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Element Contents of *Pleurotus eryngii* (DC. ex Fr.) Quel. var. *eryngii* Grown on Some Various Agro-Wastes

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Abstract

In this study, the concentrations of K, Ca, Na, Fe, Zn, Mn, Cu, Cr, Cd, Co, Ni and Pb in *P. eryngii* var. *eryngii* grown on various agro-wastes were investigated. Mineral element contents were determined as 11.0-18.9 mg g^{-1} K, 0.35-1.03 mg g^{-1} Ca, 0.16-0.88 mg g^{-1} Na, 602.4-1524.5 mg kg^{-1} Fe, 44.7-102.7 mg kg^{-1} Zn, 17.7-37.5 mg kg^{-1} Mn, and 12.6-36.0 mg kg^{-1} Cu (dry weight). Contents of metals varied significantly, with the (highest) potassium contents ranging from 11.0 to 18.9 mg g^{-1} and the (lowest) copper contents ranging from 12.6 to 36.0 mg kg^{-1} of dry weight detected among seven mineral elements. Furthermore, toxic elements such as Cr, Cd, Co, Ni and Pb were not determined in all testing groups.

Keywords: Agro-wastes, edible mushroom, mineral element, *P. eryngii* var. *eryngii*.

Bazı Tarımsal Atıklar Üzerinde Yetiştirilen *Pleurotus eryngii* (DC. ex Fr.) Quel. var. *eryngii*'nin Element İçeriği

Özet

Bu çalışmada; çeşitli tarımsal atıklar üzerinde yetiştirilen *P. eryngii* var. *eryngii*'de; K, Ca, Na, Fe, Zn, Mn, Cu, Cr, Cd, Co, Ni ve Pb konsantrasyonları araştırıldı. Mineral element içeriği: 11.0-18.9 mg g^{-1} K, 0.35-1.03 mg g^{-1} Ca, 0.16-0.88 mg g^{-1} Na, 602.4-1524.5 mg kg^{-1} Fe, 44.7-102.7 mg kg^{-1} Zn, 17.7-37.5 mg kg^{-1} Mn ve 12.6-36.0 mg kg^{-1} Cu olarak belirlendi. Element düzeylerinin değişken olduğu, miktarları tespit edilen yedi element arasında, en yüksek 11.0-18.9 mg g^{-1} ile potasyum, en düşük 12.6-36.0 mg kg^{-1} ile bakır'da saptandı. Ayrıca, tüm deneme gruplarında ise; Cr, Cd, Co, Ni ve Pb gibi ağır metaller gözlenmedi.

Anahtar Kelimeler: Mineral element, *P. eryngii* var. *eryngii,* tarımsal atıklar, yenen mantar.

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INTRODUCTION

The consumption of mushrooms has been known for many years, even it is as old as the civilization of people. More than 2000 species of mushrooms exist in nature, but approximately 22 species are intensively cultivated (Manzi et al. 2001). In most countries, there is a well-established consumer acceptance for cultivated mushrooms such as *Agaricus bisporus*, *Lentinus edodes*, *Pleurotus* spp., *Volvariella volvacea*, and *Auricularia* spp. (Diez and Alvarez 2001). They are a good source of protein, vitamins, minerals, and are preferred in many countries due to special flavours and aroma (Guo et al. 2007, Pekşen and Günay 2009). *Pleurotus* spp. represents the third largest group of cultivated mushrooms in the world, grown on a variety of plant residues, and they have been found to be nutritionally and gastronomically important (Cohen et al. 2002). The fungi selected for the present study was *P. eryngii* var. *eryngii* which is edible, basidiomycetic and saprophytic, frequently consumed and distributed in the Mediterranean, Central Europe, Central Asia, North Africa (Lewinsohn et al. 2002), and Turkey. It was found to be growing on the remains roots of *Eryngium* spp. (Læssoe et al. 1996), and is not a worldwide known with restrict to some parts of the world, unlike the other *Pleurotus* species. It is rather slow in growth, vulnerable to other fungal attacks and requires long time to develop its basidiocarp (Akyüz and Kirbağ 2009).

Mushrooms are important in ecosystems because they are able to biodegrade different substrates, among other wastes of agricultural

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production (Manzi et al. 1999). Many species accumulate several trace elements, mainly mercury, cadmium, and lead, at levels greatly exceeding contents in other foods. Heavy metal concentrations in mushroom are considerably higher than those in agricultural crop plants, vegetables and fruits (Lepsova and Mejstrik 1988). In earlier publications, data have been given on the content of metals in *Pleurotus* spp. (Chang et al. 1981, Bisaria et al. 1987, Khanna et al. 1992, Ragunathan et al. 1996, Manzi et al. 1999, Gong et al. 2003, Ragunathan and Swaminathan 2003, Doğan et al. 2006, Guo et al. 2007). Heavy metals are well-known for their toxicity at low concentrations (Vural 1993), a great deal of effort has been made to evaluate the possible danger to human health from the ingestion of mushrooms (Gast et al. 1988, Doğan et al. 2006). The principal factors influencing the accumulation of metals in mushrooms are environmental and fungal factors (Garcia et al. 1998). Therefore, it is necessary to know the levels of mineral elements in edible mushrooms. The aim of this study was to determine K, Ca, Na, Fe, Zn, Mn, Cu, Cr, Cd, Co, Ni, and Pb contents in *P. eryngii* var. *eryngii* grown on some various agro-wastes.

MATERIAL AND METHODS

Macrofungal Materials

The samples used in this study were obtained from previous culture work (Kirbag and Akyuz 2008). The 1:1 rate of wheat-cotton straw (WS-PS), wheat-millet straw (WS-MS), wheat-soybean straw (WS-SS), wheat-corn stalk (WS-CS), wheat-bean stalk (WS-BS), and wheat straw (WS) were prepared in 6 different compost. All compost were also supplemented with rice bran at a rate of 10 and 20% respectively and in this way eighteen types of compost were prepare see Table 1. The samples, obtained after culture and were harvested in sterile conditions and labeled. The samples were dried at room temperature for 15 days then placed in locked bags and stored at 25°C in lab. These samples were used in this study.

Analytical Methods

Each sample of air-dried mushroom was dried at 105°C overnight and crushed in a mortar and pestle. Digestion of mushrooms samples was performed using mixture of $HNO_3 : H_2SO_4 : H_2O_2$ (10:1:1, 12 ml for 1 g sample) and heating 100°C for about 10-15 min. After cooling, 50 ml deonized water was added and filtered. All sample solutions were clear. While amounts of Fe, Zn, Mn, Cu, Cr, Cd, Co, Ni and Pb were determined by atomic absorption spectrometer (Perkin-Elmer, model: 370 made by: The Perkin-Elmer Corporation Norwalk Connecticut, USA), those of K, Ca and Na were performed by atomic emission spectrometer (Eppendorf Geratebau, Netheler+HINZ GMBH Hamburg, GERMANY) (Anonymous 1990).

Statistical Analysis

Experimental values are given as means ± standard deviation (SD). Statistical significance was determined by one way variance analysis (ANOVA). Differences at $P<0.05$ were considered to be significant. A Tukey HSD's multiple comparison test for comparison of multiple means was used with the SPSS 13.0 computer programs (SPSS, Chicago, Illinois, USA). The experiments were repeated three times.

RESULTS

There were significant differences in the micro and macro elements for *P. eryngii* var. *eryngii* grown on various agro-wastes. The difference between the values we obtained might arise from the biological structure of substrats and additive material (Table 1). The highest and lowest levels of potassium were found to be in WS-BS (1:1) + 10% RB (18.9 mg g^{-1}) and WS-BS (1:1) (11.0 mg g^{-1}) see Table 1. The highest content of calcium was 1.03 mg g^{-1} in WS-CS (1:1) + 20% RB, whereas the lowest was 0.35 mg g^{-1} in WS-MS (1:1) + 20% RB (Table 1). Sodium levels were determined to be 0.16 mg g^{-1} in WS-SS (1:1) and 0.88 mg g^{-1} in WS-CS (1:1) + 10% RB as shown in Table 1. Maximum iron level was 1525 mg kg^{-1} in WS and minimum level was 602 mg kg^{-1} in WS-BS (1:1) see Table 1. Zinc concentrations were high in WS-CS (1:1) + 10% RB and ranged from 44.7 mg kg^{-1} to 102.7 mg kg^{-1}. The highest manganese content was 37.5 mg kg^{-1} in WS-CS (1:1) + 10% RB, but the lowest was 17.7 mg kg^{-1} in WS-PS (1:1) + 20% RB. The lowest copper contents was 12.6 mg kg^{-1} in WS-PS (1:1), while the highest was 36.0 mg kg^{-1} in WS-SS (1:1) + 20% RB as seen in Table 1. These diffence probably arose from mushroom samples cultivated with different substrates. When compared with other wastes, element contents were found to be changeable and also some values were similar statistically, depending on the raw and additive material used as shown in Table 1. Other information on toxic metals, such as Pb, Co, Ni, Cr and Cd have been reported, and

Table 1. Element contents of *P. eryngii* var. *eryngii* grown on some various agro-wastes (dry weight)

Materials	Macro elements			Micro elements (mg kg^{-1})								
	K (mg g^{-1})	Ca (mg g^{-1})	Na (mg kg^{-1})	Fe	Zn	Mn	Cu	Cr	Cd	Co	Ni	Pb
WS	18.6 ± 0.1^{ah}	0.60 ± 0.04^{agh}	170.7 ± 1.2^{a}	1524.5 ± 10.6^{a}	47.0 ± 1.0^{a}	20.2 ± 1.3^{aeg}	22.6 ± 0.5^{ae}	-	-	-	-	-
WS + 10 % RB	11.5 ± 0.4^{bg}	0.93 ± 0.06^{bc}	718.7 ± 1.3^{b}	731.3 ± 3.3^{b}	72.8 ± 2.0^{b}	22.3 ± 1.2^{abe}	23.1 ± 0.3^{bdi}	-	-	-	-	-
WS + 20 % RB	18.1 ± 0.1^{ah}	0.91 ± 0.07^{bci}	220.8 ± 3.8^{c}	652.8 ± 5.4^{c}	58.0 ± 2.0^{cf}	25.1 ± 1.9^{bef}	26.2 ± 0.6^{abd}	-	-	-	-	-
WS-CS (1:1)	12.0 ± 0.1^{bceg}	0.74 ± 0.06^{abi}	563.6 ± 3.5^{d}	963.0 ± 3.1^{d}	90.0 ± 2.0^{d}	26.3 ± 1.1^{bd}	16.1 ± 0.3^{cf}	-	-	-	-	-
WS-CS (1:1) + 10 % RB	17.4 ± 0.5^{ad}	0.80 ± 0.03^{bde}	880.1 ± 4.6^{e}	1507.0 ± 7.0^{a}	102.7 ± 6.0^{e}	37.5 ± 1.3^{c}	24.5 ± 0.7^{abhi}	-	-	-	-	-
WS-CS (1:1) + 20 % RB	12.6 ± 0.4^{bce}	1.03 ± 0.11^{c}	492.9 ± 2.1^{f}	1026.1 ± 9.7^{e}	75.5 ± 0.9^{b}	26.2 ± 1.1^{bd}	30.6 ± 1.4^{dil}	-	-	-	-	-
WS-MS (1:1)	13.0 ± 0.8^{cef}	0.63 ± 0.06^{adg}	498.1 ± 2.8^{f}	730.4 ± 3.4^{b}	95.3 ± 1.2^{de}	30.2 ± 0.8^{d}	17.9 ± 0.2^{cgh}	-	-	-	-	-
WS-MS (1:1) + 10 % RB	11.8 ± 0.2^{bcg}	0.96 ± 0.06^{ce}	468.5 ± 1.3^{g}	691.4 ± 1.6^{f}	72.5 ± 0.9^{b}	21.7 ± 2.4^{cgi}	19.6 ± 1.4^{ce}	-	-	-	-	-
WS-MS (1:1) + 20 % RB	16.6 ± 0.4^{d}	0.35 ± 0.05^{f}	715.2 ± 2.8^{b}	913.3 ± 6.8^{g}	44.7 ± 1.5^{a}	28.3 ± 0.9^{df}	24.0 ± 0.2^{eb}	-	-	-	-	-
WS-PS (1:1)	12.6 ± 0.3^{bcef}	0.50 ± 0.10^{fg}	211.3 ± 2.3^{c}	957.5 ± 7.5^{d}	49.0 ± 1.7^{a}	20.4 ± 0.9^{agh}	12.6 ± 0.3^{f}	-	-	-	-	-
WS-PS (1:1) + 10 % RB	13.2 ± 0.2^{ef}	0.41 ± 0.09^{fh}	184.2 ± 5.2^{h}	740.1 ± 5.5^{b}	50.8 ± 4.0^{ac}	27.5 ± 2.4^{dfh}	21.7 ± 0.2^{aeg}	-	-	-	-	-
WS-PS (1:1) + 20 % RB	18.1 ± 0.2^{ah}	0.53 ± 0.06^{fgi}	266.0 ± 5.0^{i}	956.9 ± 8.5^{d}	62.2 ± 1.3^{f}	17.7 ± 0.7^{g}	21.0 ± 0.9^{ehk}	-	-	-	-	-
WS-SS (1:1)	13.7 ± 0.3^{f}	0.53 ± 0.11^{afi}	160.7 ± 4.5^{a}	1208.9 ± 6.7^{h}	58.4 ± 1.6^{f}	29.6 ± 0.8^{d}	28.7 ± 0.6^{dhi}	-	-	-	-	-
WS-SS (1:1) + 10 % RB	12.8 ± 0.2^{ef}	0.89 ± 0.01^{bci}	502.3 ± 2.5^{f}	1120.6 ± 2.5^{i}	76.5 ± 3.1^{b}	29.2 ± 0.7^{d}	31.3 ± 2.8^{il}	-	-	-	-	-
WS-SS (1:1) + 20 % RB	11.4 ± 0.5^{bg}	0.58 ± 0.02^{agh}	364.9 ± 4.6^{i}	729.6 ± 4.5^{b}	60.0 ± 2.0^{f}	19.1 ± 0.9^{ag}	36.0 ± 1.0^{j}	-	-	-	-	-
WS-BS (1:1)	11.0 ± 0.1^{g}	0.57 ± 0.03^{agh}	555.9 ± 7.2^{d}	602.4 ± 3.3^{c}	72.8 ± 2.6^{b}	20.0 ± 0.6^{ag}	16.9 ± 1.6^{cfk}	-	-	-	-	-
WS-BS (1:1) + 10 % RB	18.9 ± 0.9^{h}	0.54 ± 0.05^{af}	205.0 ± 5.0^{c}	1434.4 ± 5.6^{i}	60.3 ± 2.0^{f}	23.8 ± 1.8^{beh}	33.9 ± 0.8^{jl}	-	-	-	-	-
WS-BS (1:1) + 20 % RB	12.5 ± 0.4^{bce}	0.71 ± 0.09^{adi}	361.7 ± 2.4^{i}	1031.1 ± 6.0^{e}	76.7 ± 2.1^{b}	24.5 ± 1.3^{bfi}	24.1 ± 0.9^{abci}	-	-	-	-	-

wheat straw (WS), soybean straw (SS), corn stalk (CS), millet straw (MS), cotton stalk (PS), bean stalk (BS), rice bran (RB),
Each value is expressed as mean ± SD of three replicate analyses (n=3), (-): not determined.
Values with different small letters in the same column are significantly different at the level of 0.05 ($P<0.05$).

those toxic heavy metals were not determined in this study (Table 1).

DISCUSSION

The element concentration are primarily species dependent. It has been rather difficult to determine the effects of different factors on the concentrations of elements, and but mainly affected by acidic and organic matter contents of the ecosystem and soil (Gast et al. 1988).

Potassium contents ranged from 11.0 to 18.9 mg g^{-1} of dry weight in *P. eryngii* var. *eryngii* grown on various agro-wastes, and were the highest among detected seven mineral elements and indeed were much higher than those of other mineral elements (Table 1). The highest and lowest levels of potassium were found to be in WS-BS (1:1) + 10% RB and WS-BS (1:1) respectively (Table 1). The reported potassium values for *Pleurotus* spp. were 8.10-33.8 mg g^{-1} (Chang et al. 1981, Bisaria et al. 1987, Khanna et al. 1992, Ragunathan et al. 1996, Ragunathan and Swaminathan 2003, Guo et al. 2007). These data were consistent with the data presented in this study. Manzi et al. (1999) reported that the fruiting body of *P. eryngii* var. *ferulae* and *P. eryngii* var. *eryngii* contained K 26.11-40.54 mg g^{-1}. These data were very different from the data in our work. The differences among the values obtained may arise from the genotype of mushroom and biological structure of substrate.

The highest content of calcium was 1.03 mg g^{-1} in WS-CS (1:1) + 20% RB, whereas the lowest Ca content was 0.35 mg g^{-1} in WS-MS (1:1) + 20% RB (Table 1). The reported calcium values for mushrooms were 0.19-2.45 mg g^{-1} (Chang et al. 1981, Bisaria et al. 1987, Khanna et al. 1992, Ragunathan et al. 1996, Ragunathan and Swaminathan 2003, Guo et al. 2007). Manzi et al. (1999) reported that there were Ca 0.28-0.35 mg g^{-1} in the fruiting body of *P. eryngii* var. *ferulae* and *P. eryngii* var. *eryngii*. Calcium contents of *P. eryngii* var. *eryngii* were similar and some values changeable found to be those in the cited studies. The differences between the values may arise from the fact that the strain and culture media used were different.

Sodium levels were determined to be 0.16 mg g^{-1} in WS-SS (1:1) and 0.88 mg g^{-1} in WS-CS (1:1) + 10% RB (Table 1). The reported sodium values for mushrooms were 0.02-2.5 mg g^{-1} (Chang et al. 1981, Bisaria et al. 1987, Khanna et al. 1992, Ragunathan et al. 1996, Ragunathan and Swaminathan 2003, Guo et al. 2007). These data were changeable from the data in our work. Manzi et al. (1999) reported that the fruiting body of *P. eryngii* var. *ferulae* and *P. eryngii* var. *eryngii* contained Na 0.44-0.76 mg g^{-1}. These data were similar found to be that reported study.

Iron values have been reported as 0.25-12.7 mg g^{-1} (Chang et al. 1981, Bisaria et al. 1987, Khanna et al. 1992, Ragunathan et al. 1996, Ragunathan and Swaminathan 2003) for *Pleurotus* spp. In this study, maximum Fe level was 1.5 mg g^{-1} in WS and minimum level was 0.6 mg g^{-1} in WS-BS (1:1). These data were very different from the data in our work. This difference probably arose from different mushroom samples cultivated with different substrates. For many trace elements, their usual levels are highly species-dependent.

Zinc concentrations were high in WS-CS (1:1) + 10% RB and ranged from 44.7 mg kg^{-1} to 102.7 mg kg^{-1} (Table 1). The reported zinc values for *P. eryngii* var. *ferulae* were 20-180 mg kg^{-1} (Gong et al. 2003, Guo et al. 2007). These data were different from the data in our study.

The highest manganese content was 37.5 mg kg^{-1} in WS-CS (1:1) + 10% RB, the lowest was 17.7 mg kg^{-1} in WS-PS (1:1) + 20% RB. Doğan et al. (2006) reported that the fruiting body of *P. eryngii* contained manganese (Mn) 143 mg kg^{-1}. That data was very different from the data in our study. This difference probably arose from different samples. The copper contents were between 12.6 mg kg^{-1} and 36.0 mg kg^{-1} in *P. eryngii* var. *eryngii*. The lowest and highest Cu values were found in WS-PS (1:1) and WS-SS (1:1) + 20% RB (Table 1). Doğan et al. (2006) reported that there was copper (Cu) 16.5 mg kg^{-1} in the fruiting body of *P. eryngii*. That data were consistent with the presented in this work. However, Doğan et al. (2006) reported that there were Pb 15.2 mg kg^{-1}, Cd 0.31 mg kg^{-1}, Ni 24.0 mg kg^{-1}, and Cr 46.7 mg kg^{-1} in the fruiting body of *P. eryngii*. Toxic heavy metals such as Pb, Co, Ni, Cr and Cd were not determined in *P. eryngii* var. *eryngii* grown on various agro-wastes (Table 1). Hence, those value were comparable with previously published report (Doğan et al. 2006). This difference probably arose from mushroom sample which was obtained from different growing medium. Thus, the concentrations of metals depand on mushroom species and their ecosystems, and also, mineral contents are affected heavily by the chemical differences of growing regions.

In conclusion, contents of metals in *P. eryngii* var. *eryngii* grown on some various agro-wastes were observed to be varied according to culture media. The main reason of different results is due to the use of different substrates in culture medium. Heavy metals such as Cr, Cd, Co, Ni and Pb were not determined in *P. eryngii* var. *eryngii*. Element levels in *P. eryngii* var. *eryngii* can not be considered to be of a health risk and are considered to have high nutritious elements for mammals.

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