Available free online at www.medjchem.com

Mediterranean Journal of Chemistry

Mediterranean Journal of Chemistry **2016**, 5(3), 434-441

Chemical composition and non-volatile components of three wild edible mushrooms collected from northwest Tunisia

Ibtissem Kacem Jedidi[1], Imen Kacem Ayoub[2], Thonart Philipe[3] and Nabiha Bouzouita[1,*]

[1] High School of Food Industries in Tunis, 58 Avenue, Alain Savary, 1003 Tunis, Tunisia
[2] Ecole Polytechnique Internationale Privée de Tunis, les Berges du Lac, 1053 Tunis, Tunisia
[3] Walloon Industrial Biology Center, Boulevard of Rectorat, 27, Bat. B22 Sart Tilman 4000 Liege, Belgium

Abstract: In Tunisia, many people collect wild edible mushrooms as pickers for their own consumption. The present work aims at contributing to the determination of the chemical composition, non volatile components content (soluble sugars, free amino acids) and minerals and trace elements of three popular Tunisian wild edible mushrooms species collected from the northwest of Tunisia (*Agaricus campestris, Boletus edulis and Cantharellus cibarius*).
All investigated mushrooms revealed that these species are rich sources of proteins (123.70 - 374.10 g kg^{-1} dry weight (DW)) and carbohydrates (403.3 - 722.40 g kg^{-1} DW), and low content of fat (28.2 - 39.9 g kg^{-1} DW); the highest energetic contribution was guaranteed by *C. cibarius* (1542.71 kJ / 100 g). *A. campestris* (33.14 mg/g DW) showed the highest concentration of essential amino acids. The composition in individual sugars was also determined, mannitol and trehalose being the most abundant sugars. *C. cibarius* revealed the highest concentrations of carbohydrates (722.4 g kg^{-1} DW) and *A. campestris* the lowest concentration (403.3 g kg^{-1} DW). Potassium (K) and sodium (Na) are the most abundant minerals in analyzed samples (*A. campestris* showed the highest concentrations of K and Na, 49141.44 and 9263.886 µg/g DW respectively).

Keywords: Wild edible mushrooms; chemical composition; sugar composition; free amino acids; minerals.

Introduction

In many parts of the world, edible mushroom is one of the most popular foods, not only for texture and flavor but also for their chemical and medicinal characteristics [1].
Fruiting bodies of mushrooms are appreciated for their nutritional characteristics [2]. They are valuable healthy and nutritious foods, low in calories and fats, and high in vegetable proteins, vitamins and minerals [3,4]. Mushrooms have been a perennial component of the human diet, consumed since antiquity not only as part of the normal diet but also as a delicacy, because of their texture and highly desirable taste and aroma. Wild edible mushrooms are consumed with sustainable popularity in many countries of central and Eastern Europe. In Greece, wild mushrooms comprise an important ingredient for the traditional cuisine and gastronomy [5].
In general, the fruiting bodies of mushrooms, on DW basis contain about 57% carbohydrates, 25% proteins, 5.7% fats and 12.5% ash. Dry matter of mushrooms is very low, usually in the range of 60 - 140 g kg^{-1} [6]. Low dry matter and lipids contents result in the low energy value of mushrooms. Thus, mushrooms are a food item of low energy [7].

Wild edible mushrooms are becoming more and more important in our diet for their nutritional [8], organoleptic [9] and pharmacological [10] characteristics. The consumption of wild edible mushrooms is increasing due to a good content of proteins and trace minerals [11]. Some investigations have even contended that the amino acids compositions of mushrooms are comparable to animal proteins [12].
Besides all the nutritional properties already available in the literature, there are no reports dealing about the chemical composition and nutritional value of Tunisian wild edible mushrooms. Tunisia has a large edible mushroom potential because it processes favorable environmental conditions for the growth of mushrooms. For instance, many people collect wild edible mushrooms in Tunisia. Some collected mushrooms are used for pickers own consumption, however, collection has been an economic activity for most of the rural population [13,14].

Despite of the potential economic importance of these wild growing mushrooms, this is the first study that has been carried out on their chemical and nutritional composition.

**Corresponding author: Nabiha Bouzouita*
E-mail address: bouzouita.nabiha@gmail.com
DOI: http://dx.doi.org/10.13171/mjc53/01604121130/bouzouita

Received February 15th, 2016
Accepted April 4rd, 2016
Published April 12th, 2016

The aim of the present study is to determine the chemical composition of three different Tunisian wild edible mushrooms (*A. campestris*, *B. edulis and C. cibarius*), with reference to the contents of moisture, protein, fat, carbohydrate and ash.

Among the individual components, sugar, amino acids and trace elements profiles were obtained by high performance liquid chromatography coupled to a refraction index detector (HPLC/RI) for sugar and amino acids and atomic absorption spectroscopy (AAS) for trace elements.

Experimental Section

Mushroom samples

Three wild edible species (*A. campestris*, *B. edulis*, *C. cibarius*), belonging to three different families, were collected from pasturelands and forests (unpolluted area) in northwest of Tunisia regions (Beja and Jendouba), from October 2012 to Mars 2013. The mushrooms were scientifically identified at the National Institute for Research in Rural Engineering, Water and Forest. The morphological identification of the wild macrofungi was made till species according to macro and microscopic characteristics and following several authors [15,16]. The species were selected in relation to edible quality, commercialization and frequency in the areas of the study.

The mushroom samples were cleaned from forest debris (without washing), transported to the laboratory within 10 h of collection and air dried at 40°C. Dried samples were ground to obtain fine powder and stored under vacuum for further analyses.

All the analyses were carried out in triplicate to ensure replicability of the results.

Standards and reagents

The amino acid standards (aspartic acid, glutamic acid, serine, threonine, alanine, tyrosine, cysteine, valine, methionine, phenylalanine, isoleucine, leucine, lysine) were purchased from Sigma-Al-drich (Steinheim, Germany). NaH_2PO_4 and derivatisation reagents (3 mercaptopropionic acid (3-MPA), o-phthalaldehyde (OPA), and 9-fluorenyl-methyl chloroformate (FMOC-Cl)) were from Sigma-Aldrich (Steinheim, Germany). Methanol (MeOH) and acetonitrile (ACN) (HPLC gradient grade) were from J. T. Baker (Deventer, Holland).

Equipment

The HPLC system Agilent 1100 Series consisted of a binary pump G1312A, thermostated autosampler G1313A, vacuum degasser G1379A, column owen G1330B, diode array detector (DAD) G1315C, and Fluorescence Detector (FLD) G1321A. Column ZORBAX Eclipse-AAA (3.0 x 150 mm, 3.5 µm), thermostated at 40 °C was used for analysis. The mobile phases were A: 40 mM NaH_2PO_4 pH 7.8, pH adjusted 7.8 with NaOH solution (10 M) and B: ACN:MeOH:water (45:45:10), HPLC gradient grade, at flow rate of 2 ml/min. Gradient was 0-57% B for 1.9-18.1 min, 57-100% B for 18.1-18.6 min, 100% B for 18.6-22.3 min, 100-0% B for 22.3-23.2 min. Run time was 26 min.

Detection DAD: 338 nm (for OPA-amino acids) and 262 nm (for FMOC-amino acids) FLD was time programmed: 0 - 15.6 min: ex 340, em 450, 15.6 - 26.0 min: ex 266, em 305, PMT gain 10.

Chemical composition

The chemical composition of 3 wild edible Tunisian mushrooms, including moisture, ash, total carbohydrates, crude fat, and crude protein, were determined according to Association of Official Agricultural Chemists [17] (AOAC) procedures. To obtain moisture contents, samples of the mushrooms were dried in an oven at 107°C overnight until constant weight. The ash content was determined by incineration at 550°C for 24 h. The crude protein content of the samples was estimated by the micro-Kjeldhal method. For the calculation of crude protein in mushrooms, the nitrogen content was multiplied by a factor of 4.38 [18]. The crude fat content was determined by extracting a known weight of powdered sample with petroleum ether, using a Soxhlet apparatus. The amount of total sugars was calculated by difference

$$Total\ sugars = 100 - (g\ protein + g\ crude\ fat + g\ ash)$$

Total energy was calculated according to the following equation [19]:

$$Energy\ (kJ) = 17 * (g\ protein + g\ carbohydrate) + 37 * (g\ lipid)\ .$$

Soluble sugar assay

Free sugars were determined by high performance liquid chromatography coupled to a refraction index detector (HPLC-RI) based on the method used by Barros et al.[20]. Dried powder (1.0 g) was extracted with 40 ml of 80% aqueous ethanol at 80°C for 30 min. The resulting suspension was centrifuged at 15000 g for 10 min. The supernatant was concentrated at 60°C under reduced pressure and defatted three times with 10 ml of ethyl ether, successively. After concentration at 40°C, the solid residues were dissolved in water to a final volume of 5 ml. Soluble sugars were determined by using HPLC (Agilent 1100) at 40°C. The HPLC system was equipped with a RI detector and with a Supelco C610H column (30 cm x 7.8 mm). The mobile phase was phosphoric acid (0.1 %) at a flow rate of 0.5 ml/min. The results are expressed in g kg^{-1} of DW, calculated by internal normalization of the chromatographic peak area. Sugar identification was

made by comparing the relative retention times of sample peaks with standards. The sugar standards used for identification were purchased from Sigma Chemical Co. (St. Louis, USA): L(+)-arabinose, D(-)-fructose, D(+)-galactose, D(+)-glucose anhydrous, lactose 1-hydrate, maltose 1-hydrate, D(+)-mannitol, D(+)-mannose, D(+)-melezitose, D(+)-sucrose, D(+)-trehalose and D(+)-xylose.

Free amino acid assay

Amino acids were derivatised on-line automatically with 3-MPA, 3-MPA/OPA. For derivatisation of amino acids, the following reagents were used: 0.4 M borate buffer in water with pH 10.2; 3-MPA/OPA reagent: 10 mg/ml of OPA was dissolved in 0.4 M borate buffer with 1.0% of 3-MPA. Reagents were stored at 4°C. Prior derivatisation 20 µl of 3-MPA/OPA reagent was diluted with 140 µl of 0.4 M borate buffer. Derivatisation was performed using the automatic injector: successive sampling of 2.5 µl of borate buffer and 0.5 µl of sample, then mixed two times with a wait time of 0.5 min. Subsequently, 0.5 µl of 3-MPA/OPA reagent was added. After mixing six times, 32 µl of water was added, mixed two times and finally 18 µl of the mixture was injected. Column Zorbax Eclipse-AAA (3.0 x 150 mm, 3.5 µm), thermostated at 40°C was used for analysis. The mobile phases were A: 40 mM NaH_2PO_4 pH 7.8, pH adjusted 7.8 with NaOH solution (10 M) and B: ACN:MeOH:water (45:45:10), HPLC gradient grade, at a flow rate of 2 ml/min, fluorescence detection (ex 340 nm, em 450 nm). Gradient was 0-57% B for 1.9-18.1 min, 57-100% B for 18.1-18.6 min, 100% B for 18.6-22.3 min, 100-0% B for 22.3-23.2 min. Run time was 26 min.

Mineral and trace element assay

Mineral and trace elements were determined by atomic absorption spectrometry (AAS) based on the method used by Liu et al. [1] with minor modifications. The mushroom sample (1 g) was placed in a porcelain crucible and ashed in a muffle furnace at 500°C for 24 h. After cooling, the ashed material was dissolved in 2 ml of concentrated HNO3, and diluted with distilled water up to 25 ml. The solution was then transferred to a suitable container, after it was filtered through filter paper. A blank digest was carried out in the same way. The concentrations of calcium (Ca), Potassium (K), magnesium (Mg) and sodium (Na) were determined in a flame atomic absorption spectrometry (FAAS), employing Analytic Jena (Varian, USA). The concentrations of manganese (Mn), copper (Cu), iron (Fe) and zinc (Zn) were determined in a Perkin-Elmer Optima 2000 ICP-OES.

Statistical analyses

All assays were carried out in triplicate. The results were expressed as mean values and standard deviation (SD). The results were analyzed through one-way analysis of variance (ANOVA) followed by Duncan's test with $p < 0.05$. This test was carried out by use of the SPSS v. 17.0 program.
Particular effects between mushroom species and their chemical and nutritional compositions were examined using a principal component analysis [21].

Results and discussion

Chemical composition

We studied the chemical composition and non-volatile components content of the 3 wild edible mushroom species, which are most popular collected in northwest Tunisia. The chemical composition and non-volatile components content of these mushrooms were not reported previously in Tunisia.
The results of the proximate chemical composition for investigated mushrooms and calculated energy values (expressed on DW basis) are shown in Table 1.

When the nutrition value of mushrooms is evaluated, the most important factor is their moisture content. It is known that the DW content of fresh mushrooms generally range from 5 to 15 % and the nutritional profiles of mushrooms are directly affected with their moisture content [22,23]. In addition, this variability of moisture content 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 [18].

The DW content of all studied mushroom species ranged from 11.18 % to 16.5 %. Beluhan & Ranogajec [7] reported that the DW content of *A. campestris*, *B. edulis* and *C. cibarius* were 14.89 %, 12.23 % and 14.24 %, respectively. When these results were compared with the values obtained in this study for the same mushroom species (Table 1), it can be easily seen that with exception of *C. cibarius* (11.18 %), the values from our study for *A. campestris* (16.5 %), *B. edulis* (14.45 %) were higher.

Generally, carbohydrate contents of mushrooms fruit bodies were in the range of 440 - 743 g kg^{-1} on DW basis [18]. The carbohydrate contents, calculated by difference, were found in high levels and varied between 403.3 g kg^{-1} in *A. campestris* and 722.4 g kg^{-1} in *C. cibarius*. Protein contents were also an abundant macronutrient and ranged from 123.7 g kg^{-1} in *C. cibarius* and 374.1 g kg^{-1} in *A. campestris*. The major compounds of mushrooms are proteins and sugars. It was reported that the protein contents of mushrooms are affected by a number of factors, namely the type of mushroom, the stage of development, the part sampled, level of nitrogen available and the harvest location [24].

In this study, the highest protein content was found for *A. campestris* (374.1 g kg^{-1} DW) which is in agreement with Beluhan & Ranogajec [7] who found 388.4 g kg^{-1} proteins for *A. campestris*, but Pereira et al. [25] reported a minor protein content

(185.7 g kg^{-1}) for the same mushroom species. The lowest protein content was found for *C. cibarius* (123.7 g kg^{-1}), and the obtained result was different to 309.1 g kg^{-1} and 691.4 g kg^{-1} as reported respectivly Beluhan & Ranogajec [7] and Barros et al. [26]. The distribution of proteins within a fruiting body and changes in protein content during the development of a fruiting body remain mostly unclear [6].

In general, wild mushrooms were richer sources of protein and had a lower amount of fat than commercial mushrooms [20]. They are recommended for low-calorie diet because of their low crude fat content. The fat ranged from 28.2 g kg^{-1} in *C. cibarius* and 39.9 g kg^{-1} in *A. campestris*. Ash content of mushroom is usually between 5 and 12% of DW [27]. In our results, ash contents varied between 125.7 g kg^{-1} in *C. cibarius* and 182.7 g kg^{-1} in *A. campestris*. As compared with vegetables, mushrooms proved to be good sources of many mineral elements. The main constituents in the mushrooms ash are K and P.

Wild mushroom species proved to be less energetic providing, on average, 1513.01 kJ per 100 g of a dry portion. Kalac [6] also indicated low dry matter and lipid contents result in the low energy value of mushrooms. The lowest energetic value was obtained for *A. campestris* (1469.21 kJ). As reported Beluhan & Ranogajec [7] Croatian wide species *A. campestris, B. edulis and C. cibarius* can provide 1569.55 kJ, 1488.10 kJ and 1488.27 kJ, respectively, per 100 g of dry portion. Only Tunisian wild specie *A. campestris* (1469.21 kJ) provide less energetic value, but *B. edulis* (1527.10 kJ) and *C. cibarius* (1542.71 kJ) proved to be more energetic than the same wild species collected from Croatia.

Table 1. Proximate chemical composition (g kg^{-1} of DW) and energetic value of three Tunisian wild edible mushrooms

Mushroom species	Dry matter (%)	Protein	Fat	Total carbohydrates	Ash	Energy (kJ)
Agaricus campestris	16.50 ± 0.05 ^{b}	374.1 ± 0.32 ^{c}	39.9 ± 0.20 ^{a}	403.3 ± 0.11 ^{b}	182.7 ± 0.24 ^{d}	1469.21 ± 0.31 ^{a}
Boletus edulis	14.45 ± 0.11 ^{d}	239.1 ± 0.37 ^{b}	38.5 ± 0.13 ^{a}	575.4 ± 0.18 ^{b}	147.0 ± 0.11 ^{c}	1527.10 ± 0.15 ^{a}
Cantharellus cibarius	11.18 ± 0.71 ^{a}	123.7 ± 0.11 ^{a}	28.2 ± 0.05 ^{a}	722.4 ± 0.27 ^{a}	125.7 ± 0.15 ^{b}	1542.71 ± 0.29 ^{a}

Each value represents mean ± SD of triplicates (n=3). Different letters in the same raw indicate significant difference at $p < 0.05$ levels by Duncan's Multiple Range Test.

Sugar composition

The reserve polysaccharide of mushrooms is glycogen. The usual content is 5 - 10 % of dry matter. Glycogen is a common component of widely consumed meat and liver and its low intake from mushrooms thus seems to be of low nutritional importance [28].

The sugar compositions of studied wild edible mushroom species in this work are shown in Table 2. Mannitol and trehalose, which were major mushroom polyol and sugar, respectively, according to Bano & Rajarathman [22] and Mau et *al.* [29], were found in all 3 mushrooms, as well as glucose. The accumulation of these sugars in the fruit-bodies of other species was already reported [30,31].

Mannitol participates in volume growth and firmness of fruit bodies. Other water-soluble sugars, namely arabinose, maltose and melezitose, are reported in some papers as minor components [28].

C. cibarius revealed the highest sugar contents (153.5 g kg^{-1} DW), mostly due to trehalose (120.1 g kg^{-1} DW) while *A. campestris* revealed the lowest levels (47.7 g kg^{-1} DW). Also, *A. campestris* and *B.edulis* have same content of mannitol (41 g kg^{-1} DW).

Barros et al. [20] reported levels of total sugar in Portuguese *C. cibarius* and *B. edulis* (144.5 and 134.6 g kg^{-1} DW, respectively) which were similar to our results for the first species except for Portuguese *B. edulis* which have higher level of total sugar then the Tunisian *B. edulis* (67.3 g kg^{-1} DW). In contrast, these species do not exhibit the some major sugars.

Soluble sugars contained in the mushroom contributed to the sweet taste [32]. Therefore, the high content of sugars and polyols would give rise to a moderate sweet taste perception [7].

Table 2. Content of soluble sugars and polyol (g kg^{-1} DW) of three Tunisian wild edible mushrooms

Mushroom species	Trehalose	Mannitol	Glucose	Total
Agaricus campestris	1.9 ± 0.50	41 ± 0.42	4.8 ± 0.11	47.7 ± 0.29
Boletus edulis	22.6 ± 0.12	41 ± 0.39	3.7 ± 0.01	67.3 ± 0.19
Cantharellus cibarius	120.1 ± 0.91	25.7 ± 0.01	7.7 ± 0.09	153.5 ± 0.73

Each value represents mean ± SD of triplicates (n=3).

Amino acids composition

Several authors referred to mushrooms as a good source of essential amino acids such as: leucine, phenylalanine, lysine, methionine and threonine. Wild mushroom proteins also contain considerable amounts of non-essential amino acids such as: serine, alanine, glutamic acid, aspartic acid, and cystein [33].

The composition and amount of amino acids are present in Table 3. Thirteen free amino acids were analyzed at all studied mushroom species and the most abundant components of essential amino acid were Leucine and phenylalanine in all mushrooms. Leucine content varied between 10.83 g kg^{-1} DW (*A. campestris*) and 2 g kg^{-1}DW (*B. edulis*) and phenylalanine varied between 8.38 g kg^{-1} DW (*A. campestris*) and 2.98 g kg^{-1} DW (*C. cibarius*) .The total amino acid contents ranged from 22.03 g kg^{-1} DW (*C. cibarius*) to 70.31 g kg^{-1} DW (*A. campestris*). Particularly, valine an essential amino acid was not detected in all mushroom species.

The ratios of the essential amino acids to non-essential amino acids were 0.89, 0.56 and 0.99 in *A. campestris*, *B. edulis* and *C. cibarius*, respectively. This result meets well the reference values of 0.6 recommended by FAO/WHO (1973), except B. edulis.

Table 3. Content of free amino acids of three Tunisian wild edible mushrooms (g kg^{-1} DW)

Amino Acids	*Agaricus campestris*	*Boletus edulis*	*Cantharellus cibarius*
Asp	7.34 ± 0.12	7.87 ± 0.40	2.30 ± 0.31
Ser	10.52 ± 0.16	9.39 ± 0.14	2.78 ± 0.12
Glu	5.61 ± 0.28	6.56 ± 0.23	2.00 ± 0.11
Thr[B]	3.32 ± 0.31	3.45 ± 0.04	1.08 ± 0.29
Ala	5.51 ± 0.25	5.37 ± 0.07	1.81 ± 0.45
Tyr	2.35 ± 0.22	2.38 ± 0.18	0.78 ± 0.19
Cys	5.85 ± 0.14	4.49 ± 0.12	1.39 ± 0.26
Val[B]	ND	ND	ND
Met[B]	3.67 ± 0.32	3.40 ± 0.39	1.00 ± 0.19
Phe[B]	8.38 ± 0.18	7.63 ± 0.05	2.98 ± 0.45
Ile[B]	2.54 ± 0.28	2.51 ± 0.60	0.96 ± 0.11
Leu[B]	10.83 ± 0.11	2.00 ± 0.01	3.02 ± 0.15
lys[B]	4.38 ± 0.26	1.12 ± 0.40	1.93 ± 0.17
Total	70.31 ± 0.20	56.16 ± 0.31	22.03 ± 0.40
Total EAA	33.14 ± 0.13	20.10 ± 0.18	10.97 ± 0.09

[B] Essential Amino Acids (EAA); Each value represents mean ± SD of triplicates (n=3).
Glu: glutamic acid; Ser: serine; Thr: threonine; Ala: alanine; Tyr: tyrosine; Cys: cysteine; Val: valine; Met: methionine; Phe: phenylalanine; Ile: isoleucine; Leu: leucine; Lys: lysine.
ND: Not detected;

Minerals and trace elements

As compared with vegetables, mushrooms proved to be good sources of many mineral elements. Metals such as iron, copper, magnesium and zinc are essential metals since they play an important role in biological systems [34].

Ash content of studied mushrooms varied with mushroom species and ranges between 125.7 and 182.7 g kg^{-1} DW (Tables 1). Table 4 presents the mineral composition (mg kg^{-1} of DW) of the investigated wild edible mushrooms. The mean contents of mineral element across all the mushrooms studied were in the order: K > Na > Mg > Ca > Cu > Fe > Zn.

Levels of these studied mineral elements meet well the recommended dietary allowances of NRC/NAS [35]. The main constituents in the mushrooms ash are K and P [36].

The most abundant mineral element in our studied species is K and was in the range between 16313.49 mg kg^{-1} and 49141.44 mg kg^{-1} of DW. This agrees with previous reports [1,37], which found the highest mineral to be K in various species of edible mushrooms analyzed.

Table 4. Levels of trace elements in the analyzed mushroom samples (mg/kg DW basis)

Mushroom species	Na	K	Mg	Ca	Cu	Fe	Zn
Agaricus campestris	9263.89	49141.44	5895.89	321.32	16.26	7.11	7.82
Boletus edulis	4610.24	16313.49	2267.01	40.81	2.15	2.70	6.31
Cantharellus cibarius	3088.97	20822.94	5938.35	148.20	32.73	16.80	10.43

The data reported represent an average of triplicate analyses (n=3) with the percentage SD ranging within 0.3 - 2.5 %.
Ca: Calcium; K: Potassium; Mg: magnesium; Na: sodium; Mn: manganese; Cu: copper; Fe: iron; Zn: zinc.

Effects between mushroom species and their chemical and nutritional compositions

To clarify specific relationships between chemical and nutritional compositions and mushroom species a principal component analysis was used regarding only the effects of the first two principal axes (Fig. 1).

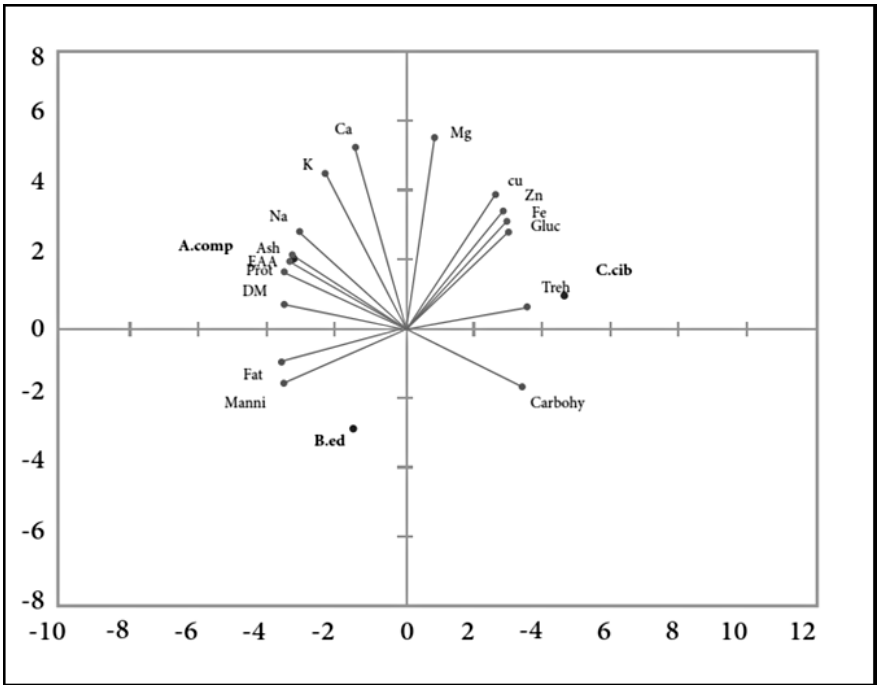

Figure 1. Biplot based on principal component analysis of mushroom chemical and nutritional compositions and species arrangement
A. campestris (*A.comp*), *C. cibarius* (*C. cib*), *B. edulis* (*B. ed*)
Dry matter (DM), Carbohydrate (Carbohy), Protein (Prot), Trehalose (Treh), Mannitol (Manni), Glucose (Gluc), Essential amino acids (EAA)
Calcium (Ca), Potassium (K), magnesium (Mg), sodium (Na), manganese (Mn), copper (Cu), iron (Fe) and zinc (Zn).

Dry matter, fat, trehalose, protein, mannitol, carbohydrates, Zn, ash, Na, glucose, Fe and lastly Cu, are the most important variables for the formation of Axis 1, judging from the values of the correlation coefficients with that axis, which are greater than 0.60 (-0.99, -0.99, 0.99, -0.96, -0.96, 0.96, -0.94, -0.92, 0.86, -0.86, 0.84, 0.80 and 0.73, respectively). For the same reason, Mg, Ca and K are the most important variables of axis 2 (0.97, 0.92 and 0.79, respectively). Both axes explain 100% of the total variation of the analysis.

Figure 1, gives a global view of the effect of all chemical and nutritional variables based on the results of the principal component analysis. Species positioned close to an arrow of a variable show strong relationship.

Species positioned close to an arrow of a variable show strong relationship. Thus, high ash content, protein and EAA concentrations are indicative of *A. campestris* presence, whereas *C. cibarius* is the richest trehalose composition.

Conclusion

From the above results we can conclude that all collected mushroom species from forests of northwest Tunisia, can be consumed as nutrient sources due to their high nutritional value related to high protein, carbohydrates and mineral content, these species have always been harvested wild in Tunisia. Therefore, collected edible mushroom species are recommended in diets because of their low content of fat and energy and also can be consumed without any health risk.

Acknowledgement

This study is a part of PhD thesis of the first author.

This work was supported by grants from the Ministry of Higher Education and Scientific Research, Tunisia.

The authors would like to express their gratitude to Dr. Slim Zgolli from the Walloon Industrial Biology Center, Liege, Belgium for valuable assistance and helpful discussion. We are very thankful to Mr. Ridha Mokni from Faculty of Sciences, Bizerta, Tunisia for his precious help.

The authors have declared no conflict of interest.

References

1- Y.T. Liu, J. Sun, Z.Y. Luo, S.Q. Rao, Y.J. Su, R.R. Xu, Y.J. Yang, Food and Chemical Toxicology, **2012**, 50 (5), 1238-1244.
2- P. Manzi, A. Aguzzi, L. Pizzoferrato, Food Chemistry, **2001**, 73 (3), 321-325.
3- M. Drewnowska, J. Falandysz, Ecotoxicology and Environmental Safety, **2015**, 113, 9-17.
4- P. K. Ouzouni, P. G. Veltsistas, E. K. Paleologos, K. A. Riganakos, Journal of Food Composition and Analysis, **2007**, 20 (6), 480-486.
5- N. Kalogeropoulos, A. E. Yanni, G. Koutrotsios, M. Aloupi, Food and Chemical Toxicology, **2013**, 55, 378-385.
6- P. Kalač, Food Chemistry, **2009**, 113 (1), 9-16.
7- S. Beluhan, A. Ranogajec, Food Chemistry, **2011**, 124 (3), 1076-1082.
8- SA.Heleno, RC.Ferreira, AL.Antonio, M-JR.P.Queiroz, L.Barros and IC.F.R.Ferreira Food Bioscience **2015**,11, 48-55.
9- J. A. Maga, Journal of Agricultural and Food Chemistry, **1981**, 29, 1-4.
10- P. Bobek, S. Galbavy, Nahrung, **1999**, 43 (5), 339-342.
11- F. Senatore, Journal of Science and Food Agriculture, **1990**, 51, 91-96.
12- E. H. Gruen, M. W. Wong, Canadian Journal of Botany, **1982**, 60 (8), 1330-1341.
13- DGF. La population forestière en Tunisie un référentiel économique et social national, **2012**, p 34.
14- DGF. Evaluation économique des biens et services des forêts tunisiennes, **2012**, p 10.
15- M. Moser, 4th Ed., Roger Phillips, **1983**.
16- R. Courtecuisse, B. Duhem, HarperCollins Publisher, **1995**.
17- AOAC. Official methods of analysis of AOAC International, 16th ed., Arlighton: Association of Official Analytical Chemists, **1995**, Vol. 1.
18- E. V. Crisan, A. Sands, New York : Academic Press, **1978**, 137-165.
19- P. Manzi, S. Marconi, A. Aguzzi, L. Pizzoferrato, Food Chemistry, **2004**, 84, 201-206.
20- L. Barros, T. Cruz, P. Baptista, L. M. Estevinho, I. C. F. R. Ferreira, Food and Chemical Toxicology, **2008**, 46 (8), 2742-2747.
21- S. Sharma, Applied Multivariate Techniques, New York : John Wiley & Sons, **1996**.
22- Z. Bano, S. Rajarathnam, K.H. Steinkraus, Critical Reviews in Food Science and Nutrition, **1988**, 27 (2), 87-158.
23- P. Mattila, P. S. Väänänen, K. Könkö, H. Aro, T. Jalava, Journal of Agricultural and Food Chemistry, **2002**, 50 (22), 6419-6422.
24- A. Colak, O. Faiz, E. Sesli, Turkish Journal of Biochemistry, **2009**, 34 (1), 25-31.
25- E. Pereira, L. Barros, A. Martins, I. C. F. R. Ferreira, Food Chemistry, **2012**, 130 (2), 394-403.
26- L. Barros, D. M. Correia, I. C. F. R. Ferreira, P. Baptista, C. S. Buelga, Food Chemistry, **2008**, 110 (4), 1046-1050.
27- L. Barros, B. A. Venturini, P. Baptista, L. M. Estevinho, I. Ferreira, Journal of Agricultural and Food Chemistry, **2008**, 56 (10), 3856-3862.
28- P. Kalac, S. Andres and N. Baumann, Ed., Science Publishers,INC, **2012**, 129-152.
29- J.L. Mau, C.C. Chyau, J. Y. Li, Y.H. Tseng, Journal of Agricultural and Food Chemistry, **1997**, 45 (12), 4726-4729.

30- A. Harada, S. Gisusi, S. Yoneyama, M. Aoyama, Food Chemistry, **2004**, 84 (2), 265-270.
31- L. Barros, P. Baptista, D. M. Correia, S. Casal, B. Oliveira, I. C. F. R. Ferreira, Food Chemistry, **2007**, 105 (1), 140-145.
32- J. H. Litchfield, Biotechnology And Bioengineering, **1967**, IX, 289-304.
33- S. A. Heleno, L. Barros, M. J. Sousa, A. Martins, I. C. F. R. Ferreira, Microchemical Journal, **2009**, 93 (2), 195-199.
34- H. A. Schroeder, The trace elements and nutrition, London : Faber and Faber, **1973**.
35- NRC/NAS. Recommended Dietary Allowances, National Academy Press, Washington, DC., **1989**.
36- P. Mattila, K. Könkö, M. Eurola, J. M. Pihlava, J. Astola, L. Vahteristo, V. Hietaniemi, J. Kumpulainen, M. Valtonen, V. Piironen, Journal of Agricultural and Food Chemistry, **2001**, 49 (5), 2343-2348.
37- X. H. Chen, L.X. Xia, H.B. Zhou, G.Z. Qiu, Journal of Agricultural and Food Chemistry, **2010**, 58, 6966-6971.