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Original Article

Proximate compositions and bioactive compounds of edible wild and cultivated mushrooms from Northeast Thailand

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ABSTRACT

Mushrooms are known as an excellent source of nutrients including macronutrients and bioactive compounds. Nutritional values were investigated involving proximate analysis, total antioxidant capacity (TAC), total phenol content (TPC) and total flavonoid content (TFC) of 10 edible wild mushroom species—*Amanita calyptroderma* Ark. et al., *Amanita princeps* Corner et Bas, A., *Astraeus odoratus*, *Heimiella retispora* (Pat. et. Bak.) Boedijn., *Mycoamaranthus cambodgensis* (Pat.) Trappe, *Russula alboareolata* Hongo, *Russula cyanoxantha* Schaeff.ex.Fr., *Russula emetic* (Schaeff. ex Fr.) S.F.Gray., *Russula virescens* (Schaeff.) fr., *Termitomyces clypeatus* Heim—and five cultivated mushroom species—*Auricularia auricula*-judae, *Lentinus polychrous* Lev., *Lentinus squarrosulus* Mont., *Pleurotus sajor-caju* (Fr.) Sing, *Volvariella vovacea* (Bull. Ex.Fr.) Sing. From the proximate analysis, the moisture contents of both wild and cultivated mushrooms ranged from 84.15% fresh weight (FW) to 90.21% FW. The ash, crude protein, fat, crude fiber and carbohydrate contents of both wild and cultivated mushrooms were in the dry weight ranges 2.56–13.96%, 11.16–50.29%, 1.43–21.94%, 2.11–38.11% and 9.56–59.73%, respectively, and the contents of macronutrients in the mushrooms varied by variety. Wild mushrooms had a high fiber content compared to cultivated mushrooms. The contents of biologically active compounds of both wild and cultivated mushrooms also varied depending on the variety. Values for the TAC, TPC and TFC of wild mushrooms were higher than those of cultivated mushrooms. In conclusion, the proximate analysis for both wild and cultivated mushrooms was variety dependent and wild mushrooms contained a higher fiber content and more biologically active compounds than cultivated mushrooms.

Introduction

Mushrooms have been consumed by humans as a part of their normal diet since antiquity and also as a delicacy, because of their texture and highly desirable taste and aroma, whilst also having a higher protein content than most vegetables and also being rich sources of minerals, vitamins and dietary fiber with a low lipid content (Sanmee et al., 2003; Manjunathan and Kaviyarasan, 2011; Lau et al., 2013; Obodai et al., 2014; Sengkhamparn and Phonkerd, 2014). Moreover, mushrooms are a rich source of bioactive compounds beneficial to human health, such as phenolic and flavonoids compounds (Cheung et al., 2003; Bruijn et al., 2009; Yim et al., 2009; Kumari et al., 2011; Seephonkai et al., 2011; Sengkhamparn and Phonkerd, 2014). Mushrooms exert antioxidant properties which are mainly attributed to their phenolic content (Elmastasa et al., 2007; Keleş et al., 2011; Kettawan et al., 2011; Gan et al., 2013; Kalogeropoulos et al., 2013).

In Thailand, there is a well-established consumer acceptance for either wild mushrooms, such as *Amanita* spp., *Astraeus odoratus*, *Russula* spp., *Termitomyces* spp. or for cultivated mushrooms, such as *Auricularia* spp., *Volvariella volvacea*, *Pleurotus sajor-caju* (Sanmee et al., 2003; Kettawan et al., 2011). Although wild mushrooms command higher prices than cultivated mushrooms (Sanmee et al., 2003), they are preferred for human consumption due to their desirable flavor and texture and are generally harvested from June to October in the forests or mountains (Sanmee et al., 2003). Phu Phan Mountain, which is located in Northeast Thailand, is well-known for its diversified natural resources and in particular its

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forest biodiversity which give rise to various untapped biological compounds, including edible wild mushrooms that could be beneficial to human health as well as a natural food for the local people (Choenkwan et al., 2014).

Some previous studies analyzing the nutritional values of wild and cultivated mushrooms in Thailand have been published (Sanmee et al., 2003; Kettawan et al., 2011; Seephonkai et al., 2011; Sengkhamparn and Phonkerd, 2014). However, there are still several varieties of wild mushrooms whose nutritive value and antioxidant activity have not been described well. Moreover, as far as is known, the characterization of species grown in different regions of Thailand has not been reported. Therefore, the present study collected samples of 10 wild mushrooms and 5 cultivated mushrooms from Sakon Nakhon province, Northeastern Thailand and evaluated them for their basic nutritional values and bioactive compounds consisting of TAC as ferric reducing antioxidant power, TPC and TFC.

Material and methods

Mushroom materials and sample preparation

Ten edible wild mushrooms were purchased from a road-side market on Phu Phan Mountain, Sakon Nakhon province, Thailand and five commercial cultivated mushrooms were purchased from a local market (Bypass market) in Sakon Nakhon province, Thailand (Table 1). The 10 selected edible wild mushrooms were: *Amanita calyptroderma*, *Amanita princeps*, *A. odoratus*, *Heimiella retispora*, *Mycoamaranthus cambodgensis*, *Russula alboareolata*, *Russula cyanoxantha*, *Russula emetic*, *Russula virescens* and *Termitomyces clypeatus*. The five selected commercial cultivated mushrooms were: *Auricularia auricula*, *Lentinus polychrous*, *Lentinus squarrosulus*, *P. sajor* and *Volvariella vovacea*. Approximately 1 kg of each mushroom species was purchased from three sellers in the market ($n = 3$). Each mushroom sample was collected in a separate plastic bag. All mushrooms were then delivered to the Food Technology Laboratory at the Faculty of Natural Resources and Agro-Industry, Kasetsart University campus, Chalermphrakiat Sakon Nakhon province within 1 h after purchase. The mushrooms were cleaned of soil with a soft brush without washing. Inedible parts and debris were removed using a sharp knife. Each mushroom sample was cut into very small pieces using a sharp knife and weighed into portions of 2 g, packed separately in plastic bags and then immediately frozen at −75 °C until use. In this study, proximate analysis, TAC, TPC and TFC of each mushroom variety from three samples were analyzed separately in triplicate and the results were recorded as mean ± SD.

Chemicals

Sodium acetate ($C_2H_3NaO_2 \cdot 3H_2O$), ferric chloride ($FeCl_3 \cdot 6H_2O$), ferrous sulfate ($FeSO_4 \cdot 7H_2O$), aluminum trichloride ($AlCl_3$), sodium nitrite ($NaNO_2$), Folin-Ciocalteu reagent, sodium carbonate (Na_2CO_3), gallic acid, (+)-catechin and 2, 4, 6-tripyridyl-s-triazine (TPTZ) were derived from Sigma Chemical Co. (St. Louis, MO, USA).

Proximate composition analysis

The proximate composition of the mushrooms was expressed on a percentage wet weight and on a percentage dry weight basis. Contents of moisture, total ash, crude protein, crude fat and crude fiber were determined using standard proximate analysis methods (Association of Official Analytical Chemists, 1990). The moisture content was determined by drying in a hot air oven at 100 ± 5 °C to a constant weight. The crude protein content was determined using a conversion factor of 4.38 instead of the common factor of 6.25 as mushrooms contain significant amounts of non-protein nitrogen (Kalac, 2009). The crude fat content was determined by extraction with petroleum ether using a Soxhlet system. After the crude fat analysis, the samples were used to investigate the crude fiber content by sequential extraction of the sample with 1.25% H_2SO_4 and then 1.25% NaOH. After the digestions, the samples were dried and the weight of each dried sample was recorded. Samples were then used to determine the ash content by incineration at 550 ± 5 °C. The carbohydrate content was calculated from the sum of the percentages of crude protein, ash, fat and crude fiber subtracted from 100.

Total antioxidant capacity, total phenol content and total flavonoid content determinations

Samples of 2 g of each mushroom were homogenized using a mortar with 20 mL of cold distilled water and then centrifuged at 12,000 × *g* for 10 min at room temperature. The extract was used for determine TFC, TPC and TAC. TFC was determined using a method described by Kim et al. (2003). A 1 mL aliquot of appropriately diluted sample or standard solutions of catechin was added to a 10 mL volumetric flask containing 4 mL double distilled water (ddH_2O). At zero time, 0.3 mL 5% $NaNO_2$ was added to the flask. After 5 min, 0.3 mL 10% $AlCl_3$ was added. At 6 min, 2 mL 1 M NaOH was added to the mixture. Immediately, the reaction flask was diluted to volume with the addition of 2.4 mL of ddH_2O and thoroughly mixed. Absorbance of the mixture was determined at 510 nm versus a prepared water blank. The data were expressed as

Table 1
Information on popular, edible, wild and cultivated mushrooms sold in Sakon NaKhon province, Thailand.

Scientific name	Local (Thai) name	Price[a] (THB/kg)	Edibility	Habitat
Amanita calyptroderma Ark. et Bal.	Hed Ra York Laung	200–300	Excellent	Wild growing
Amanita princeps Corner et Bas	Hed Ra York Kao	200–300	Excellent	Wild growing
Astraeus odoratus	Hed Phor Nung	300–400	Excellent	Wild growing
Heimiella retispora (Pat.et. Bak.) Boedijn.	Hed Phung Chart	150–200	Excellent	Wild growing
Mycoamaranthus cambodgensis (Pat.) Trappe	Hed Hum Fran	60–70	Good	Wild growing
Russula alboareolata Hongo	Hed Kao Din	50–60	Good	Wild growing
Russula cyanoxantha Schaeff.ex.Fr.	Hed Nar Lare	50–60	Good	Wild growing
Russula emetic (Schaeff. ex Fr.) S.F.Gray.	Hed Daeng	60–70	Good	Wild growing
Russula virescens (Schaeff.) fr.	Hed Chai	80–90	Good	Wild growing
Termitomyces clypeatus Heim	Hed Chone	250–300	Excellent	Wild growing
Auricularia auricular-judae	Hed Hoo Noo	40–50	Good	Cultivate
Lentinus polychrous Lev.	Hed Bod	40–50	Good	Cultivate
Lentinus squarrosulus Mont.	Hed Khon Kaw	50–60	Good	Cultivate
Pleurotus sajor-caju (Fr.) Sing	Hed Nang Pha	40–55	Good	Cultivate
Volvariella vovacea (Bull. Ex.Fr.) Sing	Hed Fang	50–70	Good	Cultivate

[a] Price during 2012.

milligrams catechin equivalents per 100 g fresh weight and per dry weight (mg CE/100 g FW and mg CE/100 g dry wt, respectively).

TPC was monitored using the method described by Slinkard and Singleton (1977). An amount of 1 mL of the supernatant was added to the solution of 1 mL of 50% (v/v) Folin-Ciocalteu reagent solution and 2 mL of saturated Na_2CO_3 solution. The mixture was left at room temperature for 30 min. The absorbance at 750 nm was recorded using a spectrophotometer. Gallic acids were used as a standard for TPC. The TPC of the mushroom was expressed in term of milligrams gallic acid equivalents per 100 g fresh weight and dry weight (mg GAE/100 g FW and mg GAE/100 g dry wt, respectively).

Ferric reducing antioxidant potential (FRAP) was assayed using the method described by Benzie and Strain (1996). The FRAP reagent was a mixture of 25 mL sodium acetate and buffer pH 3, 2.5 mL and 10 mM TPTZ and 2.5 mL 20 mM ferric chloride hexahydrate. The reaction was started when 0.3 mL of the supernatant was added into 3 mL of FRAP solution. The mixture was incubated at room temperature for 30 min and then the absorbance was measured at 630 nm. TAC was expressed as millimoles Trolox equivalents per 100 g fresh weight and dry weight (mmol TE/100 g FW and mmol TE/100 g dry wt, respectively).

Statistical analysis

Experiments were analyzed in triplicate. The data were reported as mean ± SD. The means of all parameters were examined for significance using ANOVA with Duncan's significant difference post-hoc test. Statistical significance was tested at $p < 0.05$.

Results and discussion

Proximate composition

The nutritional values of wild and cultivated mushrooms on a fresh weight basis and dry weight basis are shown in Table 2. All mushrooms contained a high moisture content, ranging from 84.15% FW in *A. odoratus* to 90.21% FW in *V. vovacea*. Both wild and cultivated mushrooms had a low ash content ranging from 0.27% FW (2.56% dry wt) in *R. cyanoxantha* to 1.53% FW (13.96% dry wt) in *M. cambodgensis*. These results were similar to those reported by Kalogeropoulos et al. (2013) for wild mushrooms from Greece containing 0.46% FW to 0.85% FW ash content. The current results also showed that the ash contents in both wild and cultivated mushrooms were slightly less than those from wild and cultivated mushrooms from Ghana as reported by Obodai et al. (2014), which ranged from 3.5% FW to 6.38% FW and also with wild mushrooms from Northern Thailand as reported by Sanmee et al. (2003), which were 6.7% dry wt to 27.6% dry wt. These differences might have been dependent on climate differences, species and geographical area. The mushroom containing the lowest protein content was *A. auricula* (11.16% dry wt) and the highest protein content was recorded for *P. sajor-caju* (50.29% dry wt; 6.65% FW). The protein content of *P. sajor-caju* in this work was less than the protein content reported by Obodai et al. (2014) of 15.33% FW. The protein contents of four mushrooms (*H. retispora*, *M. cambodgensis*, *Auricularia auricular*, *L. polychrous*) were in the same range as wild mushrooms from northern Thailand as reported by Sanmee et al. (2003) of 15.5%–24.2% dry wt. All mushrooms contained low fat contents (0.14%–2.91% FW; 1.43–21.94% dry wt), which were similar results to those in other studies (Sanmee et al., 2003; Kalogeropoulos et al., 2013; Obodai et al., 2014). The crude fiber content of cultivated mushrooms was in the range 2.11–15.32% dry wt which was significantly lower than that of wild mushrooms (25.92–38.11% dry wt). The carbohydrate content of all 15 mushrooms ranged from 1.01% FW to 6.60% FW, which was in the same range as the results reported by Kalogeropoulos et al. (2013).

Total phenol content, total flavonoid content and total antioxidant capacity

Values for the TPC, TFC and TAC of both wild and cultivated mushrooms are shown in Table 3. The wild mushroom, *H. retispora*, had the highest TPC (567.65 mg GAE/100 g dry wt). The amount of TPC in wild mushrooms range from 83.98 GAE/100 g dry wt to 567.65 mg GAE/100 g dry wt, except for *R. cyanoxantha* which recorded a low 10.66 mg GAE/100 g dry wt, but the wild mushroom results were significantly higher than those of cultivated mushrooms (3.76–21.13 mg GAE/100 g dry wt). The TPC values for all mushrooms in the current study exhibited lower levels than those reported by Cheung et al. (2003), Kettawan et al. (2011) and Yim et al. (2009).

Table 2
Proximate composition (shown as mean ± SD) of edible wild and cultivated mushrooms.

Mushroom species	Moisture	Ash		Crude protein		Fat		Crude fiber		Carbohydrate	
	(%)	% FW	% dry wt	%FW	% dry wt	% FW	% dry wt	% FW	% dry wt	% FW	% dry wt
Wild mushroom											
A. calyptroderma	87.43 ± 0.11^{cde}	1.34 ± 0.56	11.82 ± 10.71^{ab}	3.58 ± 0.46	28.49 ± 3.66^{de}	1.46 ± 0.77	11.61 ± 6.13^{cd}	2.63 ± 3.57	25.92 ± 21.38^{ab}	3.56	22.16
A. princeps	89.67 ± 2.47^{ab}	0.47 ± 0.02	4.55 ± 0.91^{bcd}	3.16 ± 0.24	30.59 ± 2.32^{cd}	1.81 ± 0.92	17.52 ± 8.90^{bc}	2.71 ± 3.34	30.30 ± 26.47^{ab}	2.18	17.04
A. odoratus	84.15 ± 0.50^{f}	0.98 ± 0.93	10.17 ± 7.08^{abc}	4.18 ± 0.12	26.37 ± 0.76^{de}	1.16 ± 0.33	7.32 ± 2.08^{de}	5.62 ± 2.88	35.46 ± 18.17^{a}	3.91	20.68
H. retispora	88.56 ± 2.55^{bc}	0.39 ± 0.03	3.41 ± 0.27^{cd}	2.73 ± 0.63	23.86 ± 5.51^{de}	1.63 ± 0.80	14.25 ± 6.99^{bcd}	4.36 ± 0.81	38.11 ± 7.08^{a}	2.33	20.37
M. cambodgensis	89.04 ± 0.67^{ab}	1.53 ± 0.22	13.96 ± 2.01^{a}	2.08 ± 0.14	18.97 ± 1.29^{ef}	1.23 ± 0.02	11.22 ± 0.18^{cd}	3.56 ± 1.25	32.47 ± 11.40^{ab}	2.56	23.38
R. alboareolata	86.35 ± 0.41^{de}	1.32 ± 0.59	10.99 ± 9.74^{ab}	4.08 ± 0.58	29.90 ± 4.25^{d}	0.63 ± 0.49	4.61 ± 3.59^{ef}	4.35 ± 2.97	31.88 ± 21.77^{ab}	3.27	22.62
R. cyanoxantha	89.45 ± 1.24^{ab}	0.27 ± 0.08	2.56 ± 0.76^{d}	5.19 ± 2.49	49.20 ± 23.61^{ab}	0.83 ± 0.16	7.87 ± 1.52^{de}	3.25 ± 0.03	30.81 ± 0.28^{ab}	1.01	9.56
R. emetic	87.57 ± 0.43^{cd}	1.03 ± 0.06	8.29 ± 0.49^{abcd}	4.13 ± 0.26	33.24 ± 2.09^{cd}	0.49 ± 0.20	3.94 ± 1.61^{g}	3.41 ± 0.05	27.44 ± 0.40^{ab}	3.37	27.09
R. virescens	86.51 ± 0.35^{de}	0.87 ± 0.42	5.40 ± 4.76^{bcd}	3.98 ± 0.28	29.50 ± 2.07^{d}	1.69 ± 0.27	12.54 ± 2.00^{cd}	4.52 ± 3.34	32.16 ± 24.75^{ab}	2.43	20.40
T. clypeatus	90.13 ± 0.25^{a}	0.29 ± 0.02	2.94 ± 0.20^{cd}	2.60 ± 0.34	26.34 ± 3.44^{de}	0.78 ± 0.18	7.90 ± 1.82^{de}	3.47 ± 1.31	35.15 ± 13.27^{ab}	2.73	27.67
Cultivated mushroom											
A. auricula	89.25 ± 0.84^{ab}	0.99 ± 0.02	9.21 ± 0.19^{abcd}	1.20 ± 0.15	11.16 ± 1.39^{f}	1.31 ± 0.13	12.18 ± 1.21^{cd}	0.83 ± 0.02	7.72 ± 0.19^{c}	6.42	59.73
L. squarrosulus	86.10 ± 1.32^{e}	1.32 ± 0.00	9.50 ± 0.00^{abcd}	5.61 ± 0.45	40.34 ± 3.23^{bc}	2.19 ± 0.29	15.75 ± 2.08^{bc}	0.39 ± 0.05	2.80 ± 0.36^{c}	4.39	31.61
L. polychrous	86.74 ± 0.70^{de}	1.03 ± 0.02	7.77 ± 0.15^{abcd}	2.42 ± 0.08	18.25 ± 0.60^{ef}	2.91 ± 0.05	21.94 ± 0.38^{a}	0.30 ± 0.06	2.26 ± 0.45^{c}	6.60	49.78
P. sajor-caju	88.63 ± 0.85^{bc}	1.09 ± 0.01	9.59 ± 0.09^{abcd}	6.65 ± 0.26	50.29 ± 4.17^{a}	1.95 ± 0.14	17.14 ± 1.23^{bc}	0.24 ± 0.04	2.11 ± 0.35^{c}	1.44	20.87
V. vovacea	90.21 ± 0.47^{a}	1.13 ± 0.02	11.54 ± 0.20^{ab}	3.19 ± 0.23	32.57 ± 2.35^{cd}	0.14 ± 0.01	1.43 ± 0.10^{f}	1.50 ± 0.17	15.32 ± 1.74^{bc}	3.83	39.14

Moisture, ash, crude protein, fat and crude fiber presented from analysis of three samples, in triplicate; carbohydrate calculated from the sum of the percentages of crude protein, ash, fat and crude fiber and subtracted from 100, where FW = fresh weight and dry wt = dry weight; in each row, different lowercase superscript letters in the same column indicate a statistical difference at $p < 0.05$ using ANOVA.

Table 3
Total antioxidant capacity (TAC), total phenolic content (TPC) and total flavonoids content (TFC) of edible, wild and cultivated mushrooms.

Mushroom species	TAC* (mmol TE/100 g)		TPC (mg GAE†/100 g)		TFC (mg CE/100 g)	
	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
Wild mushroom						
A. calyptroderma	0.15 ± 0.02§	1.89 ± 0.25$^{ef\|}$	11.15 ± 1.34	140.16 ± 16.84^{e}	3.01 ± 2.13	37.84 ± 26.77^{cd}
A. princeps	0.11 ± 0.02	1.14 ± 0.21^{fg}	8.13 ± 1.52	83.98 ± 15.70^{f}	1.60 ± 0.10	16.53 ± 1.03^{def}
A. odoratus	0.48 ± 0.03	7.61 ± 0.48^{a}	16.81 ± 0.92	266.44 ± 14.58^{d}	12.95 ± 3.09	205.26 ± 48.98^{a}
H. retispora	0.33 ± 0.14	3.78 ± 1.60^{bc}	49.62 ± 3.42	567.65 ± 39.12^{a}	3.77 ± 0.67	43.13 ± 7.66^{bc}
M. cambodgensis	0.04 ± 0.02	0.44 ± 0.22^{g}	9.60 ± 0.83	105.22 ± 9.10^{f}	3.08 ± 1.50	33.76 ± 16.44^{cde}
R. alboareolata	0.18 ± 0.01	2.46 ± 0.14^{de}	35.80 ± 2.86	488.67 ± 39.04^{b}	4.80 ± 1.76	65.52 ± 24.02^{b}
R. cyanoxantha	0.29 ± 0.02	3.06 ± 0.21^{cd}	1.01 ± 0.03	10.66 ± 0.32^{g}	0.06 ± 0.01	0.63 ± 0.11^{f}
R. emetic	0.32 ± 0.11	3.98 ± 1.37^{b}	29.44 ± 2.77	365.94 ± 34.43^{c}	1.63 ± 0.01	20.26 ± 0.12^{cdef}
R. virescens	0.16 ± 0.02	2.16 ± 0.27^{e}	35.50 ± 2.16	478.89 ± 29.14^{b}	1.16 ± 0.45	15.65 ± 6.07^{def}
T. clypeatus	0.04 ± 0.03	0.39 ± 0.29^{g}	37.86 ± 2.63	373.68 ± 25.96^{c}	0.85 ± 0.45	8.39 ± 4.44^{ef}
Cultivated mushroom						
A. auricula	0.08 ± 0.02	0.86 ± 0.22^{g}	0.35 ± 0.01	3.76 ± 0.11^{g}	0.08 ± 0.01	0.86 ± 0.11^{f}
L. squarrosulus	0.23 ± 0.01	3.20 ± 0.14^{bcd}	1.52 ± 0.01	21.13 ± 0.14^{g}	0.08 ± 0.02	1.11 ± 0.28^{f}
L. polychrous	0.23 ± 0.02	3.05 ± 0.27^{cd}	0.91 ± 0.03	12.07 ± 0.40^{g}	0.04 ± 0.01	0.53 ± 0.13^{f}
P. sajor-caju	0.22 ± 0.01	2.50 ± 0.11^{de}	0.86 ± 0.01	9.78 ± 0.11^{g}	0.08 ± 0.01	0.91 ± 0.11^{f}
V. vovacea	0.19 ± 0.02	1.86 ± 0.19^{ef}	0.86 ± 0.01	8.42 ± 0.10^{g}	0.06 ± 0.01	0.59 ± 0.10^{f}

* TE = trolox equivalents and TAC determined using ferric reducing antioxidant power (FRAP) assay; † GAE = gallic acid equivalents; ‡ CE = catechin equivalents; § data presented as mean ± SD from analysis of three samples, in triplicate; ‖ $^{a-g}$ = different lowercase superscript letters in the same column indicate a statistical difference at $p < 0.05$ using analysis of variance.

Water-soluble TFC was determined in the current study. *A. odoratus* (a wild mushroom), contained the highest TFC content (205.26 mg CE/100 g dry wt) compared to the others. The TFC values in the five wild mushrooms—*A. odoratus*, *A. calyptroderma*, *H. retispora*, *M. cambodgensis* and *R. alboareolata*—(33.76–205.26 mg CE/100 g dry wt) were significantly higher than for the cultivated mushrooms (0.53–1.11 mg CE/100 g dry wt). A low concentration of water-soluble TFC in the wild mushroom, *Grifola gargal* (6.1 mg CE/100 g FW) was also reported by Bruijn et al. (2009). However, Yim et al. (2009) reported higher TFC values in water extracts of mushroom, ranging from 37.71 mg CE/100 g dry wt in *Lentinus ciliates* to 184.80 mg CE/100 g dry wt. in *Pleurotus* sp.

From the current study, TPC constituted the major naturally occurring antioxidant components found in both wild and cultivated mushrooms when compared to the TFC. The TAC was measured using the FRAP method. The reducing power assay indicated that all mushrooms exhibited antioxidant potential in the range 0.04–0.48 mmol TE/100 g FW (0.39–7.61 mmol TE/100 g dry wt) as shown in Table 3 and *A. odoratus* had the highest TAC (7.61 mmol TE/100 g dry wt). The TAC values for mushrooms in the current work were similar to those in Kettawan et al. (2011). However, based on the current results, it seems that the amount of TAC in both wild and cultivated mushrooms depends on the species and origin. The wild mushrooms clearly showed higher contents of bioactive compounds than the cultivated mushrooms. Both the abiotic and biotic stresses that wild mushrooms derive from nature might enhance their content of bioactive compounds, whilst cultivated mushrooms having been grown in a protected area derive less stress.

According to the results above, the nutritional value of both wild and cultivated mushrooms depended on the variety and its origin. Both wild and cultivated mushrooms contained a high protein content and a low fat content. The fiber content of wild mushrooms was clearly higher than that of cultivated mushrooms. Wild mushrooms, contained higher amounts of biologically active compounds than did cultivated mushrooms. In particular, *A. odoratus* and *H. retispora* (wild mushrooms) had greater amounts of biologically active compounds than the others. Therefore, it is suggested that both wild and cultivated mushrooms are good sources of macronutrients and biologically active compounds.

Conflict of interest

The authors declare that there are no conflicts of interest.

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