Nutritional properties of wild edible mushrooms sold in Aegean region

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Abstract

Introduction. This study investigated the nutritional value and antioxidant capacity of Çıntar mushrooms cultivated in Muğla, providing data intended to enhance the current literature on mushrooms with significant dietary benefits for human health.

Materials and methods. Çıntar mushrooms, which hold significant nutritional value for human diets, were sourced from Türkiye and physicochemical and antioxidant properties of the ten Çıntar mushrooms samples were analyzed.

Result and discussion. The findings obtained were evaluated in terms of nutritional composition, functional properties, and antioxidant capacity of these mushrooms. The dry matter, moisture, ash, titratable acid, pH, total carbohydrate and protein contents of the Çıntar mushroom samples were determined in the range of 6.381–17.920%, 82.079–93.618%, 0.264–0.821%, 0.334–1.015%, 6.58–7.41, 0.062–1.066%, 3.125–5.694%, respectively. Among the antioxidant capacity properties, the total phenolic content was determined to range between 0.0017–0.0029 mg GAE/g, FRAP values were between 3.854–8.267 µmol Trolox/g, and TEAC values ranged from 0.0014–0.0146 µmol Trolox/g. Upon examining the obtained results, it is expected that the samples with the highest total phenolic compound content would also exhibit the highest antioxidant capacities in the FRAP and TEAC analyses. However, the results do not support this theory. It is hypothesized that the differences in the antioxidant capacities of the samples may be attributed to the reduction of different compounds. The compositions of the fungi depend on the type of fungus, growing conditions, chemical and physical characteristics of the growing medium, developmental stage, and location. Additionally, to accurately determine their antioxidant capacities and the specific compounds they can reduce, various capacity analyses should also be conducted.

Conclusions. More research on these mushrooms is needed in Türkiye, a country abundant in wild mushrooms, to better understand these variations.

Introduction

Macrofungi have been used as medicine and food since the times of Chinese, Roman, and Greek civilizations and can be an important food source for the rapidly growing world population (Dülger and Gücin, 1999). Mushrooms, which consist of three basic groups: *Zygomycetes*, *Ascomycetes* and *Basidiomycetes*, show different shapes, sizes and living conditions depending on whether they grow underground or above ground. Unlike other plants, they do not require sunlight and thrive in high humidity environments (Dimopoulou et al., 2022). Natural mushrooms are valued for their high content of protein, fiber, vitamins, minerals, and unsaturated fatty acids, making them useful both as medicine and as food (Acay, 2018; Stabnikova et al., 2024). On average, mushrooms contain about 90% water. The dry weight of mushrooms consists of 16-85% carbohydrates, 0.2-8.7% lipids, 14-44% proteins, and 1-29% ash (Karasüleymanoğlu, 2014). The chemical compositions of macrofungi can vary based on the type of fungus, growing conditions, characteristics of the growing medium, developmental stage, and location (Turfan et al., 2016). Macrofungi are an excellent food source for low-calorie diets due to their richness in essential amino acids and low fat content. Their nutritional properties also include antioxidant, antibacterial, antifungal, antitumor, immunomodulatory, anti-inflammatory, and antiviral effects (Acay, 2018; Dulay et al., 2015; Ghahremani-Majd and Dashti, 2015).

Wild mushrooms are collected and consumed during specific season in nearly all countries (Obodai et al., 2014). Türkiye boasts around 40 wild mushroom species, but only 25 are sold commercially. In each region, local people typically recognize and consume 3 to 5 mushroom species as food (Adanacıoğlu et al., 2016). The *Lactarius* species is one such wild mushroom that naturally grows in autumn. It is known by various names such as "Çıntar," "melki," "kanlica," and "termit" in many regions of Türkiye (Altuntaş et al., 2016).

Free radicals are produced in the human body due to various physicochemical and pathological conditions. These radicals can damage important biomolecules, like lipids, proteins, and DNA that play crucial roles in human metabolism. Consuming antioxidant-rich substances daily can help prevent damage from highly reactive oxygen species, reducing the risk of diseases such as cancer, atherosclerosis, diabetes, arthritis, malaria, AIDS, and heart diseases. Antioxidants have a protective effect against naturally occurring toxic processes in the body. Many synthetic antioxidants, however, can cause side effects like hepatotoxicity, pneumotoxicity, and cancer. Therefore, it is important to find natural non-toxic antioxidants to help prevent chronic diseases and protect the body from free radicals (Gupta and Sharma, 2006).

The natural antioxidants found primarily in vegetables include phenolic compounds (such as phenolic acids and flavonoids), carotenoids, tocopherols, and ascorbic acid, all of which are vital for human health (Barros et al., 2008; Cheung et al., 2003). Ascorbic acid and phenolic compounds are common antioxidants in fungi and considered secondary metabolites of macrofungi (Barros et al., 2008).

This study investigated the nutritional value and antioxidant capacity of Çıntar mushrooms cultivated in Muğla, providing data intended to enhance the current literature on mushrooms with significant dietary benefits for human health.

Materials and method

Collection of samples

Ten Çıntar mushroom samples were purchased from the marketplace in Muğla province in Türkiye, in the autumn of 2020. All samples were transported to the laboratory in a thermobox while still in their original packaging. The Çıntar mushroom samples were stotred at -18°C until analysis.

Reagents

The chemicals used in this study were as follows: phenolphthalein, hydrochloric acid (HCl), glucose ($C_6H_{12}O_6$), cupper (II) sulphate ($Cu SO_4*5H_2O$), potassium sodium tartarate tetrahydrate ($C_4H_4KNaO_6*4H_2O$), gallic acid ($C_7H_6O_5$), iron chloride ($FeCl_3$), and potassium peoxydisulphate ($K_2O_8S_2$) (Merck, Germany), sodium hydroxide (NaOH), phenol (C_6H_6O), methanol (CH_3OH), ethanol (C_2H_5OH), sodium carbonate (Na_2CO_3) acetate (CH_3COOH) (Tekkim, Turkey), folin ($C_{19}H_{19}N_7O_6$), Trolox ($C_{14}H_{18}O_4$), 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (Sigma-Aldrich, Germany), 2,4,6-Tri(2-pyridyl)-1,3,5-triazine (TPZT) (Alfa Aesar, Germany), oxalic acid ($H_2C_2O_4$) (Aldrich, USA), 2.6-dichlorophenoldophenol (Acros Organic, USA), sulfiric acid (H_2SO_4) (ISOLAB, Germany), bovine serum albumin (BSA) (Sigma, USA).

Physicochemical properties

The content of dry matter, total ash content, titratable acidity (citric acid, %), and pH of the research samples were analyzed using the methods established by the Association of Official Analytical Chemists (AOAC, 1995; 1997). The total carbohydrate content was determined using the phenol-sulfuric acid method (Taylor, 1995) and The total protein content of the products were analyzed using the Biuret method (Gornall et al., 1949).

Antioxidant properties

The extraction process was conducted prior to determining the antioxidant capacity. For extraction, 10 g of samples were mixed with 25 mL of the extraction solution (HCI %1: CH_3OH 80%). The mixtures were then placed in a shaking incubator at room temperature for 30 minutes, followed by storage at 4°C for 24 hours. The pellets were discarded after centrifugation (10000 × g, 5 min). The resulting supernatants were collected and stored at 4°C.

The extracts from Çıntar mushrooms were used to determine the total phenolic content (expressed as gallic acid equivalent) and antioxidant activity.

The total phenolic content was determined using the method established by Franke et al. (2004), the ferric reducing ability of plasma (FRAP) assay was measured spectrophotometrically following Benzie and Strain (1996), while the trolox equivalent antioxidant capacity (TEAC) assay was conducted spectrophotometrically according to Re et al. (1999).

Statistical analyses

All experiments were conducted with two replicates and two parallels, resulting in a total sample size of n=4. All statistical analyses were carried out with the SPSS statistical software (IBM SPSS Statistics Version 22; USA) through ANOVA variance analysis. The significance levels of $P<0.05$ were used for statistical differences. Duncan's test was used to determine significant differences between means. The relationship between variables was assessed by using Pearson's correlation and presented as a correlation matrix.

Result and discussion

Physicochemical properties

The result and statistical differences of total dry matter, moisture, total ash, pH, titratable acidity (citric acid %), protein, and total carbohydrate, are presented in Table 1. Statistically significant differences ($P\leq0.05$) were observed between the samples for total dry matter, moisture, total ash, pH, titratable acidity, and protein content. However, there was no significant difference in the total carbohydrate content ($P>0.05$).

Table 1

Physicochemical properties of Çıntar mushrooms

Sample	Total moisture %	Total dry matter %	Total ash %	pH	Titratable acid (citric acid) %	Total carbohydrate mg/g	Protein mg/g
1	82.079± 0.865^{a}	17.920± 0.865^{a}	0.546± 0.072^{abc}	6.65± 0.03^{ab}	0.457± 0.06^{abc}	0.787± 0.194^{a}	4.745± 1.049^{ab}
2	89.526± 0.595^{bc}	10.473± 0.595^{bc}	0.636± 0.182^{bc}	6.59± 0.04^{a}	0.569± 0.048^{bc}	0.411± 0.424^{a}	4.398± 0.996^{ab}
3	89.456± 0.343^{bc}	10.543± 0.343^{bc}	0.550± 0.141^{abc}	6.73± 0.06^{b}	0.607± 0.143^{c}	0.211± 0.323^{a}	4.421± 0.358^{ab}
4	89.692± 0.504^{bc}	10.307± 0.504^{bc}	0.365± 0.092^{ab}	6.58± 0.005^{a}	0.789± 0.226^{d}	0.749± 1.125^{a}	3.125± 0.243^{a}
5	90.420± 0.238^{cd}	9.579± 0.238^{cd}	0.821± 0.370^{cd}	6.72± 0.05^{b}	0.419± 0.117^{ab}	0.062± 0.074^{a}	3.611± 0.239^{ab}
6	93.618± 0.550^{f}	6.381± 0.550^{f}	0.391± 0.098^{ab}	7.41± 0.13^{c}	0.334± 0.114^{a}	0.254± 0.146^{a}	4.027± 1.172^{ab}
7	91.020± 0.387^{d}	8.979± 0.387^{d}	0.264± 0.131^{a}	6.69± 0.07^{b}	0.914± 0.069^{de}	0.427± 0.370^{a}	5.231± 3.081^{ab}
8	92.143± 0.252^{e}	7.856± 0.252^{e}	0.948± 0.309^{d}	6.60± 0.04^{a}	0.43± 0.036^{ab}	0.371± 0.323^{a}	5.694± 1.866^{b}
9	88.872± 1.221^{b}	11.127± 1.221^{b}	0.591± 0.151^{bc}	6.72± 0.02^{b}	1.015± 0.062^{e}	1.066± 1.327^{a}	4.282± 1.078^{ab}
10	90.349± 0.474^{cd}	9.650± 0.474^{cd}	0.474± 0.066^{ab}	6.64± 0.04^{ab}	0.609± 0.052^{c}	0.365± 0.209^{a}	4.259± 0.872^{ab}
MEAN	89.718	10.282	0.559	6.73	0.6143	0.471	4.379
Min	82.079	6.381	0.264	6.58	0.334	0.062	3.125
Max	93.618	17.920	0.821	7.41	1.015	1.066	5.694

* n=4 (± standard deviation). Different lowercase letters indicate differences between rows.

Mushrooms with high moisture content typically have a limited shelf life of two days (Lin et al., 2019). The average dry matter content of the samples was found 10.282%. The moisture content of the samples ranged from 82.079% to 93.618%. For comparison, *Lactarius deliciousus* samples from China were reported to have a moisture content of 92.00% (Xu et al., 2019). Similarly Altuntaş et al. (2016) found the moisture content of *Lactarius* genus to range between 86 and 92% in their study. The results are compatible with the data in the literature that have obtained.

Ash content is a measure of the total mineral substance present in food, including minerals like calcium, copper, iron, zinc, potassium, phosphorus and magnesium. The average ash content of the samples ranged from 0.264 to 0.821%, with an average value of 0.559%. The ash content of mushroom species *Pleuroyus, Termitomyces, Lentinus, and Auricularia* (3.05-6.38%) were higher than this study results (Obodai et al., 2014).

The pH value of mushrooms plays a crucial role in their storage. In this study, the pH values of the mushroom samples ranged from 6.58 in sample 4 to 7.41 in sample 6, indicating low acidity. (Table 1, Figure 1). Kumar and Ray (2016) reported a pH value of 6.67 for white button mushrooms used in Tomato-Mushroom ketchup production, which aligns well with our findings. These results are also in line with pH values reported for sample pickled in Kastamonu (pH 6.51) and for sample grown in a research center in Istanbul (pH 7.26) (Çavuşoğlu, 2018; Gül et al., 2021). In addition, obtained results are compatible with pH values (6.82-7.54) of fresh mushrooms collected from Muğla and microbiologically analyzed (Öncül and Çiftçi, 2023).

The organic acid composition of Çıntar mushrooms was examined, with citric acid identified as the main acid (Eissa, 2008). The average citric acid content in our samples was 0.6143%. In comparison, Kumar and Ray (2016) reported a titratable acidity value of 0.31% for white in terms of the citric acid. Sample no. 9 had the highest titratable acidity at 1.015%, while sample no. 6 had the lowest at 0.334%. In a study on Shiitake mushrooms from China, the titratable acidity ranged from 0.70% to 0.93% (Khaskheli et al., 2017). Additionally, another study found titratable acidity values to be 0.32 g lactic acid/100 g (Çavuşoğlu, 2018).

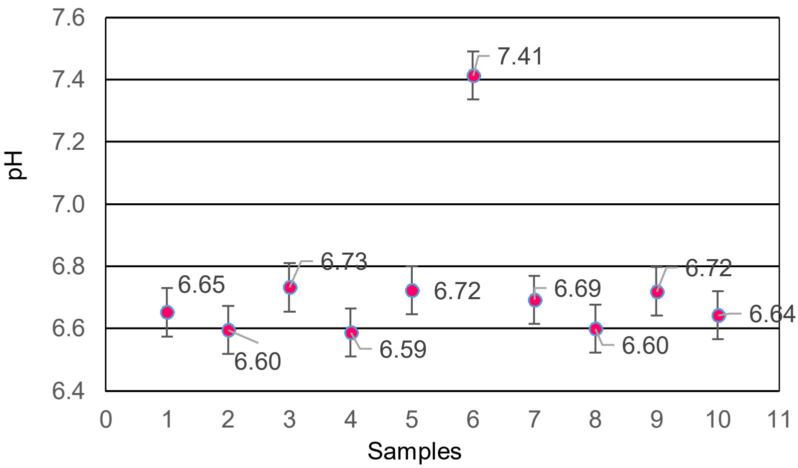

Figure 1. **Average pH values of Çıntar mushrooms**

Carbohydrates are often recommended for people with diabetes and anemia due to their low content in certain fungi (Adejumo and Awosanya, 2005; Turfan et al., 2016). The highest total sugar content was found in mushroom sample 9 at 1.066 mg/g, while the lowest was in sample 5 at 0.062 mg/g (Table 1, Figure 2). According to the Pearson correlation analysis, there was a positive correlation between carbonhydrate content and dry matter (R=0.521) as well as between carbohydrate content and titratable acidity (R=0.626) (Table 2). Vieira et al. (2014) reported an average sugar content of 77.22 g/100g in freeze-dried mushrooms, which was significantly higher than the result of this study (1.066 mg/g). Similarly, Xu et al. (2019) and Altuntaş et al. (2016) reported carbohydrate contents of 66.61 g/100 g and between 71.8 and 83.9%, respectively.

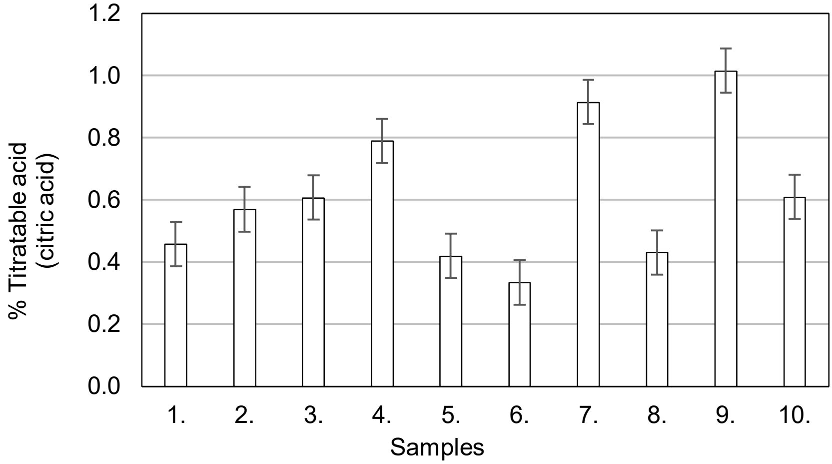

Figure 2. Average titratable acidity values of Çıntar mushrooms (% citric acid)

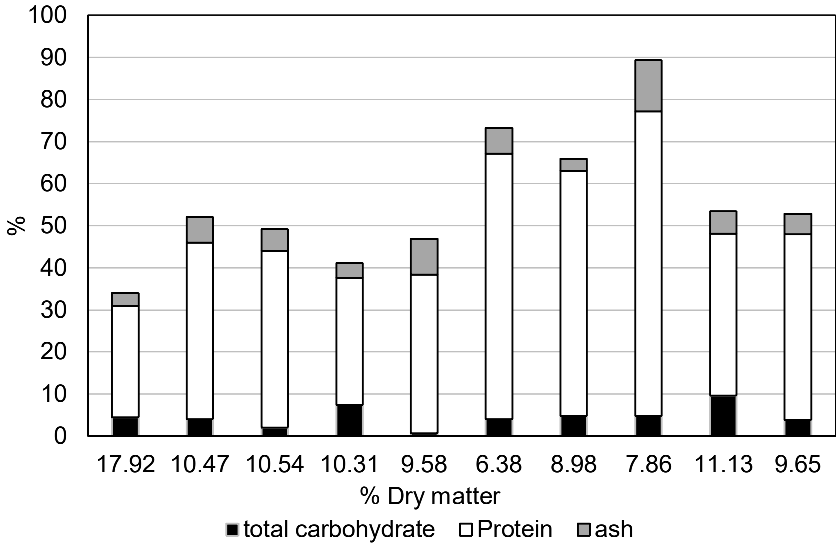

Figure 3. Total carbohydrate, protein and ash ratios of Çıntar mushrooms in dry matter

Considering the various components found in mushrooms, species that are high in protein tend to be low in carbohydrates, while those rich in carbohydrates are generally low in protein (Altuntaş et al., 2016).

The protein content of the mushroom can vary based on factors such as substrate composition, heap size, harvest time, and mushroom species. Mushrooms contain protein levels twice that of vegetables and some researchers suggest that their amino acid composition can rival that of animal proteins (Dulay et al., 2015).

Figure 3 illustrates the percentages of total carbohydrate, protein, and ash in the dry matter of the analyzed mushrooms.As shown in the figure, protein makes up the majority of the dry matter. For instance, *L. deliciousus* samples from China were found to contain 17.19 g/100 g of protein (Xu et al., 2019). Dulay et al. (2015) reported in their study that the protein content of *P. antillarium* genus mean was 15.01%. The protein content of samples 4 (3.125 mg/g) and 8 (5.694 mg/g) was found below from the value mentioned above (Table 1). Given that our samples were fresh, the lower protein content is likely attributable to storage conditions and/or spices. The mean protein values of the mushroom are 4.379 mg/g (Table 1).

Table 2

Correlation matrix for the physicochemical properties of Çıntar mushroom samples

R-Pearson Values*		1	2	3	4	5	6	7
1. Total moisture		1.00						
2. Total dry matter		-1.00**	1.00					
3. Total ash		0.018	-0.018	1.00				
4. pH		0.430	-0.430	-0.283	1.00			
5. Titratable acid		-0.068	0.068	-0.442	-0.378	1.00		
6. Total carbohydrate		-0.521	0.521	-0.226	-0.273	0.626	1.00	
7. Protein		-0.019	0.019	0.265	-0.166	0.036	-0.34	1.00

** Correlation is significant at the 0.01 level (2-tailed).

Antioxidant capacity

Free radicals can cause cell-damage, leading to DNA mutations, protein damage, lipid peroxidation, modification of low-density lipoproteins, and various diseases such as diabetes, cancer, neurodegenerative and cardiovascular diseases. Consuming antioxidant-rich foods can help prevent damage from free radicals. The antioxidant capacity of foods and their effectiveness are determined by various mechanisms. Therefore, it is essential to use multiple evaluation methods to assess the antioxidant capacity of food (Xu et al., 2019). Due to this effect, we evaluated the antioxidant activity of Çıntar mushroom samples collected from Mugla using FRAP assays, TEAC values, and total phenolic content. The results are presented in Table 3.

The total phenolic method using the Folin-Ciocalteu Reagent (FCR) relies on electron transfer from phenolic compounds and other reducing agents to molybdenum. This method is not suitable for lipophilic compounds and only allows phenolic compounds to react in a basic medium (Okan et al., 2013). The FRAP method is based on the reduction of a ferric tripyridyltriazine complex to its ferrous colored form in the presence of antioxidants. In this process, antioxidant compounds act as electron donors and function as both primary and secondary antioxidants by reducing the oxidized intermediates of lipid peroxidation (Ghahremani-Majd and Dashti, 2015). The TEAC method is based on the inhibition of the absorbance of the 2-2-azinobis (3-ethyl-bezothiazoline 6 sulfonate) (ABTS) radical cation by antioxidants. This method is relies on the discoloration of ABTS by antioxidant compounds. One advantage of this method is its applicability to both lipophilic and hydrophilic components (Büyüktuncel, 2013; Okan et al., 2013).

The lowest values for total phenolic content, FRAP, and TEAC were obtained in sample 7. Sample 5 had the highest total phenolic content, sample 1 had the highest FRAP value, and sample 8 had the highest TEAC value. While the lowest values were consistent across all three analyses in sample 7, the highest values varied. The highest total phenolic content recorded was 0.0029 mg GAE/g, and the lowest was 0.0017 mg GAE/g. FRAP values ranged from 3.854 to 8.267 µmol Trolox/g, and TEAC values ranged from 0.0014 to 0.0146 µmol Trolox/g (Table 3). A strong positive correlation was found between TEAC values and both total phenolic content (R=0.785) and FRAP values (R=0.868) (Table 4).

Table 3

Antioxidant capacity of Çıntar mushrooms samples

Samples	Total phenolic content mg GAE/g	FRAP µmol Trolox/g	TEAC µmol Trolox/g
1	0.0023 ± 0.0002^{cde}	8.267 ± 0.958^{e}	0.0141 ± 0.0008^{cde}
2	0.0019 ± 0.0008^{abc}	7.210 ± 1.122^{cde}	0.0125 ± 0.0007^{cde}
3	0.0024 ± 0.0001^{de}	6.397 ± 2.978^{bcde}	0.0143 ± 0.002^{de}
4	0.0023 ± 0.00005^{cde}	5.604 ± 0.284^{abcd}	0.0115 ± 0.002^{bcd}
5	0.0029 ± 0.0002^{f}	6.027 ± 1.274^{abcde}	0.00135 ± 0.001^{cde}
6	0.0018 ± 0.00003^{ab}	4.157 ± 0.780^{ab}	0.0092 ± 0.0011^{ab}
7	0.0017 ± 0.00008^{a}	3.854 ± 0.547^{a}	0.0075 ± 0.0007^{a}
8	0.0027 ± 0.0001^{ef}	7.512 ± 1.054^{de}	0.0146 ± 0.0003^{e}
9	0.0022 ± 0.0001^{bcd}	5.686 ± 1.304^{abcd}	0.0128 ± 0.0009^{cde}
10	0.0021 ± 0.0002^{abcd}	5.109 ± 2.136^{abc}	0.0113 ± 0.0005^{bc}
MEAN	0.0022	5.982	0.0121
Min	0.0017	3.854	0.0014
Max	0.0029	8.267	0.0146

* n=4 (± standard deviation). Different lowercase letters indicate differences between rows (P<0.05).

Table 4

Correlation matrix for the antioxidant capacity of Çıntar mushroom samples

R-Pearson Values*	1	2	3
1 Phenolic compound	1.00		
2 FRAP	0.532	1.00	
3 TEAC	0.785**	0.868**	1.00

** Correlation is significant at the 0.01 level (2-tailed).

The average phenolic content was 1.84 mg/g on a dry mass basis for eight popular edible mushrooms in Hungary, which is higher than the findings of our study (Krüzselyi et al., 2020). Bozdogan et al. (2018) reported the phenolic content 15.66 and 34.55 mg GAE/kg for two different species in Türkiye. In the same study, antioxidant capacity was assessed using the FRAP method and recorded as 0.57 and 0.28 mmol Fe^{2+}/L. In Romania, the phenolic content of eight different mushroom species ranged from 16.55 to 28.74 mg GAE/100 g (Avramıuc, 2018). TEAC and FRAP values for eight edible macrofungal species varied from 1.07 to 12.57 μmol Trolox/g dry matter and 0.10 to 16.68 μmol Trolox/g dry matter, respectively (Kıvrık et al., 2022). For six different species in Türkiye, ABTS values ranged from 44.58 to 101.36 mg Trolox/g extract (Akata et al., 2019). In the same study, antioxidant capacity assessed by the FRAP method was between 9.61 and 31.87 mg Trolox/g extract. Comparing our results with those of other studies is challenging due to various factors, such as differences in extraction methods, expression of results (based on dried or fresh mushrooms), mushroom type, harvest time, and climatic conditions (Salihović et al., 2019; Gül et al., 2021).

Conclusion

The physicochemical properties and antioxidant activities of 10 Çıntar mushrooms collected from Muğla province and its surrounding region were examined. Our results showed variations between the samples, which we believe are influenced by factors such as the carbon and nitrogen content of the environment where the mushrooms grew, temperature, and other conditions. Therefore, more research on these mushrooms is needed in Türkiye, a country abundant in wild mushrooms, to better understand these variations.

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