut honey, which, due to its high fructose-to-glucose ratio (1.26 ± 0.10), has a low tendency to crystallize and therefore typically does not require heating to liquefy. Consequently, chestnut honey is less likely to undergo thermal degradation, which helps maintain its natural biochemical integrity, preserve enzyme activity, and minimize HMF formation (Celebi et al. 2026).

The high proline content of 877.74 ± 189.58 mg/kg further confirms that the honey is a natural, mature product. Our results also show high similarity with studies examining the physicochemical properties of chestnut honeys produced in Slovenia, Croatia, Greece, and Italy (Kropf et al. 2010, Šarić et al. 2008, Thrasyvoulou and Manikis 1995, Fallico et al. 2004). In conclusion, a comprehensive evaluation of all analyzed parameters indicates that the samples in our study remain within the limits established by the TFC-HC. Furthermore, the findings indicate that these samples exhibit characteristics similar to those of high-quality chestnut honeys reported in the scientific literature.

**AI Declaration:** The author declares that artificial intelligence tools were not used in the preparation of this manuscript, except for reference management and language editing

**Conflict of Interest Statement:** The author declares that there is no conflict of interest.

**Financial Support:** This study did not receive any financial support.

**Ethical Statement:** Ethical approval was not required for this study.

**Data Availability Statement:** The data supporting the findings of this study are available from the author upon reasonable request.

## REFERENCES

Apan MA, Zorba M, Kayaboynu Ü. Bal arısı ve bal arısı ürünleri [Honeybee and honeybee products]. Sinop Univ Fen Bil Derg. 2021;6(2):202-223, doi.org/10.33484/sinopfbd.992345

Avşar C, Aslan H, Yumak T, Tabak A, Deniz NT. Determination of the superior quality properties of randomly selected chestnut honey samples from the Sinop region. Spectrosc Lett. 2023;56(6):353-363, doi.org/10.1080/00387010.2023.2221328

Barreira JC, Pereira JA, Oliveira MBP, Ferreira IC. Sugars profiles of different chestnut (*Castanea sativa* Mill.) and almond (Prunus dulcis) cultivars by HPLC-RI. Plant Foods Hum Nutr. 2010;65(1):38-43, doi.org/10.1007/s11130-009-0147-7

Bogdanov S, Jurendic T, Sieber R, Gallmann P. Honey for nutrition and health: A review. J Am Coll Nutr. 2008;27(6):677-689, doi.org/10.1080/07315724.2008.10719745

Bogdanov S, Lüllmann C, Martin P, von der Ohe W, Russmann H, Vorwohl G, et al. Honey quality and international regulatory standards: Review by the International Honey Commission. Bee World. 1999;80(2):61-69, doi.org/10.1080/0005772X.1999.11099428

Celebi, ZB, Karahalil, FY, Tunca, E, Kolaylı, S. Investigation of HMF levels during the decrystallization of different honey samples. Food Bioprocess Technol. 2026;19(1):39, doi.org/10.1007/s11947-025-04100-4

Chirsanova CA, Capcanari T, Boiştean A, Khanchel EMI. Bee honey: History, characteristics, properties, benefits and adulteration in the beekeeping sector. J Soc Sci. 2021;3:98-114, doi.org/10.52326/jss.utm.2021.4(3).11

Da Silva, PM, Gauche, C, Gonzaga, LV, Costa, ACO, Fett, R. Honey: chemical composition, stability and authenticity. Food Chem. 2016;196:309-323, doi.org/10.1016/j.foodchem.2015.09.051

Dağ B. Investigation of some properties of chestnut honey produced in Black Sea region of Turkey. Batman Univ Yasam Bil Derg. 2017;7(2/2):118-123

Fallico B, Zappalà M, Arena E, Verzera A. Effects of conditioning on HMF content in unifloral honeys. Food Chem. 2004;85(2):305-313, doi.org/10.1016/j.foodchem.2003.07.010

Kabakçı D, Çol M, Karataş Akdeniz G, Yılmaz Ö, Güney F. Ordu ve Giresun ili arı yetiştiriciliğinden toplanan kestane ballarının biyokimyasal yapılarının incelenmesi [Investigation of biochemical structures of chestnut honeys collected from beekeeping in Ordu and Giresun provinces]. Arıcılık Araşt Derg. 2012;4(8):25-26

Kanbur, ED, Yuksek T, Atamov V, Ozcelik AE. A comparison of the physicochemical properties of chestnut and highland honey: The case of Senoz Valley in the Rize province of Turkey. Food Chem. 2020;*345*:128864, doi.org/10.1016/j.foodchem.2020.128864

Kolayli S, Palabiyik I, Atik DS, Keskin M, Bozdeveci A, Karaoglu SA. Comparison of antibacterial and antifungal effects of different varieties of honey and propolis samples. Acta Aliment. 2020;49(4):515-523, doi.org/10.1556/066.2020.49.4.18

Kropf U, Korošec M, Bertoncelj J, Ogrinc N, Nečemer M, Kump P, et al. Determination of the geographical origin of Slovenian black locust, lime and chestnut honey. Food Chem. 2010;121(3):839-846, doi.org/10.1016/j.foodchem.2009.12.094

Küçük M, Kolaylı S, Karaoğlu Ş, Ulusoy E, Baltacı C, Candan F. Biological activities and chemical composition of three honeys of different types from Anatolia. Food Chem. 2007;100(2):526-534, doi.org/10.1016/j.foodchem.2005.10.010

Louveaux J, Maurizio A, Vorwohl G. Methods of melissopalynology. Bee World. 1978;59(4):139-157, doi.org/10.1080/0005772X.1978.11097714

Özkök A, Bayram NE. Kestane (*Castanea sativa*) balı örneklerinin botanik orijinlerinin doğrulanması ve toplam polen sayıları [Verification of botanical origins and total pollen counts of chestnut (*Castanea sativa*) honey samples]. Uludag Bee J. 2021;21(1):54-65. doi.org/10.31467/uluaricilik.899782

Pehlivan T. Kestane balının gastronomideki önemi ve antioksidan potansiyeli [The importance of chestnut honey in gastronomy and its antioxidant potential]. Turk J Agric Food Sci Technol. 2023;11(1):88-96, doi.org/10.24925/turjaf.v11i1.88-96.5636

Sak-Bosnar M, Sakač N. Direct potentiometric determination of diastase activity in honey. Food Chem. 2012;135(2):827-831. doi.org/10.1016/j.foodchem.2012.05.006

Saral Ö. An investigation into chestnut honeys from Artvin province in Türkiye: Their physicochemical properties, phenolic profiles and antioxidant activities. Chem Biodivers. 2023;20(3):e202201162, doi.org/10.1002/cbdv.202201162

Šarić G, Matković D, Hruškar M, Vahčić N. Characterisation and classification of Croatian honey by physicochemical parameters. Food Technol Biotechnol. 2008;46(4):355-367

Sedláčková VH, Grygorieva O, Šramková KF, Shelepova O, Goncharovska I, Mňahončáková E. The chemical composition of pollen, staminate catkins, and honey of *Castanea sativa* Mill. Potravinarstvo Slovak J Food Sci. 2021;15:218-226, doi.org/10.5219/1627

Silici S. Antioxidant and physicochemical properties of chestnut honeys from Turkey. Commun Fac Sci Univ Ank C Biol. 2018;27(2):104-114, doi.org/10.1501/commuc_0000000204

Simsek I, Kuzukiran O, Yurdakok-Dikmen B, Sireli UT, Beykaya M, Filazi A. Comparison of selected lipophilic compound residues in honey and propolis. J Food Compos Anal. 2021;102:104068, doi.org/10.1016/j.jfca.2021.104068

Singh I, Singh S. Honey moisture reduction and its quality. J Food Sci Technol. 2018;55(10):3861-3871, doi.org/10.1007/s13197-018-3341-5

Sorkun K. Türkiye'nin nektarlı bitkileri, polenleri ve balları [Nectar plants, pollens and honeys of Turkey]. Palme Yayıncılık, Ankara, Turkey, 2008.

Sorucu A. Arı ürünleri ve apiterapi [Bee products and apitherapy]. Vet Farmakol Toksikol Dern Bül. 2019;10(1):1-15

Taş-Küçükaydın M, Tel-Çayan G, Çayan F, Küçükaydın S, Çiftçi BH, Ceylan Ö, et al. Chemometric classification of chestnut honeys from different regions in Turkey based on their phenolic compositions and biological activities. Food Chem. 2023;415:135727, doi.org/10.1016/j.foodchem.2023.135727

Thrasyvoulou A, Manikis J. Some physicochemical and microscopic characteristics of Greek unifloral honeys. Apidologie. 1995;26(6):441-452, doi.org/10.1051/apido:19950601

Tosi E, Ciappini M, Ré E, Lucero H. Honey thermal treatment effects on hydroxymethylfurfural content. Food Chem. 2002;77(1):71–74, doi.org/10.1016/S0308-8146(01)00325-9

Toy NÖ, Şahinler N. Quality parameters of honey, an important bee product. Turk J Agric Food Sci Technol. 2022;10(12):2841-2847, doi.org/10.24925/turjaf.v10isp1.2841-2847.5859

Turkish Food Codex. Communiqué on Honey (Turkish Food Codex). Official Gazette of the Republic of Türkiye, No. 31137, Ankara, Türkiye, 22 April 2020.

Ucurum O, Tosunoglu H, Takma Ç, Birlik PM, Berber M, Kolaylı S. Distinctive properties of the pine, oak, chestnut and multifloral blossom and honeydew honeys. Eur Food Res Technol. 2024;250(6):1765-1774, doi.org/10.1007/s00217-024-04520-0

Uzunca H, Çelemli ÖG, Biyiklioğlu O, Karabicak S, Çeter T. Characterisation of Kastamonu honeys by palynological and physicochemical methods. Grana. 2023;62(3):192-205, doi.org/10.1080/00173134.2023.2210578

Wodehouse RP. Pollen grains and worlds of different sizes. Sci Mon. 1935;40(1):58-62

Yang Y, Battesti MJ, Djabou N, Muselli A, Paolini J, Tomi P, Costa J. Melissopalynological origin determination and volatile composition analysis of Corsican “chestnut grove” honeys. Food Chem. 2012;132(4):2144-2154, doi.org/10.1016/j.foodchem.2011.07.075

Yoldaş T, Karagül B, Düvenci ES. Investigation of some quality criteria in chestnut honey of Düzce province. Düzce Univ J Sci Technol. 2023;11(5):2255–2264, doi.org/10.29130/dubited.1383148