J. Verbr. Lebensm. (2014) 9:111–120
DOI 10.1007/s00003-014-0861-4

Journal für Verbraucherschutz und Lebensmittelsicherheit
Journal of Consumer Protection and Food Safety

RESEARCH ARTICLE

Evaluation of nutritional and nutraceutical potentials of three wild edible mushrooms from Similipal Biosphere Reserve, Odisha, India

Sameer Kumar Singdevsachan · Jayanta Kumar Patra · Kumanand Tayung · Kadambini Sarangi · Hrudayanath Thatoi

Received: 1 July 2013 / Accepted: 27 December 2013 / Published online: 4 February 2014

Abstract A variety of edible mushrooms are growing in Similipal Biosphere Reserve (SBR), some of which are used as ethno-medicine by indigenous tribals. In the present study, three wild edible mushrooms viz., *Russula vesca*, *Russula delica* and *Termitomyces eurrhizus* of SBR were analyzed for their nutritional and mineral contents along with antioxidant and antibacterial potential. The results showed that these three mushrooms are rich sources of nutrients (protein, carbohydrate, starch, reducing sugars and low fats), micronutrients (vitamins and carotenoids) and minerals (P, K, Mn, Co, Ni, Cd, Fe) with promising bioactive properties (antioxidant and antibacterial potentials). In general, these mushrooms revealed high amounts of proteins (22.82–35.17 g/100 g) and carbohydrates (45.68–63.27 g/100 g) and low contents in fats (2.03–4.62 g/100 g), while micronutrients (vitamins and carotenoids) and minerals were present in significant amounts. The antioxidant potentials of three different solvent extracts (ethanol, methanol and aqueous) of studied wild mushrooms showed strong antioxidant properties (ABTS, DPPH, H_2O_2 and metal chelating activities) with scavenging potential up to 89 % at concentration 100 μg/ml. Total phenol content was found between 21.92–41.99 mg catechol/g extract and flavonoid 2.53–7.52 mg quercetin/g extract. The studied mushrooms possess moderate antibacterial properties with zones of inhibition ranging from 13 to 30 mm against six human pathogenic bacteria which are comparable with Amphoxyllin standard. Being a source of nutrients and molecules with medicinal potential, the studied mushrooms can be used in human diet as nutraceuticals/functional foods for maintaining and promoting health, longevity and life quality.

Keywords Wild mushrooms · Nutrient composition · Vitamins · Minerals · Antioxidant activity · Antibacterial activity

1 Introduction

Wild mushrooms are valuable non-timber forest resources and their use has been documented in many countries around the world (Jones and Whalley 1994; Garibay-Orijel et al. 2006). They are sold in traditional markets or commercially exploited as food or medicines. Mushrooms grown in the wild have been found to be nutritious and medicinally important (Barros et al. 2008; Kalac 2009). Mushrooms are also demanding because of their toughness, meaty taste, desirable flavor and medicinal values. The consumption of wild edible mushrooms is increasing in the developed countries, for being a rich source of proteins as well as other nutrients and minerals such as amino acids,

Electronic supplementary material The online version of this article (doi:10.1007/s00003-014-0861-4) contains supplementary material, which is available to authorized users.

S. K. Singdevsachan · J. K. Patra · H. Thatoi (✉)
Department of Biotechnology, College of Engineering and Technology, Biju Patnaik University of Technology, Bhubaneswar, Odisha 751 003, India
e-mail: hn_thatoi@rediffmail.com

K. Tayung
Department of Botany, North Orissa University, Baripada, Mayurbhanj, Odisha 757 003, India

K. Sarangi
Department of Hydrometallurgy, Institute of Minerals and Materials Technology, Bhubaneswar, Odisha 751 013, India

sugar, vitamins with low fat and cholesterol content (Barros et al. 2008; Kalac 2009). Mushrooms are one of the natural sources of vitamin D (Mattila et al. 1994), which is essential for healthy bones and teeth. They are also a good source of the B vitamins; riboflavin (B2), niacin (B3) and pantothenic acid (B5) (Kalac 2009; Caglarlrmak et al. 2002). These vitamins help break down proteins, fats and carbohydrates so they can be used for energy. Mushrooms are not only sources of nutrients but also have been reported as therapeutic foods, useful in preventing diseases such as hypertension, hypercholesterolemia and cancer (Bobek and Galbavy 1999; Kidd 2000). These functional characteristics are mainly due to the presence of dietary fiber such as chitin and beta glucans (Kidd 2000; Lindequist et al. 2005). Recently, a number of bioactive molecules have been identified from various mushrooms which are known for their antibacterial, antioxidant, antitumor, antiviral, and immunomodulating properties (Lindequist et al. 2005; Rai et al. 2005). The bioactive compounds of mushrooms include phenolics, flavonoids, glycosides, alkaloids, carotenoids, ascorbic acid, tocopherols, folates, proteins, polysaccharides, volatile oils, organic aids etc. These molecules were quantified in many different species mainly from Finland, India, Korea, Poland, Portugal, Taiwan and Turkey (Ferreira et al. 2010). Other important phytochemicals have been isolated from medicinal mushrooms and developed as cytostatic polysaccharide drugs in Japan. These are "Krestin" (PSK) from the cultured mycelium of Kawaratake (*Trametes versicolor*), "Lentinan" from the fruiting bodies of Shiitake (*Lentinus edodes*) and "Schizophyllan" (Sonifilan) from the culture fluid of Suehirotake (*Schizophyllum commune*) (Mizuno 1993). Lentinan and Schizophyllan are pure β-glucans, whereas PSK is a protein bound polysaccharide (Larone 2002). The biological activity of these three products is related to their immunomodulating properties, which enhance the body's defences against various forms of infectious disease. However, wild mushrooms are popular and favorite all over the world for their characteristics flavor as well as for nutritional and functional properties. For instance, many people collect wild edible mushrooms from forest for substantially contributing to food intake and also for ethno-medicinal purposes.

Similipal Biosphere Reserve (SBR) in Odisha, India is one of the tropical forest ecosystems rich in diversity of flora and fauna including mushrooms. Wild mushrooms are a popular food source among the tribes of SBR. This region is a high rainfall area with dense forest. The high humidity level during the monsoon season (June–October) provides ideal atmospheric conditions for the growth of many saprophytes, including the mushrooms. Several wild mushrooms growing in the forests of SBR are frequently consumed by the tribals/local people. Mushrooms are picked up from the forest and they form an integral part of diet during the monsoon season when these are abundantly available. In spite of immense popularity of this food in the region, data are not available till date regarding nutritional and medicinal value of these wild mushroom varieties available in SBR. Thus the objective of present study was to determine the nutrients composition and nutraceuticals potential (antioxidant and antibacterial activities) of three selected wild edible mushrooms viz., *Russula vesca* Fr., *Russula delica* Fr., *Termitomyces eurrhizus* (Berk.) Heim. from SBR along with their mineral compositions.

2 Results

Three collected wild edible mushrooms (*Russula vesca*, *Russula delica* and *Termitomyces eurrhizus*) from the forest soil of Similipal Biosphere Reserve were found non toxic. The results of macronutrient composition and energetic value of three wild edible mushrooms are given in Table 1. The moisture content of all mushrooms ranged from 7 g/100 g dw in *Termitomyces eurrhizus* to 15 g/100 g fw in *Russula delica*. Crude protein contents were found to be high levels and varied between 22.83 g/100 g dw in *Termitomyces eurrhizus* and 35 g/100 g dw in *Russula vesca*. The amount of free amino acids in the mushrooms ranged from 2.81 g/100 g dw in *Russula delica* to 6.26 g/100 g dw in *Termitomyces eurrhizus.* Crude fat values ranged from 2.03 g/100 g dw in *Russula vesca* to 4.62 g/100 g dw in *Termitomyces eurrhizus*, making ideal to be included in low caloric diets. Total carbohydrate contents of mushrooms was calculated by discounting protein and fat levels, were the most abundant macronutrient which ranged from 46 g/100 g dw in *Russula delica* to 63 g/100 g dw in *Termitomyces eurrhizus.* Starch is an important polysaccharide of carbohydrate in wild mushrooms which ranged between 8.09 g/100 g dw in *Termitomyces eurrhizus* to 12.35 g/100 g dw in *Russula vesca.* Reducing sugars were only a small part of carbohydrate, found between 1.17 g/100 g dw in *Russula delica* and 2.37 g/100 g dw in *Russula vesca*. Ash content of the mushrooms varied from 14.31 g/100 g dw in *Russula vesca* to 36.04 g/100 g dw in *Termitomyces eurrhizus.* On the basis of proximate analysis, it was observed that 100 g dw of these wild mushrooms contained highest value of energy in *Russula vesca* (394 kcal) and lowest energy in *Russula*

Table 1 Macronutrient composition of three wild edible mushrooms

Mushrooms	Moisture (%)	Protein (g/100 g)	Total free amino acid (g/100 g)	Fat (g/100 g)	Carbohydrate (g/100 g)	Starch (g/100 g)	Reducing sugar (g/100 g)	Ash (g/100 g)	Energy (kcal/100 g)
Russula vesca	14 ± 2^{a}	35 ± 1^{a}	4.60 ± 0.25^{b}	2.03 ± 0.03^{c}	59 ± 2^{b}	12.35 ± 0.32^{a}	2.37 ± 0.04^{a}	20.13 ± 0.12^{b}	394 ± 9^{a}
Russula delica	15 ± 2^{a}	28.28 ± 0.24^{b}	2.81 ± 0.12^{c}	2.84 ± 0.03^{b}	46 ± 2^{c}	8.64 ± 0.30^{b}	1.17 ± 0.01^{c}	14.31 ± 0.34^{c}	322 ± 6^{b}
Termitomyces eurrhizus	7 ± 1^{b}	22.83 ± 0.03^{c}	6.26 ± 0.07^{a}	4.62 ± 0.03^{a}	63 ± 2^{a}	8.09 ± 0.10^{b}	1.63 ± 0.02^{b}	36.04 ± 0.23^{a}	386 ± 7^{a}

Results of the macronutrients are expressed in dry weight (dw) basis with the average of triplicate samples with mean ± SD ($n = 3$); Any means in the same column followed by the different superscripts are significantly different ($p < 0.05$) by Duncan's multiple range test

delica (322 kcal). Micronutrients such as vitamins and carotenoids content were also determined and the results are presented in Table 2. The thiamine contents in mushrooms varied between 0.17 mg/g dw in *Russula delica* to 0.96 mg/g dw in *Russula vesca*. Riboflavin was not found in *Termitomyces eurrhizus.* Among other two mushrooms, *Russula delica* contained highest riboflavin (0.13 mg/g dw) than that of *Russula vesca* (0.11 mg/g dw). Ascorbic acid was found most abundantly in all three wild mushrooms. The highest level of ascorbic acid was found in *Termitomyces eurrhizus* (24.66 mg/g dw) and the lowest value was found in *Russula delica* (6.97 mg/g dw). Carotenoids were found in lower amounts; the highest levels of β-carotene and lycopene were observed in *Termitomyces eurrhizus* (2.24 μg/g dw) and *Russula vesca* (1.2 μg/g dw), respectively than that of other wild mushrooms.

The results of mineral contents such as phosphorus, potassium, manganese, cobalt, nickel, cadmium and iron in wild edible mushrooms are presented in Table 3. The phosphorus content in wild edible mushrooms ranged from 0.47 g/100 gm dw in *Russula delica* to 1.65 g/100 gm in *Termitomyces eurrhizus.* The highest potassium content was present in *Russula vesca* (1.8 g/100 g dw) and *Termitomyces eurrhizus* showed lower quantity of potassium (0.81 g/100 gm). The mean heavy metal concentrations across all the mushrooms species were in the order Fe > Mn > Ni > Co > Cd. The iron concentration ranged from 2.78 mg/kg dw in *Russula delica* to 15.6 mg/kg dw in *Termitomyces eurrhizus.* The highest level of manganese and cobalt was detected in *Termitomyces eurrhizus* (0.406 and 0.008 mg/kg dw, respectively) compared to the other mushrooms whereas cadmium was not detected in all the three wild mushrooms tested. The relationship between various minerals were correlated statistically and presented in Table 4. The results showed that there is a strong linear and positive correlation between the phosphorus with manganese and iron content ($r = 0.918$ and 0.975, respectively) and manganese with iron content ($r = 0.965$) in all the three wild mushrooms (Table 4). There is also strong negative correlation between phosphorous and potassium ($r = -0.884$) and potassium with manganese ($r = -0.991$) and iron content ($r = -0.954$) (Table 4).

The percentage yields of three different extracts (ethanol, methanol and aqueous) of the studied mushrooms ranged from 11.7 to 17.3 % of the dry weight (data not shown). The percentage yield of extracts from *Russula vesca* were found to be 14.3, 13.5 and 16.4 %, yield of extracts of *Russula delica* were 15.5, 11.3 and 17 % and yield of extracts of

Table 2 Micronutrient composition of three wild edible mushrooms

Mushrooms	Thiamine (mg/g)	Riboflavin (mg/g)	Ascorbic acid (mg/g)	β-Carotene (μg/g)	Lycopene (μg/g)
Russula vesca	0.96 ± 0.04[a]	0.11 ± 0.01[a]	7.84 ± 0.06[b]	1.44 ± 0.01[b]	1.20 ± 0.52[a]
Russula delica	0.17 ± 0.01[b]	0.13 ± 0.01[a]	6.97 ± 0.08[c]	1.36 ± 0.01[c]	0.22 ± 0.01[c]
Termitomyces eurrhizus	0.74 ± 0.05[a]	0.00 ± 0.01[a]	24.66 ± 0.40[a]	2.24 ± 0.10[a]	0.74 ± 0.01[b]

Results are expressed in dry weight (dw) basis with the average of triplicate samples with mean ± SD ($n = 3$); Any means in the same column followed by the different superscripts are significantly different ($p < 0.05$) by Duncan's multiple range test

Table 3 Mineral contents of three wild edible mushrooms

Mushrooms	Phosphorus (P)	Potassium (K)	Manganese (Mn)	Cobalt (Co)	Nickel (Ni)	Cadmium (Cd)	Iron (Fe)
Russula vesca	0.81 ± 0.01[b]	1.80 ± 0.02[a]	0.155 ± 0.00[c]	0.007 ± 0.01[a]	0.056 ± 0.01[b]	0.0	4.24 ± 0.01[b]
Russula delica	0.47 ± 0.02[c]	1.60 ± 0.10[b]	0.180 ± 0.00[b]	0.007 ± 0.01[a]	0.079 ± 0.01[a]	0.0	2.78 ± 1.73[b]
Termitomyces eurrhizus	1.65 ± 0.05[a]	0.81 ± 0.01[c]	0.406 ± 0.00[a]	0.008 ± 0.01[a]	0.062 ± 0.01[b]	0.0	15.60 ± 0.03[a]

Results are expressed in dry weight (dw) basis with the average of triplicate samples with mean ± SD ($n = 3$) P and K in g/100 gm and rest of the metals in mg/kg; Any means in the same column followed by the different superscripts are significantly different ($p < 0.05$) by Duncan's multiple range test

Table 4 Correlations between the mineral contents

	P	K	Mn	Co	Ni	Fe
P	1					
K	−0.884**	1				
Mn	0.918**	−0.991**	1			
Co	0.507	−0.451	0.505	1		
Ni	−0.501	0.072	−0.126	−0.119	1	
Fe	0.975**	−0.954**	0.965**	0.491	−0.353	1

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

Termitomyces eurrhizus were 14, 11.7 and 17.3 % in ethanol, methanol and aqueous extracts, respectively. The composition of non-nutrients and in vitro antioxidant activity (scavenging potential) in the studied wild mushrooms are presented in Table 5 and Figs. 1, 2, 3, 4. The phenolic content in all the three studied wild mushrooms varied from 21.92 to 41.99 mg/g dw in three different extracts (ethanol, methanol and aqueous). Among the three extracts of mushrooms, the methanol extract of *Termitomyces eurrhizus* showed highest phenolic content (41.99 mg/g dw) whereas ethanol extract of *Russula vesca* showed lowest quantity (21.92 mg/g dw) (Table 5). The flavonoid content of studied wild mushrooms was found to be very less as compared to phenolic content. The flavonoid content of wild mushrooms ranged from 2.53 to 7.52 mg/g dw in three different extracts. Among the three wild mushrooms, *Russula delica* showed the highest amount of flavonoid (7.52 mg/g dw) in ethanol extracts whereas *Russula vesca* showed the lowest value (2.53 mg/g dw) in aqueous extract. Further, total antioxidant capacities of studied wild mushrooms were found in higher amount as compared to phenol and flavonoid. Total antioxidant capacity of *Russula vesca* ranged from 44.48 mg/g dw in ethanol extract to 48.18 mg/g dw in methanol extract. Total antioxidant capacity of *Russula delica* varied between 52.45 mg/g dw in ethanol extract to 56.44 mg/g dw in aqueous extract. In case of *Termitomyces eurrhizus*, the total antioxidant capacity was found to be highest in aqueous extract (47.21 mg/g dw) and lowest value was found in ethanol extract (40.30 mg/g dw).

The results of antioxidant properties of all these three wild mushrooms were presented in Figs. 1, 2, 3, 4. The ABTS free radical scavenging activity of the ethanol and aqueous extract from *Termitomyces eurrhizus* showed significantly high activity (27.29 and 63.37 %) among the studied mushrooms at a concentration 100 μg/ml whereas methanol extract of *Russula delica* showed significantly high scavenging activity (39.10 %) at a concentration 100 μg/ml which is comparable with the standard BHT (Fig. 1).

The DPPH radical scavenging activities of all the three extracts (ethanol, methanol and aqueous) from studied mushroom species with standard BHT are given in Fig. 2. In the DPPH radical scavenging assay, all these three extracts (ethanol, methanol and aqueous) from *Termitomyces eurrhizus* showed significantly high activity (12.89, 29.24 and 16.75 %,

Table 5 Non-nutrient composition and in vitro antioxidant properties of three wild edible mushrooms

Mushrooms	Mushroom extracts	Total Phenol (mg/g)	Flavonoid (mg/g)	Total antioxidant capacity (mg/g)
Russula vesca	Ethanol	21.92 ± 0.65^{e}	3.00 ± 0.20^{yz}	44.48 ± 0.50^{p}
	Methanol	28.44 ± 0.48^{c}	3.70 ± 0.64^{x}	48.18 ± 0.27^{o}
	Aqueous	30.90 ± 1.15^{c}	2.53 ± 0.43^{z}	46.80 ± 0.22^{o}
Russula delica	Ethanol	23.33 ± 0.29^{de}	7.52 ± 0.50^{u}	52.45 ± 0.50^{n}
	Methanol	25.50 ± 0.55^{d}	7.40 ± 0.64^{u}	55.69 ± 0.63^{m}
	Aqueous	26.11 ± 0.29^{d}	6.56 ± 0.38^{v}	56.44 ± 0.50^{m}
Termitomyces eurrhizus	Ethanol	35.49 ± 0.64^{b}	4.50 ± 0.50^{x}	40.30 ± 0.32^{q}
	Methanol	41.99 ± 0.81^{a}	5.55 ± 1.11^{w}	45.63 ± 1.13^{p}
	Aqueous	37.99 ± 0.13^{b}	3.56 ± 0.40^{y}	47.21 ± 1.06^{o}

Results are expressed in dry weight (dw) basis with the average of triplicate samples with mean ± SD ($n = 3$); Any means in the same column followed by the different superscripts are significantly different ($p < 0.05$) by Duncan's multiple range test

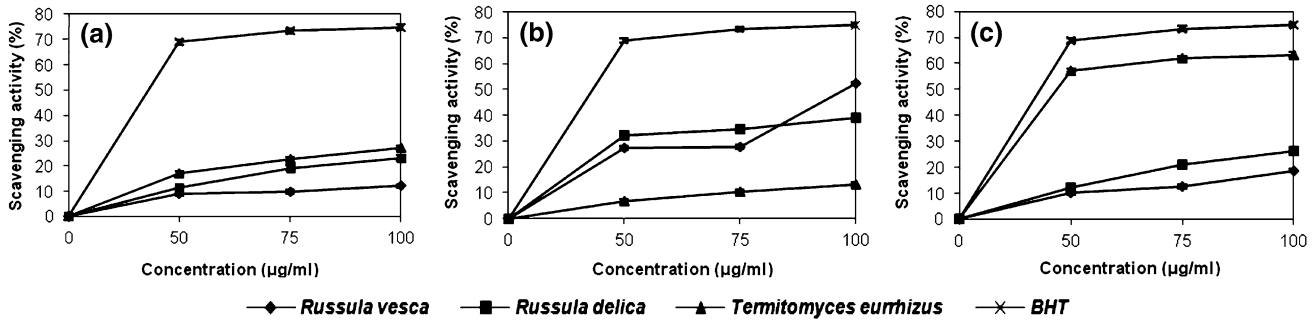

Fig. 1 ABTS free radical scavenging activities of ethanol (**a**), methanol (**b**) and aqueous extract (**c**) from three different wild mushrooms

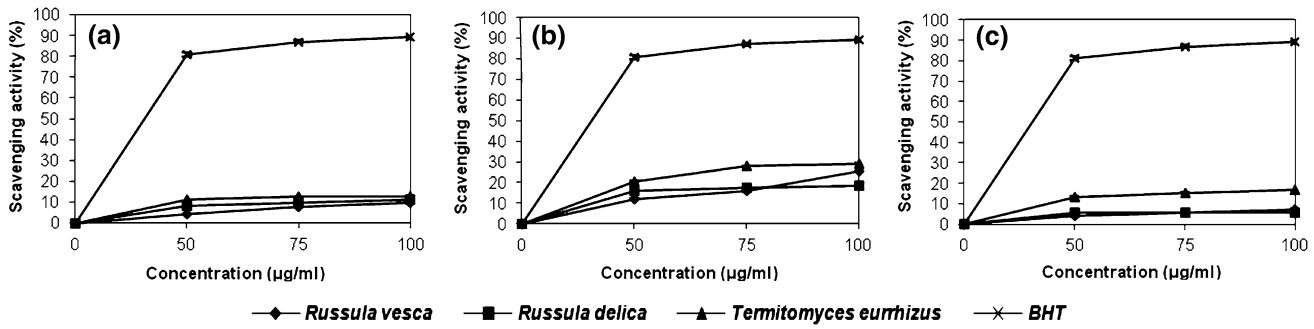

Fig. 2 DPPH free radical scavenging activities of ethanol (**a**), methanol (**b**) and aqueous extract (**c**) from three different wild mushrooms

respectively) than the other two studied mushrooms (*Russula vesca* and *Russula delica*) at a concentration 100 µg/ml which is less comparable with standard BHT (Fig. 2).

The results of H_2O_2 free radical scavenging activity of wild mushrooms compared with that of BHT are presented in Fig. 3. In the H_2O_2 free radical scavenging assay, ethanol and aqueous extract of *Termitomyces eurrhizus* showed high H_2O_2 free radical scavenging activity (13.99 and 12.27 %, respectively) than the other studied mushrooms at concentration 100 µg/ml whereas methanol extract of *Russula delica* showed significantly high scavenging activity (12.07, 21.22 and 28.48 %) at three different concentration 50, 75 and 100 µg/ml, respectively which is comparable with standard BHT (Fig. 3).

The metal chelating activity of three different extracts (ethanol, methanol and aqueous) from wild mushrooms with BHT as standard are presented in Fig. 4. In comparison with BHT, the ethanol extract of *Russula delica* revealed the highest metal chelating

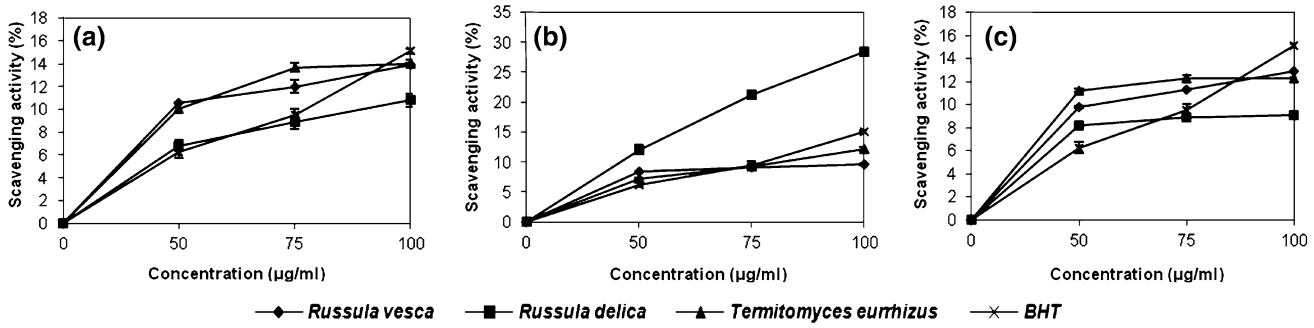

Fig. 3 H_2O_2 radical scavenging activities of ethanol (**a**), methanol (**b**) and aqueous extract (**c**) from three different wild mushrooms

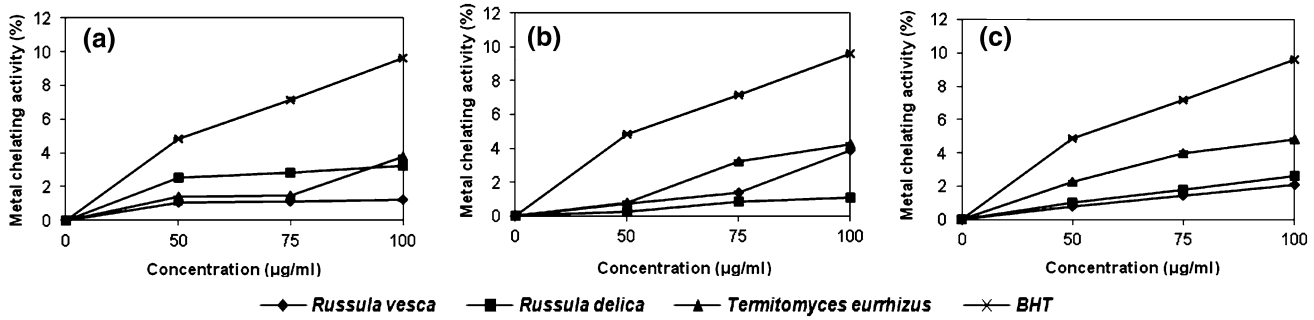

Fig. 4 Metal chelating activities of ethanol (**a**), methanol (**b**) and aqueous extract (**c**) from three different wild mushrooms

ability (3.26 %) at concentration 100 µg/ml whereas methanol and aqueous extract of *Termitomyces eurrhizus* showed high chelating ability (4.16 and 4.78 %, respectively) among the studied mushrooms at concentration 100 µg/ml which is comparable with standard BHT (Fig. 4). The results of antibacterial activity in different crude extracts of wild mushrooms against six human pathogenic bacterial strains are presented in Table 6. All the three extracts (ethanol, methanol and aqueous) of *Russula vesca* showed highest antibacterial activity (inhibition zone in mm) against *Escherichia coli* (26–29.01 mm) and *Staphylococcus aureus* (23.07–27.16 mm) than the other two wild mushrooms (*Russula delica* and *Termitomyces eurrhizus*) (Table 6). The results of antibacterial activity depended largely upon the mushroom species, solvent used for extraction and the organisms tested.

3 Discussion

Mushrooms are widely appreciated food due to their unique taste and flavor, but also for their chemical and nutritional properties (Kalac 2009). Dry matter/moisture content is an important factor during the nutritional evaluation of mushrooms, which directly affects the nutrient content of mushrooms (Mattila et al. 2002). Present moisture contents in mushrooms of Similipal Biosphere Reserve (SBR) are in agreement with earlier published data, which state that fresh mushroom contained 70–96 % moisture (Agrahar-Murugkar and Subbuakshmi 2005; Grangeia et al. 2011; Pereira et al. 2012). However, variability of moisture content (70–96 %) is dependent on the mushroom species and other parameters such as environmental temperature, relative humidity during growth and relative amount of metabolic water that may be produced or utilized during storage (Crisan and Sands 1978). The studied species of mushrooms from SBR have high proteins and carbohydrate contents, in contrast to low fat levels, which make them suitable to incorporate into low calorie diets. Energetic contributions in wild mushrooms of SBR differ from species to species due to their nutrition contents. Despite the above nutritional values, *Termitomyces eurrhizus* also contained higher amount of ash as compared to other two mushrooms (*Russula vesca* and *Russula delica*). The findings of the present study are in agreement with different studies reported by several authors (Agrahar-Murugkar and Subbuakshmi 2005; Grangeia et al. 2011; Pereira et al. 2012). It is well known that free amino acids, especially highly basic amino acid and glutamic acid contribute to the flavor properties of mushrooms (Sugahara et al. 1975; Maga 1981) thus high levels of free amino acids in *Termitomyces*

Table 6 Antibacterial activity (inhibition zone in millimeter) of mushroom extracts

Pathogenic Strains	*Russula vesca*			*Russula delica*			*Termitomyces eurrhizus*			*Amphoxyllin* (35 µg/disc)
	Ethanol extract	Methanol extract	Aqueous extract	Ethanol extract	Methanol extract	Aqueous extract	Ethanol extract	Methanol extract	Aqueous extract	
Staphylococcus aureus	26.18 ± 2.00	27.16 ± 0.14	23.07 ± 1.05	14.34 ± 0.58	15.00 ± 1.00	13.0 ± 0.00	NR	NR	NR	13.0 ± 0.35
Bacillus brevis	24.0 ± 0.00	24.02 ± 1.98	13.48 ± 0.50	NR	NR	NR	13.05 ± 0.04	NR	12.33 ± 0.57	40.0 ± 1.0
Vibrio cholerae	NR	NR	NR	14.37 ± 0.11	12.13 ± 1.90	14.24 ± 1.77	13.49 ± 1.07	14.54 ± 1.90	12.00 ± 0.00	0.0 ± 0 0.00
Bacillus subtilis	NR	NR	NR	21.33 ± 0.30	22.43 ± 0.51	30.86 ± 1.27	NR	NR	NR	0.0 ± 0.00
Escherichia coli	34.29 ± 1.95	29.01 ± 0.01	26.00 ± 0.00	NR	NR	NR	NR	NR	NR	10.0 ± 1.0

Results were expressed as the average of triplicate samples with mean ± SD ($n = 3$)

NR no result

eurrhizus and *Russula vesca* probably contribute most to their characteristics flavor which was evaluated in our study. However, the mineral contents of wild mushrooms were in relatively lower quantity compared to earlier published report (Sugahara et al. 1975; Maga 1981; Ouzouni et al. 2009). This may be due to geographic location and environmental factors of SBR.

Besides macronutrients and minerals, studied wild mushrooms have also important micronutrients such as vitamins, carotenoids and non-nutrients (e.g. phenol and flavonoids) with bioactive properties such as antioxidant and antibacterial potential, which are in agreement with other reports concerning vitamins (thiamine, riboflavin and ascorbic acid), carotenoids (β-carotene and lycopene) and non nutrients (phenol and flavonoids) quantification in different mushrooms (Singdevsachan et al. 2013; Barros et al. 2007). However, some authors have already reported a direct correlation between mushrooms antioxidant activity and total phenolic content, although the antioxidant action is raised by other substances such as vitamins and carotenes (Cheung et al. 2003; Barros et al. 2007). In present study we tested whole extracts of total mushrooms, taking advantage of the idea that complex mixture of phytochemicals may have potential additive or synergistic effects (Cheung et al. 2003; Barros et al. 2007). Three different extracting solvents were used in order to obtain low molecular weight compounds such as phenolic antioxidants (ethanol and methanol) and high molecular weight compounds such as polysaccharides (water). The percentage yields of mushroom extracts in studied wild mushrooms are found in moderate quantities whereas mushrooms are reported to contain more polar constituents (Vaskovsky et al. 1998). The group such as phenolic acids, lignans, flavonoids with structures containing –OH and –COOH functional groups are easily extracted by the polar solvent in samples. The discrepancy in the yield from fruiting bodies of the mushrooms might be due to the differences in strains and harvest times (Mau et al. 2005). In fact, the bioactivity of phenolics may be related to their ability to chelate metals, inhibit lipoxygenase and scavenge free radicals (Decker 1997). Flavonoid can act as free radical scavengers and terminate the radical chain reactions that occur during the oxidation of triglycerides in food systems (Roedig-Penman and Gordon 1998). These molecules can also play protective role in diseases related to oxidative stress, such as cancer and cardiovascular diseases (Ferreira et al. 2010). The extracts of the studied mushroom species were

demonstrated with a capacity to scavenge free radicals such as ABTS and DPPH, high inhibition power of HO^- and Fe^{2+} chelating abilities which may be due to the flavonoids.

Free radical scavenging effect has been known as an established phenomenon in inhibiting lipid oxidation, which otherwise can be deleterious to the cellular components and cellular function. Natural antioxidant can be used to replace the synthetic antioxidant in the food industry such as BHT, BHA and TBHQ, which may possess mutagenic activity (Namiki 1990). With the presence of radical scavenging activity, consumption of wild mushrooms might be beneficial to protect human body against oxidative damage, which can be further developed into health related degenerative illnesses. The ABTS free radical scavenging assay is based on the inhibition of the absorbance of the radical cation $ABTS^+$ which has a characteristic long wave length absorbance spectrum (Rice-Evans and Miller 1997). The results imply that all the three extracts (ethanol, methanol and aqueous) of the studied species inhibit or scavenge the $ABTS^+$ radicals in increasing orders with the increasing concentration of extracts (50–100 μg/ml), which supports the earlier findings of several workers on both inhibition and scavenging properties of antioxidant towards $ABTS^+$ radicals (Rice-Evans and Miller 1997; Baskar et al. 2008). The free radical DPPH· possesses a characteristic absorption at 517 nm (purple in color), which decreases significantly on exposure to radical scavengers (by providing hydrogen atoms or by electron donation). A lower absorbance at 517 nm indicates a higher radical scavenging activity of the extract. Free radical scavenging is one of the well known mechanisms by which antioxidants inhibit lipid oxidation. This antioxidant assay offers a rapid technique for screening the radical scavenging activity of specific compound or extracts (Barros et al. 2007). The DPPH radical scavenging activity of studied wild mushrooms with three different extracts (ethanol, methanol and aqueous) were found to be higher and are comparable with the standard BHT which were also reported by several authors in different species of mushrooms (Barros et al. 2007; Pereira et al. 2012). Hydrogen peroxide itself is not very reactive, but it can give highly reactive species HO^- through Fenton reaction (Halliwell 1978). It was suggested that H_2O_2 could induce DNA break in the intact cell and purified DNA (Imlay et al. 1988). Thus, removal of H_2O_2 is crucial for medicinal importance. The H_2O_2 reducing capacity of compound or extract may serve as indicator of its potential antioxidant capacity (Meir et al. 1995). The H_2O_2 reducing capacities of extracts in the studied wild mushrooms were found high as compared to standard BHT. It is an agreement which will be beneficial for human health through consumption of wild mushrooms. In the metal chelating assay, extracts of the mushroom species interfered with the formation of ferrous and ferrozine complex, suggesting that they have chelating activity and capture ferrous ions before ferrozine. Iron stimulates lipid peroxidation by the Fenton reaction and accelerates peroxidation by decomposing lipid hydroperoxides into peroxyl and alkoxyl radicals that can abstract hydrogen and perpetuate the chain reaction of lipid peroxidation (Halliwell 1991). The extracts of wild edible mushrooms in the present study demonstrated a marked capacity for iron binding, suggesting that their action as peroxidation protector may be related to its iron binding capacity. The ethanol, methanol and aqueous extract of *Russula vesca*, *Russula delica* and *Termitomyces eurrhizus*, respectively were found to be better chelators for ferrous ion, since ferrous ions are the most effective pro-antioxidants in food system where the high ferrous ion chelating abilities of extracts from wild edible mushrooms would be beneficial.

Further, antibacterial activity (inhibition zone) in three extracts of studied wild mushroom was tested against six pathogenic bacterial strains in comparison with the standard antibiotic Amphoxyllin. All three extracts of *Russula vesca* showed higher antibacterial activity against studied pathogenic strains than other two mushrooms (*Russula delica* and *Termitomyces eurrhizus*) which is comparable with standard antibiotic Amphoxyllin. The results of antibacterial activity are in agreement with previous report (Yaltirak et al. 2009; Nwachukwu and Uzoeto 2010). Thus, the study could provide valuable information to support wild mushrooms as an excellent source of antioxidants and antibacterial agents in human diet especially to the low-income community or tribal peoples of SBR those are regularly consuming such kind of mushrooms.

4 Conclusion

The studied wild edible mushrooms of Similipal Biosphere Reserve are non-toxic. They contain all the nutrients (high carbohydrate and protein levels with low fat content and toxic metals) which make them ideal food for consumption and no doubt is a good source of nutrients for tribal peoples. Based on their antioxidant potential and bioactive

compounds (vitamins and phenolics), they might have been used in ethno-medicine for curing of free radical related diseases. Besides, these mushrooms also showed antibacterial properties. The present study indicates that the daily intake of these mushrooms could provide a natural dose of antibiotic to fight against common pathogens. Further, as these are a source of nutrient, important antioxidants and antibacterial agents, the wild mushrooms of SBR can be used in the diet as nutraceuticals and/or functional foods maintaining and promoting health, longevity and life quality without any health risk.

Acknowledgments The present work was carried out as part of research work funded by Department of Science and Technology, Government of Odisha (Sanction no. 3066/ST). Thanks are due to The PCCF, Forest Department, Government of Odisha for granting permission for collection of the mushrooms from Similipal Biosphere Reserve. We are grateful to the authorities of College of Engineering and Technology, Buju Patanaik University of Technology, Bhubaneswar, Odisha, India for providing laboratory facilities.

References

Agrahar-Murugkar D, Subbuakshmi G (2005) Nutritional value of edible wild mushrooms collected from the Khasi hills of Meghalaya. Food Chem 89:599–603

AOAC (1990) Official methods of analysis, 15th edn. Association of Official Analytical Chemists, Washington, DC

Barros L, Baptista P, Ferreira ICFR (2007) Effect of *Lactarius piperatus* fruiting body maturity stage on antioxidant activity measured by several biochemical assays. Food Chem Toxicol 45:1731–1737

Barros L, Cruz T, Baptista P, Estevinho LM, Ferreira ICFR (2008) Wild and commercial mushrooms as source of nutrients and nutraceuticals. Food Chem Toxicol 46:2742–2747

Baskar R, Lavanya R, Mayilvizhi S, Rajasekaran P (2008) Free radical scavenging activity of antitumor polysaccharide fraction isolated from *Ganoderma lucidum* (Fr) P Karst. Nat Prod Rad 7:320–325

Bobek P, Galbavy S (1999) Hypocholesterolemic and antiatherogenic effect of Oyster mushroom (*Pleurotus ostreatus*) in rabbit. Nahrung 43:339–342

Caglarlrmak N, Unal K, Otles S (2002) Nutrional value of edible mushrooms collected from the black sea region of Turkey. Micol Apl Int 14:1–5

Cheung LM, Cheung PCK, Ooi VEC (2003) Antioxidant activity and total phenolics of edible mushroom extracts. Food Chem 81:249–255

Crisan EV, Sands A (1978) Nutritional value. In: Chang ST, Hayes WA (eds) The biology and cultivation of edible mushrooms. Academic Press, New York

Decker EA (1997) Phenolics: prooxidants or antioxidants. Nutr Rev 55:396–407

Ferreira ICFR, Vaz JA, Vasconcelos MH, Martins A (2010) Compounds from wild mushrooms with antitumor potential. Anticancer Agents Med Chem 10:424–436

Garibay-Orijel R, Cifuentes J, Estrada-Torres A, Caballero J (2006) People using macro-fungal diversity in Oaxaca, Mexico. Fungal Divers 21:41–67

Grangeia C, Heleno SA, Barros L, Martins A, Ferreira ICFR (2011) Effects of trophism on nutritional and nutraceutical potential of wild edible mushrooms. Food Res Int 44:1029–1035

Halliwell B (1978) Super oxide-dependent formation of hydroxy free radicals in presence of iron chelators. FEBS Lett 92:321–326

Halliwell B (1991) Reactive oxygen species in living systems: source, biochemistry, and role in human disease. Am J Med 91:S14–S22

Imlay JA, Chin SM, Linn S (1988) Toxic DNA damage by hydrogen peroxide through the Fenton reaction in vivo and in vitro. Science 240:640–642

Jones EB, Whalley J (1994) A fungus foray to Chiang Mai market in Northern Thailand. The Mycologist 8:87–90

Kalac P (2009) Chemical composition and nutritional value of European species of wild growing mushrooms: a review. Food Chem 113:9–16

Kidd PM (2000) The use of mushroom glucans and proteoglycans in cancer treatment. Alt Med Rev 5:4–27

Largent DL, Stuntz DE (1977) How to identify mushrooms to genus I: Macroscopic features. Mad River Press, Eureka

Largent DL, Johnson D, Stuntz DE, Watling R (1977) How to identify mushrooms to genus III, Microscopic features. Mad River Press, Eureka

Larone DH (2002) Medically important fungi, 14th edn. Amer Society for Microbiology, USA

Lindequist U, Niedermeyer THJ, Julich WD (2005) The pharmacological potential of mushrooms. eCAM 2:285–299

Maga JA (1981) Mushroom flavor. J Agric Food Chem 29:1–4

Mattila PH, Piironen VI, Uusi -R, Koivistoinen PE (1994) Vitamin D contents in edible mushrooms. J Agric Food Chem 42:2449–2453

Mattila P, Salo-Vaananen P, Konko K, Aro H, Jalava T (2002) Basic composition and amino acid contents of mushrooms cultivated in Finland. J Agric Food Chem 50:6419–6422

Mau J-L, Tsai S-Y, Tseng Y-H, Huang S-J (2005) Antioxidant properties of hot water extracts from *Ganoderma tsugae* Murrill. LWT-Food Sci Technol 38:589–597

Meir S, Kanner J, Akiri B, Hadas SP (1995) Determination and involvement of aqueous reducing compounds in oxidative defense systems of various senescing leaves. J Agric Food Chem 43:1813–1815

Mizuno T (1993) Food function and medicinal effect of mushroom fungi. Foods Ingred J 158:55–70

Namiki M (1990) Antioxidants, antimutagens in food. Crit Rev Food Sci Technol 6:271–277

Nwachukwu E, Uzoeto HO (2010) Antimicrobial activity of some local mushrooms on pathogenic isolates. J Med Plants Res 4:2460–2465

Okwu DE, Josiah C (2006) Evaluation of the chemical composition of two Nigerian medicinal plants. Afr J Biotechnol 5:357–361

Ouzouni PK, Petridis D, Koller WD, Riganakos KA (2009) Nutritional value and metal content of wild mushrooms collected from West Macedonia and Epirus, Greece. Food Chem 115:1575–1580

Pereira E, Barros L, Martins A, Ferreira ICFR (2012) Towards chemical and nutritional inventory of Portuguese wild mushrooms in different habitats. Food Chem 130:394–403

Prieto P, Pineda M, Aguilar M (1999) Spectrophotometric quantitation of antioxidant capacity through the formation of a

phodphomolybdenum complex: specific application to the determination of vitamin E. Anal Biochem 269:337–341
Purkayastha RP, Chandra A (1985) Manual of Indian Edible Mushrooms. Today and Tomorrow's Printers and Publishers, New Delhi
Rai M, Tidke G, Wasser SP (2005) Therapeutic potential of mushrooms. Nat Prod Rad 4:246–257
Rice-Evans C, Miller NJ (1997) Factors influencing the antioxidant activity determined by the $ABTS^{+}$ radical cation. Free Radic Res 26:195–199
Roedig-Penman A, Gordon MH (1998) Antioxidant properties of myricetin and quercetin in oil and emulsions. J Am Oil Chem Soc 75:169–180
Singdevsachan SK, Patra JK, Thatoi HN (2013) Nutritional and bioactive potential of two wild edible mushrooms (*Lentinus sajor-caju* and *Lentinus torulosus*) from Similipal Biosphere Reserve, India. Food Sci Biotech 22:137–145
Singer R (1986) The *Agaricales* in the modern taxonomy, 4th edn. Koeltz Scientific Books, Koenigstein
Sugahara T, Arai S, Aoyagi Y, Kunisaki N (1975) Contents of 50-nucleotides and free amino acids in different varieties of dried shiitake mushroom (*Lentinus edodes* Sing.). J Jpn Soc Nutr Food Sci 28:477–483
Thaipong K, Boonprakob U, Crosby K, Cisneros-Zevallos L, Byrne DH (2006) Comparison of ABTS, DPPH, FRAP, and ORAC assays for estimating antioxidant activity from guava fruit extracts. J Food Compos Anal 19:669–675
Vaskovsky VE, Svetlana VK, Boolukh EM (1998) Distribution of diacylglycero-trimethlhomoserine and phosphatidylcholine in mushrooms. Phytochem 47:755–760
Yaltirak T, Aslim B, Ozturk S, Alli H (2009) Antimicrobial and antioxidant activities of *Russula delica* Fr. Food Chem Toxicol 47:2052–2056