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Nutritional composition and antioxidant capacity of several edible mushrooms grown in the Southern Vietnam

*Hung, P. V. and Nhi, N. N. Y.

School of Biotechnology, International University, Vietnam National University in HoChiMinh City, Quarter 6, Linh Trung Ward, Thu Duc District, HoChiMinh City, Vietnam

Abstract: Mushrooms are a good source of nutrients. They are popular in daily food over the world. This study was conducted to evaluate the nutritive values, total phenolic compounds and antioxidant activity of five popular Vietnamese edible mushrooms (*Pleurotus ostreatus*, *Volvariella volvacea*, *Lentinula edodes*, *Auricularia polytricha* and *Ganoderma lucidum*). Protein, lipid, ash and total carbohydrate contents ranged from 7.2 – 36.6%, 1.7 – 3.0%, 1.4 – 9.0% and 52.3 – 88.6%, respectively, on a dry weight basis. *P. ostreatus*, *V. volvacea*, *L. edodes* and *G. lucidum* contained large amounts of total free phenolic compounds, which exhibited significant antioxidant capacity of the extracts. In addition, the total bound phenolic content of *G. lucidum* was also high resulting in high antioxidant capacity of the extract. The findings show that the edible mushrooms can be used not only as nutritious foods but also as pharmaceutical medicines with high antioxidants.

Keywords: Edible mushrooms, nutrition, antioxidant capacity, phenolic compounds

Introduction

Nowadays, mushrooms are becoming a popular food in daily meal because of their nutritious and medicinal values. Edible mushrooms contain high amount of proteins, and are excellent source of fibers, vitamins and minerals (Cheung, 1996; Mattila *et al.*, 2002; Barros *et al.*, 2007; Ouzouni *et al.*, 2009; Manjunathan and kaviyarasan, 2011). In general, the fruiting bodies of mushrooms contain about 56.8% carbohydrate, 25.0% protein, 5.7% fat and 12.5% ash on a dry weight basis (Ouzouni *et al.*, 2009). In addition, edible mushrooms also contain various polyphenolic compounds recognized as an excellent antioxidant due to their ability to scavenging free radicals by single-electron transfer (Ribeiro *et al.*, 2006; Lee *et al.*, 2007; Kim *et al.*, 2008). Fu *et al.* (2002) reported that several cultivated edible mushrooms such as *Agaricus bisporus, Hericium erinaceus, Flammulina velutipes, Lentinus edodes, Pleurotus eryngii* and *Pleurotus ostreatus* had significant antioxidant and free radical scavenging activities which have been also found in medicinal mushrooms including *Agaricus blazei, Sparassis crispa, Phellinus linetus, Ganoderma lucidum*, and *Inonotus obliquus* (Lee *et al.*, 2007). In addition, twenty-eight of 30 phenolic compounds monitored were detected in mushroom species *Pleurotus ostreatus, Agaricus bisporus, Flammulina velutipes, Lentinus edodes, Pleurotus erygii, Agaricus blazei, Sparassis crispa, Ganoderma lucidum, Innotus obliquus, Phellinus linteus* (Kim *et al.*, 2008). Notably, the consumption of edible mushrooms is considered to have significantly heath benefits. Mushrooms are not only found to be medicinally effective as antitumor, antibacterial, antiviral and haematological agents and in immunomodulating treatments (Wasser and Weis, 1999) but also found to possess significant antioxidant capacity. Therefore, mushrooms can be used both as a food ingredient and in pharmaceutical industry.

Mushrooms exist in various varieties. More than 2,000 species of mushrooms exist in nature; however, less than 25 species are widely accepted as food and only a few have attained the level of an item of commerce (Lindequist *et al.*, 2005). In Vietnam, various species of mushrooms, ranging from the species of tropical regions like straw mushroom to the mushrooms of temperate zone like button or shiitake mushroom have been cultivated, in which oyster mushroom (*Pleurotus ostreatus*), straw mushroom (*Volvariella volvacea*), shiitake (*Letinula edodes*), wood ear mushroom (*Auricularia polytricha*), lingzi or reishi (*Ganoderma lucidum*) are five popular mushrooms commercially sold. Although these commercial mushrooms have been widely consumed as daily foods, lack of researches on their nutritive values as well as antioxidant capacity has been done in Vietnam. Therefore, the objective of this study is to evaluate nutritive values and antioxidant capacity of commercially popular mushrooms grown in the southern Vietnam.

Materials and Methods

Materials

Five commercial mushrooms used in this study were grown in the southern regions of Vietnam

*Corresponding author.
Email: *hungphambk@yahoo.com*
Tel: +84 83 724 2181/3344

including *Pleurotus ostreatus* (oyster mushroom) grown in HoChiMinh City, *Volvariella volvacea* (straw mushroom) grown in Ben Tre province, *Letinula edodes* (shiitake mushroom) grown in Lam Dong province and *Auricularia polytricha* (wood ear mushroom) and *Ganoderma lucidum* (lingzi or reishi mushroom) grown in Dong Nai province. These mushrooms are commercially popular products and are easily bought at local super markets. In this study, *P. ostreatus, V. volvacea* and *L. edodes* were bought from a local market in HoChiMinh City, and *A. polytricha* and *G.lucidum* were bought from a cultivation farm in Dong Nai province. All mushroom species were cleaned, freeze-dried, grinded into powder and stored in a desiccator for later use.

All chemicals including Folin-Ciocalteu's phenol reagent, 2,2-diphenyl-1-picrylhydrazyl (DPPH), gallic acid and other solvents were purchased from Sigma-Aldrich Chemical Company (Singapore).

General composition analysis

The general composition of mushrooms was determined using standard methods. Moisture contents of fresh and freeze-dried mushrooms were determined by drying at 105°C for 6 h according to the AACC Approved Methods 44-15A (AACC International, 2000). Protein contents were determined using a Kjeldahl digestion system (KI 26, Gerhardt, Germany) based on the Association of Official Analytical Chemists (AOAC) method (AOAC, 1995). Lipid contents were determined by extraction with hexane for 6h using a Soxhlet apparatus. Ash contents were determined by burning in a muffle furnace at 550°C for 3h according to the AACC Approved Methods 08-01 (AACC International, 2000). Total carbohydrate was calculated as follows: total carbohydrate (%, DW) = 100% - protein content (%, DW) – lipid content (%, DW) – ash (%, DW).

Extraction of phenolic compounds

Free and bound phenolic of mushroom powders were extracted using 80% chilled ethanol and alkaline-hydrolysis, respectively as described by Hung and Morita (2009). One gram of the freeze-dried mushroom powder was extracted with 80% chilled ethanol for 10 min with vortex mix and the supernatant was collected after centrifuging at 1,500 × *g* for 10 min. After triplicate extraction, the combined supernatant was then evaporated at 45°C, reconstituted with methanol to a final volume of 10 ml and stored in a refrigerator at -4°C for later use. The residue after free phenolic extraction was hydrolyzed with 20 ml of 2N NaOH and shaken at room temperature for 24 h. The solution was then extracted 6 times with diethyl ether-ethyl acetate (1:1) after acidification to pH 2 with 6 N HCl. The ether/ethyl acetate extracts were evaporated to dryness and the bound phenolic acids were dissolved in 10 ml of methanol and stored at -4°C until later use. All extractions were performed in triplicate.

Determination of total phenolic content

Contents of free and bound phenolics in mushrooms were evaluated using the Folin-Ciocalteu's colorimetric method as previously reported by Hung and Morita (2009). A blue color was developed by reaction of phenolic compounds and Folin-Ciocalteu's reagent and then recorded at 725 nm using a spectrophotometer (UVD-2960, Labomed, Inc.). Gallic acid was used as a standard and total phenolic content were calculated and expressed as µg gallic acid equivalent (GAE) per g sample. All analyses were performed in triplicate.

Determination of antioxidant capacity

Antioxidant capacity of free and bound phenolic extracts was measured by using DPPH scavenging as previously described by Hung and Morita (2009). The extracted solution (0.1 ml) was mixed with 3.9 ml of 0.075 mM DPPH. The mixture was left in the dark at room temperature for exactly 30 min. The absorbance was then measured using a spectrophotometer (UVD-2960, Labomed, Inc.) at 525 nm. The blank was made by replacing the extracted solution by methanol (0.1 ml) and then measured at t = 0.

The DPPH scavenging was calculated according to the following equation:

$$\%\,DPPH\,scavenging = \frac{Abs(t=0) - Abs(t=30)}{Abs(t=0)} \times 100$$

Where: *Abs(t=0)* is absorbance of DPPH radical and methanol at t = 0 and *Abs(t=30)* is absorbance of DPPH radical and extracts at t = 30.

Statistical analysis

All analyses were performed in triplicate. Analysis of variance (ANOVA) was performed using Duncan's multiple-range test to compare treatment means at $P < 0.05$ using SPSS software version 16 (SPSS Inc., USA).

Results and Discussions

General composition of edible mushrooms

Table 1 shows moisture contents of the fresh edible mushrooms grown in the southern Vietnam and nutritional composition of the selected mushrooms. The moisture contents of the fresh *P. ostreatus* and

Table 1. Nutritional composition of several Vietnamese mushrooms

Sample	Moisture content (%)	Nutritional composition (%, DW[c])			
		Protein (%)	Lipid (%)	Ash (%)	Total carbohydrate (%)
P. ostreatus	90.1 ± 0.7d	28.6 ± 0.1d	2.5 ± 0.1c	7.6 ± 0.2d	61.3 ± 0.2b
V. volvacea	90.7 ± 0.2d	36.5 ± 0.2e	2.2 ± 0.1b	9.0 ± 0.1e	52.3 ± 0.2a
L. edodes	85.3 ± 0.3c	26.3 ± 0.1c	2.3 ± 0.1b	6.3 ± 0.1c	65.1 ± 0.2c
A. polytricha	83.8 ± 0.1b	7.2 ± 0.1a	1.7 ± 0.1a	2.5 ± 0.0b	88.6 ± 0.2e
G. lucidum	66.7 ± 0.1a	13.3 ± 0.1b	3.0 ± 0.1d	1.4 ± 0.1a	82.3 ± 0.1d

[a]All values are means of two determinations.
[b]The different letters in the same column is significantly different ($p<0.05$).
[c]DW is dry weight basis

V. volvacea were 90.1 and 90.7%, repectively, higher than those of the fresh *L. edodes* (85.3%) and *A. polytricha* (83.8%), whereas the moisture content of the fresh *G. lucidum* was the lowest (66.7%). This variability was dependent on the mushroom species and other parameters such as environment temperature, relative humidity during growth and relative of metabolic water that may be produced or utilized during storage (Crisan and Sands, 1978).

Protein content of the *V. volvacea* was 36.5% on a dry weight basis (DW), which was the highest, following by the *P. ostreatus* (28.6%, DW), *L. edodes* (26.3%, DW), *G. lucidum* (13.3%, DW) and *A. polytricha* (7.2%, DW) (Table 1). The difference in protein contents of mushroom is due to the number of factors, namely the type of mushroom, the stage of development, the part samples, level of nitrogen available and the location (Longvah and Deosthale, 1998). Mattila *et al.* (2002) also studied several species of mushrooms grown in Finland and reported that protein content of *P. ostreatus* and *L. edodes* were 24.6 and 21.4% of dry matter, respectively. These results indicate that the *V. volvacea*, *P. ostreatus* and *L. edodes* are good sources of protein for human as compared to green vegetables.

Lipid contents of the edible mushrooms varied from 1.7% to 3.0% on a dry weight basis, in which *A. polytricha* contained the lowest lipid content (1.7%, DW) and *G. lucidum* had the highest lipid content (3.0%, DW). Lipid content of mushrooms may be different in the same species and other species depending on the nutritive of substrate used to grow mushrooms, genus of species, environment conditions. Previous study reported that lipid content of *L. edodes* varied from 1.3% to 8.0% on a dry weight basis (Crisan and Sands, 1978, Huang *et al.*, 1989), and lipid content of *P. ostreatus* varied from 1.6% to 5.0% on a dry weight basis (Crisan and Sands, 1978, Zaki *et al.*, 1993).

Ash contents of the mushrooms ranged from 1.4% (*G. lucidum*) to 9.0% (*P. ostreatus*) on a dry weight basis. The highest ash content was in *V. Volvacea* (9%, DW), following by *P. ostreatus* (7.6%, DW), *L. edodes* (6.3%, DW), (2.5%, DW) and the lowest was in *G. lucidum* (1.4%, DW). Mattila *et al.* (2002) also reported that ash contents of *P. ostreatus* and *L. edodes* grown in Finland were 8.0% and 5.8% on a dry weight basis, respectively, which are not significant different from our findings in this study. Thus, mushrooms proved to be good source of minerals as compared to vegetables.

Total carbohydrates which include polysaccharides such as glucans, mono- and disaccharides, sugar alcohols, glycogen, and chitin varied in a range of 52.3% to 88.6% in a dry weight basis, in which 52.5% was in *V. Volvacea*, 61.3% in *P. ostreatus*, 65.1% in *L. edodes*, 82.3% in *G. lucidum* and 88.6% in *A. polytricha*. Mattila *et al.* (2002) informed that carbohydrate contents found in *P. ostreatus* was 62.5% and in *L. edodes* was 69% of dry matter. Other studies reported that the carbohydrate contents of *L. edodes* varied 67.5-78% on a dry weight basis (Crisan and Sands, 1978; Bano *et al.*, 1988) and that of *P. ostreatus* varied 46.6-81.8% (Bano *et al.*, 1988, Zaki *et al.*, 1993). Thus, the findings in our study are consistent with earlier published reports.

Total phenolic compounds of Vietnamese edible mushrooms

Total phenolic compounds such as flavonoids, phenolic acids, and tannins are considered to be major contributors to the antioxidant capacity of plants. In this study, total free and bound phenolic compounds of several edible mushrooms in Vietnam are investigated and given in Figure 1. The results show that phenolic compounds of mushrooms existed mostly in free form, which can be extracted by organic solvents. Among five selected edible mushrooms, *V. volvacea* contained the highest amount of total free phenolics (4122.7 µg GAE/g sample, DW), following by *L. edodes* (2876.3 µg GAE/g sample, DW), *P. ostreatus* (2603.3 µg GAE/g sample, DW), *G. lucidum* (2351.4 µg GAE/g sample, DW) and *A. polytricha* (474.4 µg GAE/g sample, DW) (Figure 1A). Different results are seen for the bound phenolics of the mushrooms, which are in decreasing order of *G. lucidum* (670.9 µg GAE/g sample, DW), *L. edodes* (290.4 µg GAE/g sample, DW), *V. volvacea* (190.6 µg GAE/g sample, DW), *A. polytricha* (70.7 µg GAE/g sample, DW) and *P. ostreatus* (70.1 µg GAE/g sample, DW) (Figure 1B). Totally, *V. volvacea*, *L. edodes* and *G. lucidum* are determined to contain a significant

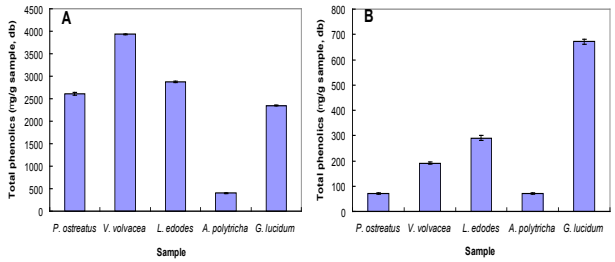

Figure 1. Total free phenolics (A) and bound phenolics (B) of several Vietnamese mushrooms

amount of phenolic compounds which are major contributors to the antioxidant capacity and give protection against the risks for chronic angiogenic diseases, such as cardiovascular diseases, arthritis, chronic inflammation and cancers (Ames *et al.*, 1993; Weisburger, 1999). Especially, *G. lucidum* was found in this study to contain high both total free and bound phenolic compounds which is different from the other mushrooms.

DPPH radical scavenging of free and bound phenolic extracts

The DPPH scavenging values of the selected edible mushrooms are shown in Figure 2. The antioxidant activity of the free phenolic extracts was the highest in *V. Volvacea* (82.9%), following by *L. edodes* (75.8%), *P. ostreatus* (45.4%), *G. lucidum* (40.7%) and the lowest in *A. polytricha* (21.1%) (Figure 2A), whereas the bound phenolic extract of *G. lucidum* exhibited the highest antioxidant capacity (7.5%) and decreasing in an order of *L. edodes* (6.7%), *V. volvacea* (4.2%), *P. ostreatus* (1.8%) and that of *A. polytricha* had the lowest (0.7%) (Figure 2B). However, the antioxidant capacity of the free phenolic extracts was much higher than that of the bound phenolic extracts. The high antioxidant capacity of mushroom phenolic extracts confirms that mushrooms are not only consumed as nutritious foods but also used as pharmaceutical medicines and functional foods.

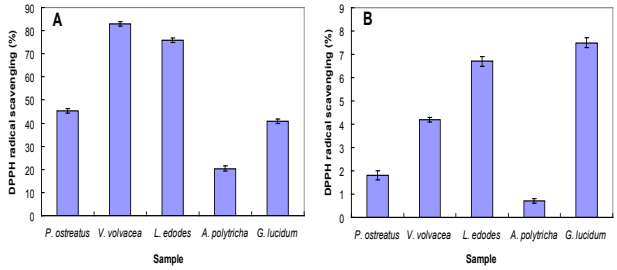

Figure 2. DPPH radical scavenging (%) of total free phenolic (A) and bound phenolic (B) extracts of several Vietnamese mushrooms

Correlation between DPPH radical scavenging and total free and bound phenolic compounds

Correlation between DPPH scavenging (%) and total free and bound phenolic extracts are shown in Figure 3. There is a high correlation (r^2 = 0.8236) between DPPH scavenging and total free phenolic extracts of the selected mushrooms (Figure 3A). The results indicate that the high total free phenolics in the mushroom alcoholic extracts mainly contribute to the significant antioxidant capacity of the extracts. In addition, amount of the bound phenolics of mushrooms is also highly correlated with DPPH scavenging as shown in Figure 3B. These result show that the bound phenolics of mushroom extracts also significant contribution to the antioxidant capacity of the extracts and have highly health benefits. The high correlation between total bound phenolics and DPPH scavenging of mushroom extracts is different from the result of the vegetable extracts, which is no correlation between bound phenolics and DPPH scavenging is observed with r^2 = 0.003 (Hung and Duy, 2011).

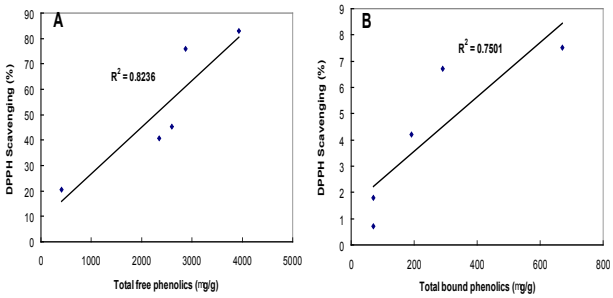

Figure 3. Correlation between DPPH scavenging (%) and total free (A) and bound (B) phenolic extracts

Conclusion

The nutritive values, total phenolic compounds and antioxidant capacity of the edible mushrooms grown in Vietnam were investigated in this study. *P. ostreatus*, *V. volvacea* and *L. edodes* are found to be a good source of protein (26.3 – 36.5%, DW) and ash content (6.3 – 9.0%, DW), whereas *A. polytricha* and *G. lucidum* have low protein (7.2 – 13.3%, DW) and ash content (1.4 – 2.5%, DW), but high total carbohydrate (82.3 – 88.6%, DW). *P. ostreatus*, *V. volvacea*, *L. edodes*, and *G. lucidum* are also good sources of phenolic compounds which contribute to high antioxidant capacity of mushroom extracts. Especially, both free and bound phenolic compounds of *G. lucidum* exhibited the significant antioxidant capacity which is considered as a medicinal species.

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