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Research Article

Antioxidant Enzyme Activities of Some Wild and Cultivated Edible Mushrooms in Turkey

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Abstract. In this study; wild and cultivated edible mushrooms [*Boletus edulis* Bull.: Fr, *Craterellus cornucopioides* (L.) Pers., *Lactarius deliciosus* (L. ex Fr.) S.F.Gray, *Laetiporus sulphureus* (Bull.: Fr.) Murr., *Marasmius oreades* (Bolt. ex Fr.) Fr., *Morchella conica* Pers., *Ramaria botrytis* (Pers.: Fr.) Ricken, *Tricholoma terreum* (Schaeff.: Fr.) P. Kumm., *Hericium erinaceus* (Bull.: Fr.) Pers., *Lentinula edodes* (Berk.) Pegler, *Ganoderma lucidum* (Curt.: Fr.) P. Karst., and *Pleurotus ostreatus* (Jacq. ex Fr.) P. Kumm. (1-4)] were obtained from different locations in Turkey. Phenylalanine ammonia lyase (PAL) enzyme activity, ascorbate peroxidase (APX), peroxidase (POD), and superoxide dismutase (SOD) activity changes and nitrate, β-carotene and lycopene levels were investigated in 15 samples to determine antioxidant enzyme capacity. As a result of the study, the highest amount of β-carotene and lycopene were determined in *H. erinaceus*. *P. ostreatus*-2 had the lowest amount of β-carotene, whereas *Pleurotus ostreatus*-1 had the lowest amount of lycopene. Species rich in nitrate content were *C. cornucopioides* and *P. ostreatus*-4. *P. ostreatus*-3 was the poorest species in terms of nitrate compared to other mushroom samples. PAL activity of mushrooms varied between 5.863 and 8.893 EU mg^{-1} protein. For APX values, *P. ostreatus*-4 had the highest value, while *H. erinaceus* species had the lowest value. Among mushroom species, the highest and the lowest POD values were determined in *H. erinaceus* and *B. edulis*, respectively. *C. cornucopioides* had the highest and *P. ostreatus*-3 had the lowest SOD values.

Türkiye'deki Bazı Doğa ve Kültürü Yapılan Yenebilir Mantarların Antioksidan Enzim Aktiviteleri

Anahtar kelimeler:
Antioksidan, karoten, enzim, likopen, mantar

Özet. Bu çalışmada; Türkiye'nin farklı yörelerinden temin edilen 15 doğa ve kültür mantar türüne [*Boletus edulis* Bull.: Fr, (Ayı mantarı), *Craterellus cornucopioides* (L.) Pers. (Borazan mantarı), *Lactarius deliciosus* (L. ex Fr.) S.F.Gray (Kanlıca mantarı), *Laetiporus sulphureus* (Bull.: Fr.) Murr. (Kükürt mantarı), *Marasmius oreades* (Bolt. ex Fr.) Fr. (Cincile mantarı), *Morchella conica* Pers. (Kuzugöbeği mantarı), *Ramaria botrytis* (Pers.: Fr.) Ricken (Pürpürüm mantarı), *Tricholoma terreum* (Schaeff.: Fr.) P. Kumm. (Karakız mantarı), *Hericium erinaceus* (Bull.: Fr.) Pers. (Aslan yelesi mantarı), *Lentinula edodes* (Berk.) Pegler (Meşe mantarı), *Ganoderma lucidum* (Curt.: Fr.) P. Karst. (Reishi mantarı) ve *Pleurotus ostreatus* (Jacq. ex Fr.) P. Kumm. (1-4) (Kayın mantarı)] ait örnekte antioksidan enzim kapasitesini belirlemek için fenilalanin amonyum liyaz (PAL) enzim aktivitesi, askorbat peroksidaz (APX), peroksidaz (POD) ve süperoksid dismutaz (SOD) aktivite değişimleri ve nitrat, β-karoten ile likopen düzeyleri araştırılmıştır. Sonuç olarak, farklı yörelerden temin edilen mantar örnekleri içerisinde en yüksek β-karoten ve likopen miktarı *H. erinaceus* türünde belirlenmiştir. β-karoten miktarının en düşük olduğu tür *P. ostreatus*-2 iken en düşük likopen miktarı *P. ostreatus*-1 türünde saptanmıştır. Nitrat içeriği bakımından zengin olan türler; *C. cornucopioides* ve *P. ostreatus*-4 olarak tespit edilmiştir. *P. ostreatus*-3, diğer mantar örneklerine kıyasla nitrat bakımından en fakir tür olarak belirlenmiştir. Mantarların PAL aktivitesi 5.863 ve 8.893 EU mg^{-1} protein arasında değişmiştir. En yüksek APX değerinin *P. ostreatus*-4 türüne, en düşük değerin ise *H. erinaceus* türüne ait olduğu bulunmuştur. Mantar türleri arasında en yüksek ve en düşük POD değerleri sırasıyla *H. erinaceus* ve *B. edulis* türlerinde saptanmıştır. SOD değeri en yüksek tür *C. cornucopioides*, en düşük tür ise *P. ostreatus*-3 olarak belirlenmiştir.

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INTRODUCTION

Mushrooms are important food sources in terms of nutritional and medicinal values. They have been consumed as food since ancient times thanks to their nutritional properties and aromas (Barros *et al.*, 2008a; Wasser, 2014). Edible mushrooms contain 88-94% water, 15-42% protein, 2-6% crude fat, 42-71% carbohydrates, and 6-13% ash in the remaining part of 6-12% (Pekşen *et al.*, 2016). Mushrooms are low-calorie foods because of their low dry matter and fat content. Nowadays, mushrooms are also important as a nutraceutical and dietary support (Üstün *et al.*, 2018; Atri *et al.*, 2019). Besides, they are widely used in medical, pharmaceutical, cosmetic, and commercial fields due to the secondary metabolites, carotenes, and antioxidants they contain (Martinez-Espinosa *et al.*, 2011; Bulam *et al.*, 2018a). Due to their medical properties, they are used in traditional medicine in many countries (Boa, 2004; Lelley, 2005). Moreover, they contribute to the ecosystem and conservation of biodiversity as well as to the nutrient and carbon cycles (Martinez de Aragón *et al.*, 2011; Buntgen *et al.*, 2017).

It was reported in many studies that regarding the synthesis of toxic compounds caused by oxidative stress of mushrooms, they have enzymatic and non-enzymatic antioxidants (Barros *et al.*, 2009; Robaszkiewicz *et al.*, 2010; Georgescu *et al.*, 2016; Bulam *et al.*, 2018a; Bulam *et al.*, 2018b; Turfan *et al.*, 2018). Especially, parasol mushrooms are effective to prevent oxidative damage due to tocopherols, polyketides, steroids, terpenes, vitamins C and A, flavones, and β-carotene they have (Rao and Rao, 2007; Robaszkiewicz *et al.*, 2010). Turfan *et al.* (2019) investigated the anthocyanin, β-carotene, lycopene, phenolic, nitrate, soluble protein, proline, glucose, sucrose, and total carbohydrate levels and PAL activity of some mushrooms (*Agaricus campestris, Cantharellus cibarius, Hericium erinaceus,* and *Lactarius piperatus*).

Studies on the nutrient content and antioxidant properties of wild mushrooms grown in natural habitats and consumed as edible were very few until the last decade. However, studies on the functional use of edible mushrooms in Turkey and the world are showing an increasing trend. When studies on mushrooms in Turkey were viewed, studies on antioxidant enzymes of edible wild and cultivated mushrooms were found to be inadequate. In this study, it is aimed to determine nitrate, β-carotene, and lycopene content, phenylalanine ammonia lyase (PAL), ascorbate peroxidase (APX), peroxidase (POD), and superoxide dismutase (SOD) activities in 15 mushroom samples obtained from different locations in Turkey.

MATERIAL AND METHOD

Supplying and Preparation of Mushroom Samples for the Analyses

Information about mushroom samples is given in Table 1. The fruiting bodies (sporocarps) of wild edible species were collected from different provinces of Turkey during the spring and autumn seasons. Cultivated edible mushrooms were supplied from different mushroom production enterprises. Whole sporocarps consisted of pileus and stipes were used for analysis. All of the analyses were performed on the same mushroom sample lots with three replications. Fresh mushroom samples (~500 g for each replication of each mushroom species to use in analyses) were cut into small pieces and dried in an oven at 65 °C to a constant weight. Then, the dried samples were ground into a fine powder using a laboratory mill. The ground samples were put into polyethylene bags, labeled, sealed, and kept at 4 °C.

Chemical Analysis

The nitrate content of the mushrooms was determined using the rapid colorimetric method according to Cataldo *et al*. (1975). 500 mg dry samples were homogenized in 10 ml of de-ionized water at 4 5°C for an hour. After, the homogenate was centrifuged at 5000 rpm for 20 min. The supernatant was used for nitrate estimation. 200 µl of the extract was mixed thoroughly with 800 µl of 5% (w/v) salicylic acid (prepared in concentrated H_2SO_4) in 50 ml test tubes. Samples were kept at room temperature for 20 minutes and 10 ml of 2N NaOH was put slowly. Then, all mixtures were cooled and absorbance was noted at 410 nm. The amount of nitrate (µg of NO_3 g^{-1} dry weight) was estimated with a standard curve of KNO_3.

Antioxidants were measured by using fresh leaf tissues (500 mg), which were ground into powder using liquid nitrogen. These samples in 7 mL phosphate potassium (pH 7.6) with 0.1 mM of EDTA and the homogenate were centrifuged to 10,000×g for 15 min at 4°C. The activity of SOD was determined by estimating its ability to inhibit the photochemical reduction of NBT (nitroblue tetrazolium), following Cakmak (1994). One unit of SOD was defined as the amount of enzyme necessary to cause 50% inhibition of the rate of NBT reduction at 560 nm.

Table 1. Information about mushroom species which were collected from different areas.
Çizelge 1. Farklı yerlerden toplanan mantar türleri hakkında bilgi.

Scientific name of mushroom	Common names	Wild/cultivated	Location
Boletus edulis Bull.: Fr.	Penny bun, Cep, Porcino, or Porcini	Wild	Giresun
Craterellus cornucopioides (L.) Pers.	Horn of plenty, Black chanterelle, Black trumpet	Wild	Samsun, Lâdik
Ganoderma lucidum (Curt.: Fr.) P. Karst.	Reishi or Lingzhi or Hemlock varnish shelf	Cultivated	Denizli, Agroma
Hericium erinaceus (Bull.: Fr.) Pers.	Lion's mane mushroom, Monkey head mushroom, Bearded tooth mushroom, Satyr's beard, Bearded hedgehog mushroom, Pom pom mushroom, or Bearded tooth fungus	Cultivated	Samsun Ondokuz Mayıs Üniversitesi
Lactarius deliciosus (L. ex Fr.) S.F.Gray	Saffron milk cap or Red pine	Wild	Giresun, Bektaş
Laetiporus sulphureus (Bull.: Fr.) Murr.	Crab-of-the-woods Sulphur polypore, Sulphur shelf, and Chicken-of-the-woods	Wild	Giresun, Bulancak
Lentinula edodes (Berk.) Pegler	Shiitake mushroom	Cultivated	Denizli, Agroma
Marasmius oreades (Bolt. ex Fr.) Fr.	Fairy ring mushroom or Fairy ring champignon	Wild	Sinop
Morchella conica Pers.	True morel, Black morel, or Sponge mushroom	Wild	Samsun, Vezirköprü
Pleurotus ostreatus (Jacq. ex Fr.) P. Kumm.-1	Oyster, Abalone, or Tree mushrooms	Cultivated	Giresun, Eynesil
Pleurotus ostreatus (Jacq. ex Fr.) P. Kumm.-2			Rize-Town
Pleurotus ostreatus Jacq. ex Fr.) P. Kumm.-3			Bursa
Pleurotus ostreatus (Jacq. ex Fr.) P. Kumm.-4			Rize-Centrum
Ramaria botrytis (Pers.: Fr.) Ricken	Clustered coral, Pink-tipped coral mushroom, or Cauliflower coral	Wild	Samsun, Lâdik
Tricholoma terreum (Schaeff.: Fr.) P. Kumm.	Grey knight or Dirty Tricholoma	Wild	Samsun, Vezirköprü

APX was estimated by recording the decrease in absorbance at 290 nm because of the decrease in ascorbic acid content (Nakano and Asada, 1981). The activity of the POD was assayed according to Chance and Maehly (1955). The reaction mixture contained 50 µL enzyme extract, 100 µL of 40 mmol L^{-1} H_2O_2, 100 µL of 30 mmol L^{-1} guaiacols, and 2.75 mL of 50 mmol L^{-1} sodium phosphate buffer (pH 7.0). The increase in absorbance was recorded at 470 nm. APX and POD were expressed per mg protein and one unit represented 1 µmol of a substrate undergoing reaction per mg protein per min.

PAL activity was determined by following the procedure given by Dickerson *et al*. (1984). 1 g sample was extracted with 3 ml of 0.1 M sodium borate buffer (pH 7.0) containing 1.4 mM of 2-mercaptoethanol in an ice bath. The extract was filtered and centrifuged at 10.000×g for 15 min. Then, the supernatant was used for PAL activity. Enzyme activity was assayed as the rate of conversion of L-phenylalanine to trans-cinnamic acid at 290 nm. Enzyme activity was expressed as nmol trans-cinnamic acid min^{-1} mg^{-1} protein.

β-carotene and lycopene contents were measured according to Nagata and Yamashita (1992). Mushroom samples were extracted with acetone-hexane (4:6) at once, then, the optical density of the supernatant at 663 nm, 645 nm, 505 nm, and 453 nm were taken by spectrophotometer at the same time. The concentrations of β-carotene and lycopene in extracts were determined as spectrophotometric using the following equations:

$$\beta\text{-carotene} = 0.216 \times A_{663} - 1.22 \times A_{645} - 0.304 \times A_{505} + 0.452 \times A_{453} \quad (1)$$

$$\text{Lycopene} = -0.0458 \times A_{663} + 0.204 \times A_{645} + 0.372 \times A_{505} - 0.0806 \times A_{453} \quad (2)$$

A-Absorbans

Statistical Analysis

Analysis of variance (ANOVA) was applied for analyzing the differences in the chemical composition of edible mushroom species by using the SPSS program version 11.0 for Windows. Following the results of ANOVAs, Tukey's multiple test ($\alpha = 0.05$) was used for testing differences between group means.

RESULTS AND DISCUSSION

The β-carotene, lycopene, and nitrate contents, and APX, POD, SOD, and PAL activities values of 15 mushroom samples are given in Table 2 and 3, respectively. Results showed that the significant differences ($p<0.05$) among the measured components for mushroom samples were found.

In respect of results acquired, the highest content of β-carotene was observed in *H. erinaceus* with 0.346 mg g^{-1}. This was followed by *P. ostreatus*-3 with 0.138 mg g^{-1}. *P. ostreatus*-2, *P. ostreatus*-4, *G. lucidum*, and *P. ostreatus*-1 have been found to have less β-carotene content than the other mushroom species. Species rich in lycopene content were *H. erinaceus*, *P. ostreatus*-3, and *G. lucidum,* while *P. ostreatus*-1, *P. ostreatus*-4, and *T. terreum* had the least lycopene content (Table 2).

Table 2. β-carotene, lycopene and nitrate contents of mushroom species.
Çizelge 2. Mantar türlerinin β-karoten, likopen ve nitrat içerikleri.

Name of mushroom species	β-carotene (mg g^{-1})	Lycopene (mg g^{-1})	Nitrate (mg g^{-1})
Boletus edulis	0.044e±0.001	0.031c±0.001	5.49e±0.06
Craterellus cornucopioides	0.053f±0.001	0.029c±0.001	12.71i±0.11
Ganoderma lucidum	0.008c±0.40	0.076e±0.007	6.04f±0.10
Hericium erinaceus	0.346i±0.012	0.188f±0.003	3.07c±0.01
Lactarius deliciosus	0.069g±0.001	0.034c±0.002	3.05c±0.03
Laetiporus sulphureus	0.071g±0.001	0.034c±0.001	3.15c±0.02
Lentinula edodes	0.054f±0.001	0.032c±0.001	6.50g±0.10
Marasmius oreades	0.089h±0.001	0.059d±0.001	9.16ı±0.06
Morchella conica	0.044e±0.001	0.018b±0.001	3.74d±0.02
Pleurotus ostreatus-1	0.009c±0.001	0.008a±0.001	1.77b±0.03
Pleurotus ostreatus-2	0.002a±0.001	0.030c±0.001	6.50g±0.10
Pleurotus ostreatus-3	0.138ı±0.001	0.092e±0.001	0.40a±0.00
Pleurotus ostreatus-4	0.006b±0.001	0.013b±0.001	12.65i±0.10
Ramaria botrytis	0.056f±0.001	0.039d±0.001	8.48h±0.03
Tricholoma terreum	0.026d±0.001	0.019b±0.001	5.38e±0.05
Range (R)	0.35	0.18	12.54
F value	65.813	491.857	3369.590
Sig. level	0.000	0.000	0.000

Mushrooms are significant sources of food due to higher levels of protein, carotenoid, phenolic molecules, vitamins, minerals, enzymatic and non-enzymatic compounds, and lower values of calorie and fat. Because of having high antioxidant compounds, they can be considered as a functional food that provides health benefits (Ramkumar *et al*., 2010; Mueller and Boehm, 2011). β-carotene and lycopene are carotenoids, which are natural pigments present in different food sources such as vegetables, fruits, and mushrooms. They can neutralize free radicals by inhibiting the oxidation reactions with antioxidant properties and may stabilize them (Rao and Rao, 2007). They are synthesized via mevalonate pathway and may enhance taste, smell, and flavor of mushrooms (Barros *et al*., 2008b; Robaszkiewicz *et al*., 2010). In this study, the highest values of β-carotene and lycopene were recorded in *H. erinaceus*, but the lowest β-carotene and lycopene values were observed in *P. ostreatus*-2 and *P. ostreatus*-1, respectively (Table 2). Robaszkiewicz *et al*. (2010) in *B. edulis*, *Cantharellus cibarius* and *Suillus bovinus*, Barros *et al*. (2008a) in *Agaricus bisporus* and *B. edulis*, Jayakumar *et al*. (2009) in *P. ostreatus*, Zürcher *et al*. (1997) in *C. cibarius* determined higher β-carotene and lycopene according to the results of this study. Hussein *et al*. (2015) reported that *Lentinus squarrolosus* have higher β-carotene and lycopene than carrot, persimmon, and tomato.

Mushrooms are rich in nitrogenous compounds such as amino acid, protein, and enzymes. It has been shown that a high percentage of fat is taken along with protein compounds taken from animal foods (Martinez-Espinosa *et al*., 2011). Therefore, the mushrooms, which have very low fat in daily nutrition, can be benefit to consume only pure protein (Barros *et al*., 2008a).

As seen in Table 2, the amount of nitrate ranged from 0.40 to 12.71 mg g^{-1}. *C. cornucopioides* and *P. ostreatus*-4 had the highest values with 12.71 and 12.65 mg g^{-1}, respectively, while the lowest value was found in the *P. ostreatus*-3 with 0.40 mg g^{-1} (Table 2). There is a limited number of studies on the determination of nitrate level of mushrooms. However, Bobics *et al*. (2016) investigated nitrate content of saprophytic, mycorrhiza, and woody mushroom species, and the amount of nitrate was 216.5 mg kg^{-1} in the mycorrhiza species and 228.6 mg kg^{-1} in woody mushrooms. And also, in the saprophytic species, nitrate level varied between 151.40 and 12715 mg kg^{-1}. Turfan *et al*. (2018) investigated the soluble protein level of the same mushroom species used in the study. Their results showed that the amounts of free amino acid ranged from 2.77 to 7.43 mg g^{-1}, but total soluble protein contents varied 33.57 and 126.57 mg g^{-1}. Ayaz *et al*. (2011) reported that the amount of nitrogen varied between 1.73 and 5.20 g 100 g^{-1}, while protein level changed between 10.80 and 32.50 g 100 g^{-1} in some mushrooms collected from Black Sea region. Also, Dembitsky *et al*. (2010) determined essential amino acid content of 15 wild edible mushrooms and they found that the amount of arginine as amino acid was the highest level compared to other amino acid varieties as 133 μM g^{-1}. Sun *et al*. (2017) determined that amino acid content changed between 1462.6 and 13106.2 mg 100 g^{-1} in the 13 mushroom samples. Teklit (2015) stated that the amount of protein varied between 28.38 and 49.20 g 100 g^{-1} in *A. bisporus*, *L. edodes*, and *P. ostreatus*.

APX activity ranged from 0.201 and 2.118 EU mg^{-1} protein APX activities were quite low for *H. erinaceus* (0.201 EU mg^{-1} protein), *C. cornucopioides* (0.250 EU mg^{-1} protein), and *G. lucidum* (0.278 EU mg^{-1} protein). As shown in Table 3, *P. ostreatus*-4 had the highest APX value as 2.118 EU mg^{-1} protein among other mushroom samples. Also, it was found that APX activity values of *L. edodes* (1.711 EU mg^{-1} protein), *L. deliciosus* (1.333 EU mg^{-1} protein), and *T. terreum* (1.057 EU mg^{-1} protein) were high.

Table 3. APX, POD, SOD, and PAL activity values of mushroom species.
Çizelge 3. Mantar türlerinin APX, POD, SOD ve PAL aktivite değerleri.

Name of mushroom species	**APX (EU mg^{-1} protein)**	**POD (EU mg^{-1} protein)**	**SOD (EU mg^{-1} protein)**	**PAL (EU mg^{-1} protein)**
Boletus edulis	0.397c±0.004	0.206a±0.001	23.87b±0.10	8.893e±0.082
Craterellus cornucopioides	0.250b±0.002	0.485b±0.001	58.23l±0.12	6.362a±0.018
Ganoderma lucidum	0.278b±0.003	2.472ı±0.005	33.34h±0.25	5.863a±0.047
Hericium erinaceus	0.201a±0.002	6.941k±0.011	35.13ı±0.15	6.487a±0.031
Lactarius deliciosus	1.333h±0.009	2.041f±0.003	27.12d±0.13	6.487a±0.031
Laetiporus sulphureus	0.735e±0.003	1.645e±0.003	31.42g±0.22	5.899a±0.031
Lentinula edodes	1.711ı±0.013	0.844d±0.002	48.48k±0.06	6.237a±0.018
Marasmius oreades	0.692e±0.006	2.337h±0.070	49.18k±0.16	8.145d±0.031
Morchella conica	0.772f±0.008	2.179g±0.003	30.13f±0.12	6.861b±0.031
Pleurotus ostreatus-1	0.623d±0.002	0.435b±0.001	21.81b±0.16	6.754b±0.031
Pleurotus ostreatus-2	0.603d±0.005	0.285a±0.001	24.36c±0.06	6.273a±0.031
Pleurotus ostreatus-3	0.780f±0.004	4.760j±0.002	19.12a±0.06	7.289c±0.031
Pleurotus ostreatus-4	2.118i±0.016	0.722c±0.002	46.49j±0.12	6.861b±0.031
Ramaria botrytis	0.700g±0.005	0.429b±0.001	28.28e±0.16	8.216d±0.047
Tricholoma terreum	1.057e±0.012	3.160i±0.004	39.35i±0.12	6.647b±0.031
Range (R)	1.95	6.76	39.43	3.21
F value	5326.163	9696.766	6805.831	555.181
Sig. level	0.000	0.000	0.000	0.000

Beside of this, POD activity varied between 0.206 and 6.941 EU mg^{-1} protein. Also, the POD values of *H. erinaceus*, *P. ostreatus*-3, and *T. terreum* (6.941, 4.760 and 3.160 EU mg^{-1} protein, respectively) were higher than others. But, *B. edulis* (0.206 EU mg^{-1} protein) and *P. ostreatus*-2 (0.285 EU mg^{-1} protein) have come to the forefront as POD value low mushroom samples (Table 3). Considering the changes in enzymes activity, APX activities were the highest in the *P. ostreatus*-4, *L. edodes*, *L. deliciosus* and *T. terreum*. POD activities of the samples were the maximum in the *H. erinaceus* collected from the university campus, *P. ostreatus-3*, and *T. terreum*.

SOD activity of the samples ranged from 19.12 to 58.23 EU mg^{-1} protein. *C. cornucopioides*, *M. oreades*, and *L. edodes* were species which had the highest SOD activity whereas *P. ostreatus*-3, *P. ostreatus*-1, *B. edulis*, and *P. ostreatus*-2 were species that had the lowest SOD activity (Table 3). It has been shown by many searchers that mushrooms are abundant in antioxidant compounds as SOD, POD, CAT, and APX (Cai *et al*., 2006). Ramkumar *et al*. (2010) studied with nine mushroom species to determine CAT, SOD, and POD activities. They found that CAT, SOD and POD activities were 42.21, 37.12 and 7.21 μmol respectively in the mushroom species. Georgescu *et al.*

(2016) worked the effect of heavy metal stress on the activities of the enzymes of some mushroom species. Their result indicated that POD activity lowered with higher heavy metal accumulation, but CAT activity increased with higher concentration of heavy metals. Chen *et al*. (2017) investigated the effect of hydrogen-rish waters (HRW) on *the Hypsizygus marmoreus* depended on storage time. According to the result of them, SOD, CAT, APX, and GR activities enhanced with 25% HRW. Besides, this concentration stimulated gene expression of some antioxidant enzymes in mushrooms.

It was determined that *B. edulis* was the richest species in terms of PAL activity among the studied mushrooms samples. Also, it was seen that the PAL activity of *B. edulis* was quite high, too. However, *C. cornucopioides*, *G. lucidum*, *H. erinaceus*, *L. deliciosus*, *L. sulphureus*, *L. edodes,* and *P. ostreatus*-2 were the poorest species in terms of PAL activity (Table 3). PAL is an important enzyme involved in the seconder metabolite metabolism in the plant cell. There are many workings on the importance of PAL in plants, but, the biological role of PAL in fungi and information on fungal PAL are not clear (Hyun *et al*., 2011). In this study, PAL activity also had significant effects among the mushroom samples. The highest level of PAL activity was observed with *B. edulis*. The lowest value of PAL was obtained from *G. lucidum* (Table 3). There is limited information on PAL activity in the literature on mushrooms. Hyun *et al*. (2011) reported that PAL activity was observed during organismal development and exposure to abiotic stress in *P. ostreatus*. Yun *et al*. (2015) investigated the cloning and activity of PAL in the mycelium and fruiting body of the edible mushroom *Flammulina velutipes*. The results showed that PAL activity varied in the different organs of the mushroom. Turfan *et al*. (2019) determined that PAL activities ranged between 5.79-6.99 EU mg^{-1} in different mushroom species.

When all chemical results were considered, the amount of chemical compound as antioxidants showed significant variations among mushroom samples collected from different areas. It has been shown that the amount of nutrient level and antioxidative chemicals may vary depending on species, in various parts of the fruiting body of mushrooms, seasonally as well changing of environmental conditions (Barros *et al*., 2009; Ayaz *et al*., 2016; Pekşen *et al*., 2016; Turfan *et al*., 2018).

CONCLUSION

Differences regarding the contents of chemical components of mushroom species were significant. These variations may result from location, ecological conditions, and also nutrient accumulation or antioxidant synthesis capacity as enzymatic and non-enzymatic. Also, examined 15 mushroom samples collected from different locations are a good source of β-carotene, lycopene, nitrate, and antioxidant enzyme activities such as APX, POD, SOD, and PAL. As a result, it can be said that these mushrooms are edible as alternative food supplements in daily nutrition.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

AUTHORS' CONTRIBUTIONS

Nezahat TURFAN and Aysun PEKŞEN discussed the research concept and designed the experiment. Nezahat TURFAN, Sezgin AYAN ve Şeyma Selin AKIN carried out the experiment and statistical analysis which were finally verified. Aysun PEKŞEN wrote the manuscript with the support of other researchers.

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