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The nutrients of exotic mushrooms (*Lentinula edodes* and *Pleurotus* species) and an estimated approach to the volatile compounds

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Abstract

Texture, nutritive values and volatile compounds of *Lentinula edodes*, *Pleurotus ostraetus* and *Pleroutus sajor-caju* mushrooms were determined. The volatiles have been found out with an estimation approach by carrying out gas chromatography and mass spectrophotometer (GS–MS) Library Catalogue comparison. Neither regular increase nor decreases were observed for the values of texture, moisture, ash and protein values of *L. eddoes*. While a decrease, negative correlation was seen in values of vitamin C, folic acid and niacin values from the first flush to fourth flush periods, there was no correlation in the values of riboflavin and thiamin. Average mineral values of Shiitake (mg/kg wet basis) were: Zn, 10.18; Fe, 5.69; P, 998.47; Ca, 64.55; Mg, 191.89; K, 2347.33; Na, 622.40, proximate composition, vitamin C, folic acid, niacin, B1, B2 were determined in *Pleurotus* mushrooms. These mushrooms can contribute nutrition for protein and vitamin daily requirements. The mean mineral values of *Pleroutus* species (mg/kg, wb) *were*: Zn, 11.18–9.31; Fe, 14.80–7.94; P, 998.47–716.31; Ca, 81.16–23.66; K, 2225.00–2687.00; Na, 750.77–773.67, respectively. The volatile compounds, typical esters which are found in the mushrooms, hydrocarbons and fatty acids derivatives were determined with estimated approach by comparing library catalog of (GS–MS).

Keywords: Nutrients; Volatiles; Aroma; Compounds; Flush terms

1. Introduction

Consumption of mushrooms have been known in many years even it is as old as the civilization of people all over the world. Mushrooms are a good source of vitamins and minerals and are preferred due to special flavor and aroma in many countries and in Turkey. Increasing consumption of mushroom is good for preventing malnutrition, although mushrooms cannot be an alternative protein source instead of meat, fish, and egg (Garcha, Khanna, & Soni, 1993; Ünal, Ötleş, & Çağlarirmak, 1996; Çağlarirmak, Ünal, & Ötleş, 2002).

In Turkey, there have been important studies and development strategies done on mushroom productions at the universities and in the developed private companies. Not only the quantity and the numbers of cultivated mushroom species, but also scientific researches about cultivation techniques of edible wild mushrooms which have nutritional and medicinal aspects (Aksu, 2001; İlbay & Atmaca, 2004) are increasing.

Mushroom species also have functional properties such as the richness in vitamin B complex and vitamin D and antitumor, anticancer and antiviral activities due to lentinan. Shiitake, which contains lentinacin and lentysine, has serum cholesterol lowering effect (Mattila, Suanpaa, & Piironen, 2000).

In this research, nutritive values; proximate composition, B complex vitamins and vitamin C, nutritive minerals

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textures and volatiles of *Lentinula edodes* were investigated in the four flash terms also determined above mentioned same components for the *Pleurotus sajor-caju* and *Pleurotus ostreotus*.

The aroma was typical and special for each of the species of edible mushrooms (Cronin & Wada, 1971; Jong & Birmingan, 1993; Cuppet, Parhurs, Chung, & Bullerman, 1998). Approximate compositions of mushrooms were found by Kurasawa, Sugahara, and Hayashi (1982); moisture content of *P. ostreatus* was 88.6% ash of *L. edodes* was 7% dw. Manzi, Gambelli, Marconi, Vivanti, and Pizzoferrato (1999) have reported that the nutrients of *P. ostreotus* and *L. edodes* are as follows: (g/100 g) on wet basis (wb). The moisture value range and average were 85.24–94.70 and 90.0, respectively; protein ranged from 1.18 to 4.92 and 1.53; ash ranged from 0.52 to 1.15 and 0.71; minerals: Na range and average are 1.3–20.1 and 10.11; K, 182.5–395.9 and 264.7; Mg, 8.6–24.5 and 11.6; Ca, 1.4–3.9 and 4.2.

There are less amounts of scientific data and the researches are about nutrients and volatiles and some properties of *L. edodes* and *Pleurotus* spp. Thus, this research will be a contribution to the literature from the point of interesting ratios for both Turkey and the world consumption. In the other nutrients of the Shiitake and Oyster mushrooms that Ca, K, Mg, Na, P, Cu, Fe, Mn, and vitamins (B1, B2, B12, C, folates (Mattila et al., 2001)) have been determined.

L. edodes mushroom can harvest in four or five flash terms. Volatiles and nutrients can be affected in flash terms and compost or growing medium (Cruz, Suberville, & Montry, 1997). Patrabansh and Madan (1999) investigated those minerals of *P. sajor- caju* in different kinds of biomass. Obtained results showed that there were differences between different substrates, minerals of *P. sajor-caju* increased in containing high mineral content substrate. *L. edodes* and *Pleurotus* spp. are good sources of B complex vitamins and minerals, and can contribute to human diet (Timmel & Kluthe, 1997; Latiff, Daran, & Mohamed, 1996).

Proximate composition of mushroom species including *L. edodes* was examined that nutrients could be affected in harvesting stage period (Dikeman, Bauer, Flincker, & Fahey, 2005). Mushrooms also contain vitamins especially B complex vitamins. Approximate vitamin contents of *L. edodes* and (mg or μg/100 g): B1 0.05, 0.07 (mg/100 g); B2 0.15, 0.2 (mg/100 g); folates 21.51 (μg/100 g); B12 0.07–0.05 (μg/100 g); vitamin C 2.1–1.6 (mg/100 g) (Breene, 1990). They are more than nutritional; they are of desirable taste and aroma.

One of the objectives of this research is the determination of volatiles of *L. edodes* and *Pleurotus* spp. (Oyster mushrooms) by estimating with the identification of GC–Mass library catalog comparing.

Oyster mushrooms should have distinct sensory properties including aroma Cuppet et al. (1998) studied sensory properties texture and aroma of Oyster mushroom *P. sajor-caju*. In this research, we evaluated texture as three texture attributes, tough, rubbery and fibrous; and three flavor descriptors such as fresh fish, meat and buttery.

Mushroom texture can be affected by various factors like heat treatment and storage in pH ranges. In their study, Zivanic, Buescher, and Kim (2003) established that shear force exhibited similar trend to firmness but with distinguishable differences.

2. Materials and methods

2.1. Samples

4080 was a medium brown variety of *L. edodes* produced by Sylvan, provided in four different flush terms from MAMTAŞ exotic mushroom producing company in Kocaeli province. HK35 was the variety name of Sylvan's strain *P. ostreatus* provided from PEMA cultivated mushroom company, which is located in Menemen town of İzmir province in the western part of Turkey. These companies work as an integer mushroom plant, since they produce their own compost for growing mushroom species. *P. sajor-caju* was obtained from local producers in a village of İzmir province.

2.2. Methods

2.2.1. Physical properties

Texture: Mushroom caps were measured by a fruit hardness tester FHR-5, maximum pressure (%kg/mm^2), Cat. No. 5 (FHR-5) and 510-1 (FHR-1).

Physical analysis: texture was measured for 10 caps of 3 batches of mushrooms. Each of the mushroom batches which belonged to different flushes had 10 cap mushroom samples. These measurements had been performed in fresh samples after harvesting immediately (Altuğ et al., 2000; Zivanic et al., 2003).

2.2.2. Chemical analysis

Ash: moisture was determined using a Sartarius automatic moisture measurement device. Protein (AOAC, 1995): total protein contents were determined by the Kjeldhal method. Calculated nitrogen was multiplied by 4.38 (Garcha et al., 1993; Manzi et al., 1999).

2.2.3. Mineral analysis

AOAC (1995): ash was dissolved in 5 ml of 20% HCI, diluted and filtered through a 0.45 μm pore size filter. Lanthanum was added to overcome interferences for Ca and Mg determination. Minerals were established by AAS (atomic absorption spectrophotometry) except N, K which were detected by FES (flame emission spectrophotometry).

2.2.4. Water soluble vitamins

L-Ascorbic acid (vitamin C), B1 (thiamin), B2 (riboflavin), folic acid, and niacin were determined in the research. Vitamin C was determined by the 2,6-dichlorophenolindo-

phenol titration method, in which this dye is reduced by the ascorbic acid, resulting in the disappearance of the color of the dye (AOAC, 1995).

B complex vitamins B1 (thiamin), B2 (riboflavin), folic acid, and niacin were determined according to Finglas and Foulks (1984) and Kamman et al. (1980) high pressure liquid chromatography (HPLC) method and Dionex Vydac Application Note: 1994.

2.2.5. B complex vitamin sample preparation

Ten samples were weighed and put into a flask (250 ml). Then 30 ml 0.1 M HCl was added and the flask was closed with cotton than with aluminum foil and put in an autoclave. After this step, the pH of sample was adjusted to 6.5 and 4.5 with sodium acetate and HCI and the volume was made up with distilled water, filtrated with a normal filter paper. If there was turbidity, this was centrifuged to 10 min at 6000 rpm. If turbidity persisted, sample was filtered by using a filter of a 0.45 μm pore size. The samples were ready for measurement.

2.2.6. HPLC conditions

A colon oven was used. This had heating and cooling. Colon: C18 Omni Sphere 5, 250 4.6 mm, λ: 254 nm B6, B2, folic acid, λ: B1, flowing rate: 1.9 ml/min, injection volume is 20 μl, mobile phase: 1000 ml phosphate solvent +360 ml methanol mixture, pressure: 150–160 bar, running time is 22 min.

2.3. Analysis of aroma compounds by GS–MS (gas chromatography and mass spectrometry)

2.3.1. Extraction of aroma

A 150 g sample was cut into small cubes and then blended with 300 ml distilled water. The homogenized sample was rested to forming aroma compounds enzymatically (Venkatshwarlu, Chandravadana, & Tewari, 1999). The sample was placed in a liquid–liquid extraction apparatus (Heath & Reineccius, 1986) and 150 ml ethanol was added to the sample. One twenty five milliliter of hexane was added into an Erlenmeyer flask and then heated in a water bath. Thus, evaporated hexane condensed onto the sample and volatile compounds taken to its structure. The collected hexane was obtained as a result of condensation onto the sample, then refluxed and volatile compounds were obtained by collection. This extraction processes were repeated every 6 h. At the end of this period, hexane was evaporated till 5 ml volume, under nitrogen gas. The prepared sample was injected into equipment.

2.3.2. GS parameters

Instrument name: Inst 1, instrument type: PE (Perkin–Elmer) autosystem XL GC Perkin–Elmer Torbomas, column: OV 17 (%50 dimethyl) length, 30 m; inside diameter: 0.25 mm, film thickness (HP-50): 0.25 μm. Carrier gas: helium, flow rate of carrier gas: 5 ml/min; temperature program: 50 °C (2 min), 10 °C/min/240 °C (19 min), injection temperature: 230 °C, injection quantity: 0.5 μl, injection mode: splitless, electron energy: 70 eV, MS mass weight range: 40–400, MS library: WILEY and NIST libraries.

The determination of aroma compounds was performed by comparing mass spectra with those of the MS library.

Analyses of the research were done in triplicate. These measurements had been performed in fresh samples after harvesting immediately.

2.3.3. Statistical analysis

Difference tests were analyzed for Shiitake mushrooms. Standard deviations were established for *Pleurotus* species, since they were studied only for single flush terms. The mean of the arithmetic data of estimated volatile compounds was calculated.

In this research, one way ANOVA test was applied for *L. edodes* flush terms. Homogeneity of variances was checked with Levene statistic. If variances were homogeny, differences among the four flushes were established using *f*-test pairwise comparisons. If variances were not homogeny, four groups were compared with the Welch statistic. Pair analyses were established by Dunnett T3.

3. Results and discussion

Table 1 shows texture, moisture, ash and protein contents of Shiitake or Japan mushrooms in the four different stages and their contents are established for oyster mushrooms, *P. ostreatus* and *P. sajor-caju* in single stage.

The cell wall in fungi consists mainly of glucans, chitin and proteins (Zivanic et al., 2003). These exotic mushrooms have medicinal, nutritional and functional importance because of special polysaccharides and protein contents. Proteins of mushrooms can have water binding and water holding capacity, like meat. The functional properties are dealt with texture and consumer acceptance (Altuğ et al., 2000). Texture values of *L. edodes* varied between 0.81 and 1.23. These values were the highest in the first and second stages of mushrooms. Texture values of *P. ostreatus* and *P. sajor-caju* were 0.30 and 0.33 kg/mm^2, they possessed very close values. The mean values were 1.07 and 0.315 kg/mm^2, firmness of Shiitake mushroom is the superior according to Oyster mushroom species. There was positive correlation between the proteins and the texture and this evidence was in good agreement with the literature (Zivanic et al., 2003).

Moisture contents of *L. edodes* in four stages have no important differences, mean value of moisture contents of *L. edodes*, *P. ostreatus* and *P. sajor-caju* (%) were; 90.73, 92.63 and 94.04, respectively. Shiitake mushroom has less moisture content than *Pleurotus* species.

Moisture contents of Shiitake shows almost stable values in four stages due to the growing conditions of Shiitake. This situation estimated that provided stable relative humidity in growing environment (Manzi et al., 1999) and keeping of sample conditions were stable and standardized. Ash contents of Shiitake of four stages varied

Table 1
Texture, moisture, ash and protein contents of *Lentinula edodes, Pleurotus ostreatus* and *Pleurotus sajor-caju*

Mushrooms	Texture (kg/mm^2)	Moisture % (wb)	Ash % (wb)	Protein % (wb)[a]
L. edodes flush I	1.23 ± 0.22c	90.76 ± 0.69ab	0.80 ± 0.10a	2.93 ± 0.09c
L. edodes flush II	1.22 ± 0.08c	90.14 ± 0.6a60	0.77 ± 0.01a	2.07 ± 0.40a
L. edodes flush III	0.81 ± 0.02a	90.86 ± 0.37ab	0.95 ± 0.05b	2.48 ± 0.03b
L. edodes flush IV	1.00 ± 0.00b	91.16 ± 0.10b	0.78 ± 0.44a	2.94 ± 0.02c
P. ostreatus	0.33 ± 0.08	92.63 ± 0.11	0.63 ± 0.03	0.92 ± 0.17
P. sajor-caju	0.30 ± 0.07	94.07 ± 0.03	1.13 ± 0.03	1.76 ± 031

Data explain analyses of triplicates ± standard deviation. Variations were homogeny for texture, moisture, ash and protein of *L. edodes*. Thus, *F*-test was applied and the mean difference is significant at the $P < 0.05$ level.
[a] N × 4.38.

from 0.77% to 0.95% (wb). Ash contents of *P. ostreatus* and *P. sajor-caju* were 1.13% and 0.63% (wb), respectively. Ash contents can affect human mineral intake, these minerals of mushrooms were bioavailable (Dikeman et al., 2005) (Table 1). The protein content was calculated by using the protein conversion factor 4.38% total N. This estimation of protein was more accurate than the conversion factor 6.25 because of chitin or other N contributor compounds in mushrooms (Dikeman et al., 2005; Garcha et al., 1993; Manzi et al., 1999). Protein values ranged from 2.07% to 2.94% (wb). First and fourth stages protein values were almost the same; 2.93% and 2.94% (wb), respectively. There were no positive or negative correlations of protein values among the flush terms of Shiitake mushroom. Mushrooms can contribute to human nutrition because of protein quality and containability of some essential amino acids. Reported mean of protein values of *L. edodes*, *P. ostreatus* and *P. sajor-caju* were as 2.61%, 1.76% and 0.92% (wb) (Table 1). *L. edodes* should be of superior quantity according to *Pleurotus* sp. but both mushroom varieties are valuable for protein requirement for human nutrition (Breene, 1990; Garcha et al., 1993; Dikeman et al., 2005; Manzi et al., 1999; Mattila et al., 2000).

Table 2 gives B complex and vitamin C of exotic mushrooms. When examined vitamin C contents of Shiitake decreased from the first stage to the fourth stage slightly. Mean content of vitamin C was 14.68 mg/100 g. wb, vitamin C contents of *L. edodes* can pose a nutritive value for this result of this research for human vitamin C requirement, recommended daily intake (RDI) of vitamin is 60 mg (Demirci, 2006). In *Pleurotus* species, vitamin C content levels varied from 5.38 to 16.1 mg/100 g wb. *P. sajor-caju* has the highest vitamin content in this research. On the other hand, there was a variation about vitamin C contents in the literature (Mattila et al., 2001). Some research studies did not report vitamin C values; some of them reported very high values such as *L. edodes* 40.4–59.9 mg/100 g dw and *Pleurotus* sp.: 36.4–144 mg/100 g dw (Li & Chang, 1985; Bano & Rajaratham, 1986).

Folic acid contents of *L. edodes* tend to decrease in four flush terms except third flush which exhibited a slight increase from second flush terms to third flush 72.00 and 76.00 μg/100 g wb, respectively (Table 2). Folic acid contents of *P. ostreatus* and *P. sajor-caju* were 42–9.089 μg/100 g wb, respectively. Shiitake mushrooms have a higher folic acid content than *Pleurotus* sp. Thus it is a better source of folic acid. RDI of folic acid is 200 μg approximately (Demirci, 2006; Sencer, 1983). This means that Shiitake ad Oyster mushrooms are a good source of this vitamin which causes megablastic anemia insufficient intakes and especially development of fetus during pregnancy (Sencer, 1983).

Thiamin (B1) is a Beriberi preventing factor and plays an important role in energy metabolism (Baysal, 1996; Demirci, 2006; Sencer, 1983). Thiamin levels of *L. edodes* exhibited variations in four flush terms in the study (Table 2). The lowest thiamin value was obtained in the first stage 0.043 mg/100 g wb and the highest value in the fourth stage 0.17 mg/100 g wb. Mean of thiamin was 0.107 mg/100 g wb in the Shiitake mushrooms, RDI is 1.00 mg approximately or each of 1000 calorie containing diet which needs 0.4 mg thiamin daily intake. Thiamin contents of *Pleurotus* species

Table 2
Vitamin C and vitamin B complex *L. edodes*, *P. ostreatus* and *P. sajor-caju* mushrooms (mg/100 g wb)

Mushrooms	Vitamin C	Folic acid (μg/100 g)	Thiamin	Riboflavin	Niacin
L. edodes flush I	15.45 ± 1.18c	90.0 ± 0.00a	0.04 ± 0.01a	0.10 ± 0.00 c	3.23 ± 0.00d
L. edodes flush II	15.24 ± 0.13c	72.00 ± 0.57b	0.12 ± 0.00c	0.07 ± 0.00a	2.97 ± 1.11c
L. edodes flush III	14.28 ± 0.25b	76.00 ± 2.40c	0.09 ± 0.00b	0.09 ± 0.20b	2.75 ± 1.10b
L. edodes flush IV	13.73 ± 0.22a	59.33 ± 1.23d	0.17 ± 0.06d	0.22 ± 0.02d	1.95 ± 0.80a
P. ostreatus	3.38 ± 0.13	9.08 ± 1.17	0.15 ± 0.10	0.21 ± 0.00	4.44 ± 0.04
P. sajor-caju	16.01 ± 0.21	42.00 ± 2.00	0.14 ± 0.06	0.12 ± 0.11	2.96 ± 0.04

Data explain analyses of triplicates ± standard deviation. The *F*-test was applied since variances of the vitamin C and folic acid were homogeny ($P > 0.05$), the variances of the thiamin, riboflavin and niacin were not homogeny ($P < 0.05$), Welch statistic were analyzed for them. The mean difference is significant at the $P < 0.05$ level.

were 0.14 and 0.15 mg/100 g, respectively. Thiamin values in the research were higher amount from those found in the literature (Mattila et al., 2001). The organic substance levels can be varied in a large scale by depending on some factor like growing conditions, using ingredients in compost (Patrabansh & Madan, 1999).

Riboflavin (B2) levels of *L. edodes* ranged from 0.072 to 0.22 mg/100 g wb. The correlations among the flush terms of *L. edodes* are those good agreements with the literature (Breene, 1990; Mattila et al., 2001; Table 2). Mean riboflavin values of *L. edodes* were 0.12 mg/100 g wt, and *P. ostreatus* and *P. sajor-caju* contains 0.21–0.12 mg/100 g wb, respectively, which were similar with the literature (Breene, 1990; Mattila et al., 2001). RDI of this vitamin is 1–3 mg (Demirci, 2006) but requirement of B2 varies according to daily calorie intake needs 0.55 mg B2 (Sencer, 1983). This means that *P. ostreatus* is better source than *L. edodes* and *P. sajor-caju* and can have nutritive importance for B2 requirement.

Niacin is Pellagra Preventive factor and RDI of this vitamin is 6.6 mg for each 1000 calorie intake daily or 15–20 mg (Sencer, 1983; Demirci, 2006). In the study there was a negative correlation for the niacin level among the four flush terms. It tended to decrease from the first flush to the fourth flush term (3.23–1.95 mg/100 g wb). The mean of the niacin values of *L. edodes* mushrooms was 2.71 mg/100 g wb. Shiitake should be good source of niacin. Breene (1990) established the niacin value of *L. edodes* and *P. ostreatus* as 2.6 and 5.2 mg/100 g wb, respectively. Investigated values of mushrooms are reported in Table 2. These species are suitable for niacin requirement for nutrition.

In Table 3 the nutritive minerals of investigated exotic mushrooms are reported for evaluations from the point of nutrition. Zn content of *L. edodes* was the highest 11.55 mg/kg wb in second flush term, but after this stage, it tent to decrease until last flush term. Mean Zn value of *L. edodes* mushrooms was 10.18 mg/100 g wb Kikuchi et al. (1984) found that Zn content to be 4.22–7.70 μg/g wb. The determined value of Zn was higher amount than in the literature. It can be estimated that nutrient contents can vary according to the prepared compost composition (Patrabansh & Madan, 1999). Zn of *Pleurotus* species were 9.31 and 11.18 mg/kg wb. Kikuchi et al. (1984) found Zn content among the 12.0 and 18.4 μg/g wb. In the current research, Zn values of *Pleurotus* species were similar with the literature values. RDI of Zn is 15 mg for adults and 3–5 mg for babies (Sencer, 1983). These mushrooms can contribute to human nutrition as a good source of Zn.

The amount of Fe *L. edodes* ranged from 3.98 to 7.22 mg/kg wb. The highest value was obtained in the first flush term (7.22 mg/kg wb). The mean of the Fe value of mushrooms of *L. edodes* was 5.76 mg/kg. Fe contents of *Pleurotus* species were 7.94–14.80 mg/kg wb, respectively. *P. ostreatus* had the highest Fe value. Kikuchi et al. (1984) established Fe values of Shiitake and Oyster (Hiratake) mushrooms (mg/kg wb) in range of 5.5–13.4 and 9.6–12.3, respectively. Fe contents of mushrooms were law like vegetables. The obtained Fe levels in the present study were generally in accordance with the values reported by Kikuchi et al. (1984).

P contents of *L. edodes* ranged from 700.61 to 986.67 mg/kg wb. There was no positive or negative correlation among the flush terms. P contents of *P. ostreatus* and *P. sajor-caju* were 998.47 and 716.31 mg/kg wb. Mean P values of *L. edodes* were 850.54 mg/kg. These exotic mushrooms can contribute to human nutrition for P intake, since recommended daily intake of P is 0.7 g (Demirci, 2006).

Ca levels of *L. edodes* in four terms were variable. The contents of calcium in four flush terms of *L. edodes* ranged from 25.37 to 116.40 mg/kg wb. Ca levels of *Pleurotus* species were 81.16 and 23.66 mg/kg, respectively (Table 3). Ca levels of studied mushrooms were insufficient for nutrition. The Ca contents determined in this research were generally in accordance with the previous studies (Kikuchi et al., 1984; Manzi et al., 1999; Mattila et al., 2001).

The Mg contents of *L. edodes* exhibited negative correlation into four flush terms. Mg content to decrease in four different stages from 328.13 to 128.77 mg/kg wb. There were differences in quantities of Mg in the first and the fourth flush terms. Mg of *Pleurotus* species are established as follows: 221.9 and 157.67 mg/kg wb. Studied Mg levels of Shiitake and Oyster mushrooms were similar with the literature Kikuchi et al. (1984), Manzi et al. (1999) and Mattila et al. (2001). Mg contents of these mushrooms have nutritive value for human health.

Table 3
Mineral contents of *L. edodes*, *P. ostreatus* and *P. sajor-caju* (mg/kg wb)

Mushrooms	Zn	Fe	P	Ca	Mg	K	Na
L. edodes flush I	10.44 ± 0.13c	7.22 ± 0.03d	986.67 ± 1.20d	116.4 ± 0.10d	328.13 ± 1.80d	1619.33 ± 2.82a	435.43 ± 0.66a
L. edodes flush II	11.55 ± 0.11d	3.98 ± 0.00a	799.07 ± 72.85b	25.37 ± 1.13a	161.78 ± 0.41c	2719 ± 34.77cd	853.80 ± 29.39d
L. edodes flush III	9.81 ± 0.08b	5.86 ± 0.01c	915.82 ± 0.57c	60.71 ± 0.16c	148.87 ± 0.21b	2716 ± 7.00cd	539.67 ± 1.85b
L. edodes flush IV	8.91 ± 0.05a	5.69 ± 0.21b	700.61 ± 15.68a	55.99 ± 0.25b	128.77 ± 0.31a	2338.67 ± 468.54b	677.37 ± 2.91c
P. ostreatus	11.18 ± 0.02	14.80 ± 0.03	998.47 ± 16.08	81.16 ± 0.51	221.9 ± 0.95	2225.00 ± 4.58	773.67 ± 0.57
P. sajor-caju	9.31 ± 0.04	7.94 ± 0.12	716.31 ± 14.00	23.66 ± 0.02	157.67 ± 0.47	2687 ± 1.00	750.77 ± 1.15

Data explain analyses of triplicates ± standard deviation. *F*-test was applied since variances of the Zn, Fe and Mg were homogeny ($P > 0.05$), the variances of the P, Ca, K and Na niacin were not homogeny ($P < 0.05$), Welch statistic were analyzed for them. The mean difference is significant at the $P < 0.05$ level.

Table 4
Volatiles of exotic mushrooms are determined by GS–MS library catalog estimation

Estimated main volatile compounds *of L. edodes* and *Pleurotus* species obtained by comparing GS–MS library catalog					
Volatiles of *L. edodes*	%[a]	Volatiles of *Pleurotus ostreatus*	%[a]	Volatiles of *P. sajor-caju*	%[a]
DL-limonene	5.28	1-Dodecanal-lauraldehyde	1.97	2,5-Dimethyloctane	12.10
Hexadecanoic acid–palmitic acid	47.13	1,2-Di(choloroacetoxy) octane	2.56	4-Ethyloctane	3.68
Octadecenoic acid, 2-propyl ester	6.05	Octadecanoic acid	1.74	*N*-octan-3-ol	3.19
9-Octadecenoic acid	16.41	Nonadecanoic acid	26.28	2-Methoxythiozole	3.44
Cyclohexane, 1-((1,5-dimethyl)hexyl)-4-(4-methylpenthyl)	3.01	2-Nitrocyclooctanone	5.58	Hexadecanoic acid–palmitic acid	31.61
2-Bromo-6-ethylnapthalene	2.75	9,12-Octadecadien-1-ol	24.64	3,4-Dimethyldecane	4.01
Octadecanoic acid, octadecyl ester	3.99	*Cis*-Linoleic acid methyl ester	13.11	Octadecanoic acid	6.12
1,2-Benzenedicarboxylic acid	10.69	Akuammilan-17-ol	2.04	9-Hexadecenoic acid, 9-hexadecenyl ester	9.37
Eicosamethylcyclodecasiloxane	4.69	Hexadecadienoic acid, methyl ester	5.66	9-Dodecenol	4.32
				Palmitic acid, (2-tetradecyloxy)ethyl ester	14.92
				9-Octadecanoic acid–octadecyl ester	5.59

[a] % Area of volatile compounds in the chromatogram.

K and Na contents of *L. edodes* tent to increase after the first flush stage. Average levels of K and Na of *L. edodes* were 2348.24 and 757.32 mg/kg wb. K and Na levels of *P. ostreatus* and *P. sajor-caju* were (2225.0 and 750.8 mg/kg wb); (2687.0 and 773.67 mg/kg wb), respectively (Table 3). *Pleurotus ostreatus* had the highest value of K, but values of Na were almost same in all of the investigated samples. There is a good balance between high content of K and law content of Na because of curing the high blood pressure. The results of K and Na are usually in accordance with the published researches Kikuchi et al. (1984), Manzi et al. (1999) and Mattila et al. (2001).

Estimated aroma volatiles of mushrooms are reported in Table 4. In this study, volatiles of mushrooms were determined as estimated approach by the comparing gas chromatography and mass spectrophotometer library catalog (GS–MS).

In the nutrition, one of the most important consumer acceptances is the flavor of the foods (Altuğ et al., 2000). Mushrooms contain typical volatile of aroma compounds. The most important components are terpenes including hydrocarbons formed from isoprene unit, open chain, closed chain, cyclic, saturated and unsaturated fatty acids (Jong & Birmingan, 1993). In this research, volatiles of mushrooms estimated by the comparing library catalog of GS–MS (Table 4). We estimated the most of abundant volatile compounds and their % area of mushrooms in the chromatogram were as follows: first flush of flavor or aroma volatiles of *L. edodes* were *hexadecanoic* acid–palmitic acid 47.13%, 10.09%; octadecanoic acid 16.41%; 1,2 benzendicarboxylic acid 10.69; octadecanoic acid 2-propyl ester 6.05%; DL-limonene 5.28%. The highest quantities of the *P. ostreatus* volatiles were nonadecanoic acid 26.28%, 9,12-octadecadien-1-ol 24.64%; *cis*-linoleic acid methyl ester 13.11%; 2-nitrcyclooctanone 5.58% and hexadecadienoic acid, methyl ester 5.66%. The esters can be synthesized by mushrooms (Jong & Birmingan, 1993): hexadecanoic acid–palmitic acid 31.61%; palmitic acid, (2-tetradecyloxy)ethyl ester 14.92%; 2,5-dimethyloctane 12.10%; 9-hexadecenoic acid, 9-hexadecenyl ester 9.37%; 9-octadecanoic acid 6.12%; octadecanioc acid–octadecyl ester 5.59% and *N*-octan-3-ol 3.19% were estimated as volatile compounds of *P. sajor-caju* in these quantities.

On the other hand, there were also typical aroma volatiles of mushrooms like DL-limonene and 1,2-benzenedicarboxylic acid and also determined that the most important aroma components were a series of eight carbon atoms similar with the literature (Mau, Chyau, Li, & Tseng, 1997). However, the flavors of mushrooms were affected by compositions of growth medium, growth conditions, and genetic variation (Jong & Birmingan, 1993). Reported results could be influenced by some ecological and genetic factors of mushrooms.

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