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

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Received: 09.06.2020 Accepted: 13.07.2020

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. Karrst., 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.

Keywords: Antioxidant, enzyme, mushroom, carotene, lycopene

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Antioksidan Enzim Aktiviteleri

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

Özet. Bu çalışmada; Türkiye’nin farklı yörelerinden temin edilen 15 doğa ve kültür mantar türüne [Boletus edulis Bull.: Fr, Aycı mantarı), Craterellus cornucopioides (L) Pers. (Borazan mantarı), Lactarius deliciosus (L ex Fr.) S.F.Gray (Kanlıca mantarı), Laetiporus sulphureus (Bull.: Fr.) Murr. (Kükürt mantarı), Morchella conica Pers. (Kızılıkabaklı mantarı), Ramaria botrytis (Pers.: Fr.) Ricken (Pürpürcü mantarı), Tricholoma terreum (Schaeff.: Fr.) P. Kumm. (Karakız mantarı), Hericium erinaceus (Bull.: Fr.) Pers. (Aşıl mantarı), Lentinula edodes (Berk.) Pegler (Meşe mantarı), Ganoderma lucidum (Curt.: Fr.) P. Karrst., ve Pleurotus ostreatus (Jacq. ex Fr.) P. Kumm. (1-4) (Kayın mantarı)] ait örnekte antioksidan enzim kapasitesini belirlemek için fenilalanin amonyum iyaz (PAL) enzim aktivitesi, ascorbat peroksidaz (APX), peroksidaz (POD) ve süperoksid dismutaz (SOD) aktivite değişimleri ve nitrat, β-karotene ile likopen düzeyleri araştırılmıştır. Sonuç olarak, farklı yörelerden temin edilen mantar örnekleri içerisinde en yüksek β-karotene ve likopen miktarı H. erinaceus türünde belirlenmiştir. β-karoteni 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 fazla tür olarak belirlenmiştir. Mantarların PAL aktivitesi 5.863 ve 8.893 EU mg⁻¹ protein arasında değişmiştir. En yüksek APX değerinin P. ostreatus-4 türünde, en düşük değerin ise H. erinaceus türune 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.
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, carotenoids, 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; Leley, 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 °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 H₂SO₄) 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 NO₃⁻ g⁻¹ dry weight) was estimated with a standard curve of KNO₃.

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.

| 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. | 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 Crab-of-the-woods | Wild | Giresun, Bektas |
| Laetiporus sulphureus (Bull.: Fr.) Murr. | Sulphur polypore, Sulphur shelf, and Chicken-of-the-woods | Wild | Giresun, Balancak |
| 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 Oyster, Abalone, or Tree mushrooms | Wild | Samsun, Vezipkoprü |
| Pleurotus ostreatus (Jacq. ex Fr.) P. Kumm.-1 | Oyster, Abalone, or Tree mushrooms | Cultivated | Giresun, Eynesil |
| Pleurotus ostreatus (Jacq. ex Fr.) P. Kumm.-2 | Cluttered coral, Pink-tipped coral mushroom, or Cauliflower coral | Wild | 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 | | | Samsun, Lâdik |
| Tricholoma terreum (Schaeff.: Fr.) P. Kumm. | Grey knight or Dirty Tricholoma | Wild | Samsun, Vezipkoprü |

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\(_2\)O\(_2\), 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 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:

\[
\beta\text{-carotene} = 0.216 \times A_{663} - 1.22 \times A_{645} - 0.304 \times A_{505} + 0.452 \times A_{453}
\]

\[
\text{Lycopene} = -0.0458 x A_{663} + 0.204 \times A_{645} + 0.372 \times A_{505} - 0.0806 \times A_{453}
\]

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 (α= 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.

| Name of mushroom species | β-carotene (mg g⁻¹) | Lycopene (mg g⁻¹) | Nitrate (mg g⁻¹) |
|-------------------------|-------------------|-----------------|-----------------|
| *Boletus edulis*        | 0.044±0.001       | 0.031±0.001     | 5.49±0.06       |
| *Craterellus cornucopioides* | 0.053±0.001   | 0.029±0.001     | 12.71±0.11      |
| *Ganoderma lucidum*     | 0.008±0.040       | 0.076±0.007     | 6.04±0.10       |
| *Hericium erinaceus*    | 0.346±0.012       | 0.188±0.003     | 3.07±0.01       |
| *Lactarius deliciosus*  | 0.006±0.001       | 0.034±0.002     | 3.15±0.03       |
| *Laetiporus sulphureus* | 0.071±0.001       | 0.034±0.001     | 6.50±0.10       |
| *Lentinula edodes*      | 0.054±0.001       | 0.032±0.001     | 9.16±0.06       |
| *Marasmius oreades*     | 0.089±0.001       | 0.059±0.001     | 3.74±0.02       |
| *Morchella conica*      | 0.044±0.001       | 0.018±0.001     | 1.77±0.03       |
| *Pleurotus ostreatus*-1 | 0.009±0.001       | 0.008±0.001     | 6.50±0.10       |
| *Pleurotus ostreatus*-2 | 0.002±0.001       | 0.030±0.001     | 3.05±0.03       |
| *Pleurotus ostreatus*-3 | 0.138±0.001       | 0.092±0.001     | 8.48±0.03       |
| *Pleurotus ostreatus*-4 | 0.006±0.001       | 0.013±0.001     | 3.15±0.03       |
| *Ramaria botrytis*      | 0.056±0.001       | 0.039±0.001     | 6.50±0.10       |
| *Tricholoma terreum*    | 0.026±0.001       | 0.019±0.001     | 9.16±0.06       |

Table 2 (continued)

| Name of mushroom species | β-carotene (mg g⁻¹) | Lycopene (mg g⁻¹) | Nitrate (mg g⁻¹) |
|-------------------------|-------------------|-----------------|-----------------|
| *Boletus edulis*        | 0.044±0.001       | 0.031±0.001     | 5.49±0.06       |
| *Craterellus cornucopioides* | 0.053±0.001   | 0.029±0.001     | 12.71±0.11      |
| *Ganoderma lucidum*     | 0.008±0.040       | 0.076±0.007     | 6.04±0.10       |
| *Hericium erinaceus*    | 0.346±0.012       | 0.188±0.003     | 3.07±0.01       |
| *Lactarius deliciosus*  | 0.006±0.001       | 0.034±0.002     | 3.15±0.03       |
| *Laetiporus sulphureus* | 0.071±0.001       | 0.034±0.001     | 6.50±0.10       |
| *Lentinula edodes*      | 0.054±0.001       | 0.032±0.001     | 9.16±0.06       |
| *Marasmius oreades*     | 0.089±0.001       | 0.059±0.001     | 3.74±0.02       |
| *Morchella conica*      | 0.044±0.001       | 0.018±0.001     | 1.77±0.03       |
| *Pleurotus ostreatus*-1 | 0.009±0.001       | 0.008±0.001     | 6.50±0.10       |
| *Pleurotus ostreatus*-2 | 0.002±0.001       | 0.030±0.001     | 3.05±0.03       |
| *Pleurotus ostreatus*-3 | 0.138±0.001       | 0.092±0.001     | 8.48±0.03       |
| *Pleurotus ostreatus*-4 | 0.006±0.001       | 0.013±0.001     | 3.15±0.03       |
| *Ramaria botrytis*      | 0.056±0.001       | 0.039±0.001     | 6.50±0.10       |
| *Tricholoma terreum*    | 0.026±0.001       | 0.019±0.001     | 9.16±0.06       |

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 squarrosolus* 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 462.6 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.

| 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                  | 58.231±0.12                  | 6.362a±0.018                 |
| Ganoderma lucidum        | 0.278b±0.003                  | 2.472i±0.005                  | 33.34h±0.25                  | 5.863a±0.047                 |
| Hericium erinaceus       | 0.201e±0.002                  | 6.941k±0.011                  | 35.13i±0.15                  | 6.487a±0.031                 |
| Lactarius deliciosus     | 1.335h±0.009                  | 2.041f±0.003                  | 27.12d±0.13                  | 6.487a±0.031                 |
| Laetiporus sulphureus    | 0.753e±0.003                  | 1.645e±0.003                  | 31.42g±0.22                  | 5.899a±0.031                 |
| Lentinula edodes         | 1.711i±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                  | 8.154d±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                  | 39.35f±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. (2010) determined 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-rich 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. cornucopiaeoides, 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 secondary metabolite metabolism in the plant cell. There are many works 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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