PAPER

FATTY ACID COMPOSITION IN WILD *BOLETUS EDULIS* FROM POLAND

R. PIETRZAK-FIEĆKO[1]*, M. GAŁGOWSKA[1] and S. BAKUŁA[2]
[1]Department of Commodities and Food Analysis, University of Warmia and Mazury in Olsztyn, Pl. Cieszyński 1, 10-719 Olsztyn, Poland
[2]Institute of Food Technology and Gastronomy, State College of Computer Science and Business Administration in Łomża, Akademicka 14 Str., 18-400 Łomża, Poland
*Corresponding author: Tel.: +48 8952335 70
E-mail address: renap@uwm.edu.pl

ABSTRACT

The aim of this study was to determine the content of fat and fatty acids profile in wild *Boletus edulis*. The research material consisted of 33 samples of wild *Boletus edulis* in the form of caps and stems, collected from selected regions of Poland. Methyl esters of fatty acids were prepared by Peisker's method. Separation of the examined compounds was performed by gas chromatography (FID). The dominant fatty acids in all samples under study were: C18:2, C18:1 and C16:0. The profile of fatty acids in *Boletus edulis* varied between the regions where the mushrooms were collected as well as the morphological parts of the fruiting body.

Keywords: *Boletus edulis*, edible mushrooms, fatty acids, human nutrition, Poland

1. INTRODUCTION

Edible wild mushrooms are a raw material consumed in many countries of the world as a delicacy (RIBEIRO *et al*., 2009). They are most appreciated by gourmets as well as enthusiasts of mushroom picking which, apart from being a piece of cultural heritage, has recently become a highly valued recreational activity (KALAČ, 2009; 2013). Widespread consumption of mushrooms is related primarily to their taste and smell properties, which give a sophisticated flavor to dishes. In our previous studies we examined the toxicological aspects of edible mushrooms (chlorinated hydrocarbons residues) due to the fact they are considered to be bioindicators of the level of environment contamination (GAŁGOWSKA *et al*., 2012). Nevertheless, in recent years, researchers have begun to focus on to their significant role in human nutrition. The growing awareness of consumers of food quality has made mushrooms a subject of scientific interest. The attention of researchers has been focused on their chemical composition and content of necessary nutrients essential for basic human diet supplementation. Since the last decade, a synoptic knowledge of the composition and nutritional value of the most important species of edible mushrooms has been available.

Bano suggested that the food value of mushrooms lies between vegetables and meat. Mushrooms are source of beneficial bioactive compounds (BANO, 1976). They are quite rich in protein, providing all the essential amino acids and contain relatively high amounts of carbohydrates and fiber (KALAČ, 2009). Due to the fact that mushrooms have a low fat content, they are considered low-energy functional foods, which could significantly contribute to the design of healthy dietary patterns (ALOBO, 2003; BARROS *et al.,* 2007; KAVISHREE *et al*., 2008; LEE *et al*., 2011). They contain significant amounts of vitamins and vitamin precursors, minerals and trace elements (KALAČ, 2009; 2013). Mushrooms also include sterols, with the predominance of ergosterol, the precursor of vitamin D (KALOGEROPOULOS *et al*., 2013). Apart from rich composition, mushrooms have therapeutic properties, including prevention of such health problems as: atherosclerosis, diabetes mellitus, chronic inflammation, cancer and aging (YILMAZ *et al*., 2006).

Physical and psychological development and health maintenance involves supplying the human body with proper nutrients, including animal and vegetable fat (BARROS *et al*. 2008, MOIOLI *et al*., 2007). Lipids are a basic component of a diet and play many varied roles in the organism, primarily as the richest and the most concentrated source of energy (GAWĘCKI and HRYNIEWIECKI, 2000). Lipid consumption provides the body with the proper amounts of fatty acids, including saturated (SFA), monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA). Although each member of the group of fatty acids is important in the human diet, it is also necessary to preserve the relative proportions of their consumption. Interest in MUFAs is related to their function in preventing cardiovascular diseases such as atherosclerosis (HUNTER *et al*., 2010; KANU *et al*., 2007; MOTARD-BELANGER *et al*., 2008; VON SCHACKY and HARRIS, 2007). The dietetic value of fat is to the highest extent, determined by the presence of PUFAs in its content, particularly of linoleic (C18:2 n-6) and α-linoleic acid (C18:3 n-3), which form a family of so-called "essential" fatty acids (INNIS, 2005; PRZYSŁAWSKI and BOLESŁAWSKA, 2006). They are converted to tissue hormones, which affect the functions of numerous tissues and organs and reinforce or weaken the regulatory effect of the hormonal and nervous systems. EFAs (essential fatty acids) prevent blood clotting and hypertension. Additionally, they increase the blood supply to the heart and contribute to the proper distribution of cholesterol in the body (KRIS-ETHERTON and ETHERTON, 2003; WILLIAMS, 2000).

Polish literature contains only few references concerning the profile of fatty acids in edible mushrooms. Based on international reports, mushrooms contain significant amounts of

unsaturated acids and low amounts of saturated acids (RIBEIRO *et al*., 2009; KALAČ, 2009; 2013; BARROS *et al*., 2007; KAVISHREE *et al*., 2008; YILMAZ *et al*., 2006; BARROS *et al*., 2008; PEDNEAULT *et al*., 2006). This is an important reason to recommend the raw material in various diets. The growing interest in the consumption of edible mushrooms provides an incentive to carry out a broad scope of analytical research concerning the composition of fatty acids in these raw materials.
In Poland, the picking and consumption of mushrooms is very popular due to the occurrence of large areas of forests. Of the many species of mushrooms, *Boletus edulis*, (a member of the *Boletaceae* family), is highly valued by consumers due to its unique flavor characteristics.
Taking the above into account, the aim of this study was to determine the content of the fat and fatty acid profile in wild *Boletus edulis*, indicate potential differences in the composition of fatty acids between the various morphological parts and examine the impact of the mushrooms' vegetative sites on the fatty acid profile.

2. MATERIALS AND METHODS

The research material consisted of 33 samples of whole fruiting bodies of wild Boletus edulis from four selected regions of Poland (Fig. 1) and 29 averaged samples in the form of caps and stems, collected in 2010 during the period from July to September. The samples were prepared (selected, cleaned, dried in a fruit and vegetable drier) according to PN-68/A-78508-1968 (PN-68/A-78508-1968). The dried and finely cut-up material was subjected to extraction in a Soxhlet's apparatus in order to obtain lipid substances PN-A-78509:2007 (PN-A-78509:2007). Methyl esters of fatty acids were prepared by Peisker's method, using a mixture of methyl alcohol, sulphurous acid and chloroform (PEISKER, 1964).

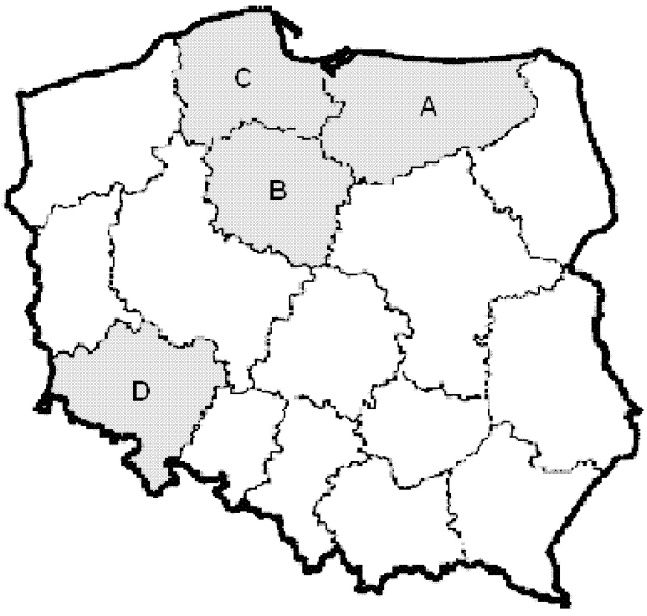


Figure 1: Location of sampling of *Boletus edulis*.

Separation of the examined compounds was performed by gas chromatography. The conditions of chromatographic separation involved a gas chromatographer (7890A Agilent Technologies) and a flame ionization detector (FID); capillary column Supelcowax 10: length - 30 m, inside diameter - 0.32 mm, liquid phase – Supelcowax 10, film thickness 0.25 μm; temperature: detector – 250°C, dispenser – 230°C and column – 195°C; carrier gas - helium, flow rate - 1.5 ml/min (51 cm/s); split 50:1.
The identification of fatty acids was carried out on the basis of their retention time in relation to the standard retention time of fatty acid methyl esters. For this purpose, a mixture of 37 standards of Supelco 37 Component FAME Mix (10 mg/ml in methylene chloride (varied)) was applied. For the calculation of the percentage share of fatty acids, a Chemostation computer program was used. In the experiment, there were 17 fatty acids identified from C12:0 to C24:1, which were divided into three groups: saturated (SFA), monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA).
Statistical analyses were conducted with Microsoft Excel software, which included calculation of the mean values as well as the standard deviations. The significance of difference of the mean values between the samples was determined using Statistica 10 software (Duncan's test, analysis at the level of significance of p=0.05).

3. RESULTS AND DISCUSSIONS

The fatty acid profiles of *Boletus edulis* are shown in Tables 1 and 2 and in Figs. 3 and 4. Statistical differences were found in the fat content, depending on the morphological parts of a mushroom. The average fat content in caps and stems of *Boletus edulis* was 4.38% and 1.75%, respectively (Fig. 2).
In Boletus edulis there 17 different fatty acids from C 12:0 to C24:1 were determined. Table 1 presents the fatty acids composition in whole fruiting bodies of wild Boletus edulis depending on research regions.

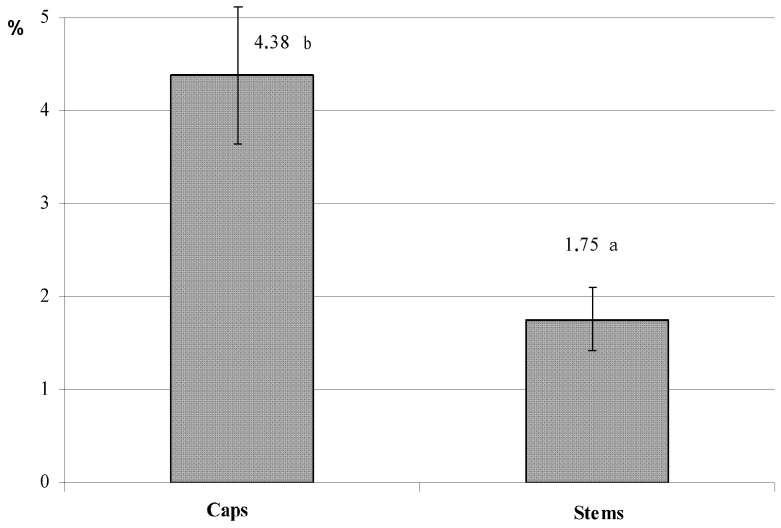


Figure 2: The average content of fat in *Boletus edulis* depending on the morphological parts of fruiting body.

The content of every fatty acid was varied depending on the region. Analyzing the dominant acids (C16, C18: 1 and 18: 2), the highest percentage of palmitic acid was found in the region B, while the lowest - statistically different from the rest - in the region A. However, for the region A, was the highest percentage share of C18:1 acid reported. The lowest contribution of this acid was observed for the region B. In the case of C18:2 acid no statistically significant differences were found between regions A and B. The highest content of this acid was indicated for the region D, and the lowest for region C. Determinated differences between regions can be related with different composition of the soil, weather conditions, *et al*.

Table 1: The fatty acids profile in *Boletus edulis* originating from different regions of Poland (n= 33).

	Region			
Fatty acids	**A**	**B**	**C**	**D**
	(n = 4)	**(n = 9)**	**(n = 10)**	**(n = 10)**
C12:0	0.10±0.00^{a}	0.41±0.06^{c}	0.22±0.04^{b}	0.77±0.09^{d}
C14:0	0.13±0.01^{a}	1.11±0.18^{c}	0.65±0.11^{b}	0.76±0.13^{b}
C15:0	0.10±0.00^{a}	0.89±0.14^{c}	1.00±0.13^{c}	0.50±0.09^{b}
C16:0	8.39±0.42^{a}	28.84±3.35^{c}	25.10±1.03^{c}	16.82±1.21^{b}
C16:1	0.75±0.06^{a}	1.69±0.14^{c}	1.50±0.18^{c}	1.11±0.19^{b}
C17:0	0.10±0.00^{a}	0.24±0.04^{c}	0.32±0.07^{c}	0.19±0.03^{b}
C18:0	3.12±0.04^{b}	2.87±0.27^{ab}	2.78±0.38^{ab}	2.49±0.30^{a}
C18:1	44.75±0.70^{d}	19.56±3.11^{a}	31.71±2.56^{c}	24.33±0.95^{b}
C18:2	40.71±0.51^{b}	40.07±4.02^{b}	32.78±2.60^{a}	50.62±2.00^{c}
C18:3	0.31±0.02^{a}	1.30±0.22^{d}	0.60±0.12^{c}	0.42±0.06^{b}
C20:0	0.40±0.01^{b}	0.23±0.02^{a}	0.27±0.06^{ac}	0.40±0.07^{bc}
C20:1	0.74±0.05^{b}	0.35±0.06^{a}	0.73±0.11^{b}	0.35±0.05^{a}
C20:2	0.20±0.01^{a}	0.92±0.16^{c}	0.29±0.04^{b}	0.18±0.02^{a}
C22:0	0.26±0.08^{a}	0.68±0.09^{d}	0.54±0.06^{cd}	0.44±0.06^{bc}
C22:1	0.16±0.04^{a}	0.23±0.04^{a}	0.53±0.08^{b}	0.43±0.07^{b}
C24:0	0.10±0.00^{a}	0.51±0.10^{b}	0.77±0.11^{c}	0.10±0.02^{a}
C24:1	0.11±0.01^{a}	0.10±0.00^{a}	0.22±0.05^{b}	0.10±0.01^{a}

$^{a-d}$ The significance of difference of the mean values between the samples; p = 0.05.

A similar relation in the case of content of predominant fatty acids (linoleic acid (C18:2), oleic (C18:1) and palmitic (C16:0)) in this species was also observed by other authors (KAVISHREE *et al*., 2008, BARROS *et al*. 2008). In presented studies, linoleic acid content ranged from 32.78-50.62%. A similar amount of C18:2 was found by the following authors: BARROS *et al*. (2008) - 44.32% (Portugal), KAVISHREE *et al*. (2008) - 33.80% (India), PEDNEAULT *et al*. (2006) - 42.20% (Canada), YILMAZ *et al*. (2006) - 33.60% (Turkey). The content of C18:1 acid in the *Boletus edulis* under study ranged from 19.56 to 44.75%. In their research BARROS *et al*. (2008) found 39.72%, PEDNEAULT *et al*. (2006) - 36.01%, KAVISHREE *et al*. (2008) - 31.10%, YILMAZ *et al*. (2006) - 30.20%. Palmitic acid (C16:0) was

found in samples in the range of 8.39 - 28.84%. The content of the acid in the studies of PEDNEAULT *et al*. (2006) was that of 9.80%, of KAVISHREE *et al*. (2008) - 21.60% and of BARROS *et al*. (2008) - 10.03%.
In none of the samples were short-chained fatty acids detected, while BARROS *et al*. (2008) and PEDNEAULT *et al*. (2006) observed the presence of trace amounts of C6:0, C8:0 and C10:0 in *Boletus edulis*. The presence of fatty acids in the *trans* configuration was also not stated.
The obtained results varied depending on the morphological parts of the mushroom, what is presented in Table 2.

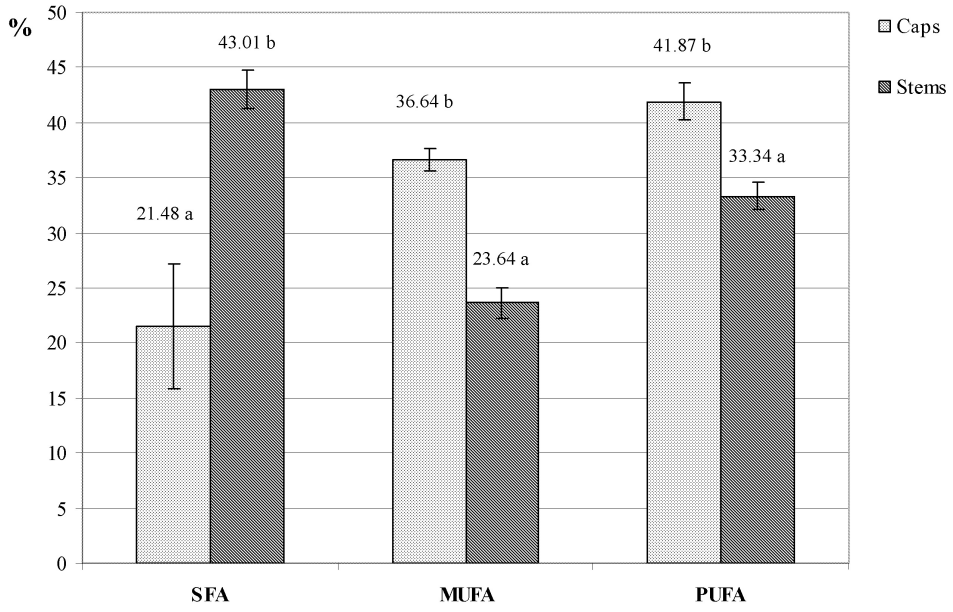
Table 2: The fatty acids profile in *Boletus edulis* depending on morphological parts of the mushroom.

Fatty acids	Caps (n = 15)	Stems (n = 14)
C12:0	0.57±0.16^{b}	0.30±0.07^{a}
C14:0	0.69±0.03^{a}	0.61±0.07^{a}
C15:0	0.46±0.11^{a}	1.45±0.20^{b}
C16:0	15.96±4.77^{a}	35.95±0.95^{b}
C16:1	1.11±0.07^{a}	1.94±0.11^{b}
C17:0	0.16±0.02^{a}	0.26±0.06^{b}
C18:0	2.69±0.48^{a}	2.40±0.14^{a}
C18:1	34.51±0.80^{b}	20.69±1.12^{a}
C18:2	40.71±1.41^{b}	32.68±1.18^{a}
C18:3	0.90±0.20^{b}	0.48±0.04^{a}
C20:0	0.36±0.08^{a}	0.33±0.02^{a}
C20:1	0.61±0.09^{b}	0.35±0.05^{a}
C20:2	0.26±0.06^{a}	0.18±0.03^{a}
C22:0	0.36±0.03^{a}	0.85±0.11^{b}
C22:1	0.31±0.08^{a}	0.55±0.07^{b}
C24:0	0.23±0.02^{a}	0.86±0.12^{b}
C24:1	0.10±0.01^{a}	0.11±0.02^{a}

$^{a-d}$ The significance of difference of the mean values between the samples; p = 0.05.

The predominant fatty acids in caps were C18:2, C18:1 and C16:0 (40.71%, 34.51%, 15.96%, respectively). In the case of three predominant fatty acids in stems, the biggest share had C16:0 (35.95 %), next – C18:2 and C18:1 (32.68%, 20.69%, respectively).
In the examined morphological parts of the mushrooms statistically significant differences in the content of C18:2 acid were found, where in the caps 40.71% was determined and 32.68% in the stems. The stems of the same species of mushroom from Turkey had 28.40% C18:2 acid content (YILMAZ *et al*., 2006). A statistically significant difference in the content of oleic acid (C18:1) in the caps (34.51%) and stems (20.69%) was found. The content of this acid in the stems at level of 8.30% was determined by YILMAZ *et al*. (2006). The stems of

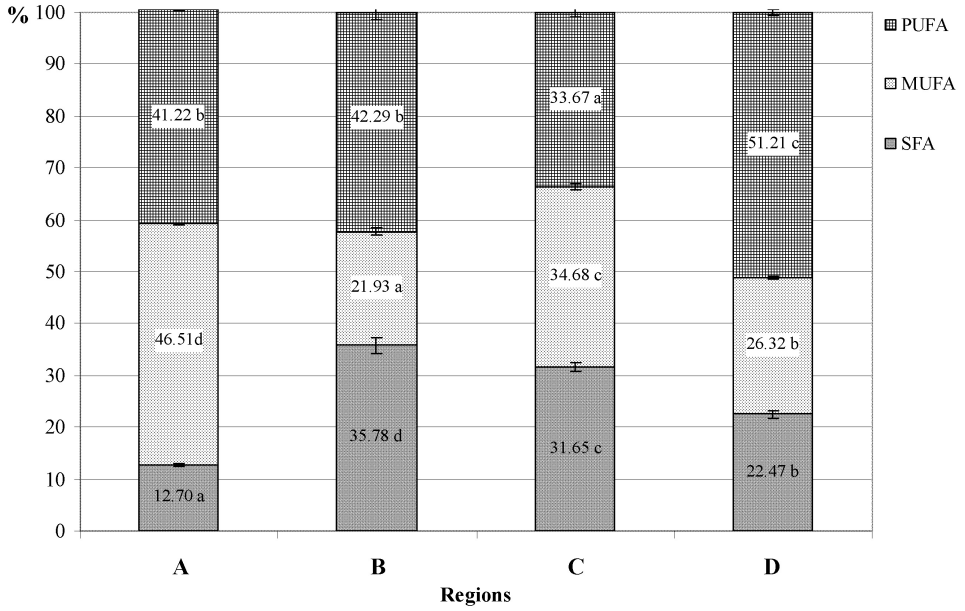
Boletus edulis (35.95%) were characterized by a significantly higher content of C16:0 acid compared to caps (15.96%).
The content of other fatty acids ranged from 0.10 - 2.69% and was dependent on the morphological parts of the mushroom.
It was found that the percentage share of each group of fatty acids (SFA, MUFA PUFA) in the studied morphological parts of *Boletus edulis* was statistically different (Fig. 3).



[a–d]The significance of difference of the mean values between the samples; p = 0.05.

Figure 3: Percentage contribution of SFA, MUFA, PUFA in *Boletus edulis* depending on morphological parts of the mushroom.

In the case of saturated fatty acids the share was about twice as high in caps (43.01%) than in the stems (21.48%). The caps were characterized by a higher contribution of monounsaturated (36.64%) and polyunsaturated fatty acids (41.87%) compared to the stems (23.64% and 33.34%, respectively).
The main groups of fatty acids present in the mushrooms under study were unsaturated fatty acids (from 64.22 to 87.73 %). PEDNEAULT *et al*. (2006) also obtained similar amounts 84.50%. There were significant statistical differences found in the contents of particular groups of fatty acids (SFA, MUFA, PUFA) in *Boletus edulis* from different regions (Fig. 4). The analyzed samples had the largest share of polyunsaturated (33.67 - 51.21%) and the lowest contribution of saturated fatty acids 12.70 - 35.78%.
The biggest share of unsaturated fatty acids (41.22% of PUFA and 46.51% of MUFA) was observed in Boletus edulis from region A (87.73%). In the regions B and C there were similar contributions of unsaturated fatty acids (64.22% and 68.35%, respectively) determined. Nevertheless the region B characterized the higher content of PUFA (42.29%) and only 21.92% of MUFA, while in the region C there was indicated 33.67% of PUFA and 34.68% of MUFA. The mushrooms from the region D were the richest source of PUFA (51.21%) (Fig. 4).



[a–d]The significance of difference of the mean values between the samples; p = 0.05.

Figure 4: Percentage contribution of SFA, MUFA, PUFA in *Boletus edulis* originating from different regions of Poland.

4. CONCLUSIONS

The profile of fatty acids in *Boletus edulis* varied between the regions where the mushrooms were collected as well as the morphological parts of the fruiting body. This confirms view of SANMEE *et al*. (2003) and DIEZ and ALVAREZ (2001), that a number of factors usually influence the nutritional composition of mushrooms. These factors include growing site, type of substrates, mushroom type, developmental stages and part of the fungal samples analyzed (DIEZ and ALVAREZ, 2001; SANMEE *et al*., 2003). The observed differences in the fatty acids content in mushrooms under study may result, among others, from the different chemical composition of the substrate in particular regions. However, this thesis requires confirmation in further studies.

In terms of human nutrition, caps of *Boletus edulis* are a more valuable raw material than stems due to the significantly higher content of MUFA and PUFA and lower SFA. Among polyunsaturated fatty acids, the most noteworthy is linoleic acid C18:2 (Ω-6), which is a precursor of 1-acetic-3-ol the major component of mushrooms giving them a specific aroma (RIBEIRO *et al*., 2009; BARROS *et al*., 2007). The high content of this acid in Polish *Boletus edulis* provides that the mushroom may be recommended in different types of diets for people with high blood cholesterol (KAVISHREE *et al*., 2008; VAZ *et al*., 2011).

REFERENCES

Alobo A.P. 2003. Proximate composition and functional properties of *Pleurotus tuberregium sclerotia* flour and protein concentrate. Plant Foods Hum. Nutr. 58:1-9.

Bano Z. 1976. Nutritive value of Indian mushroom. Ind. Mushroom Sc. 1, 2:473-484.

Barros L., Baptista P., Correia D.M., Casal S., Oliveira B. and Ferreira I.C.F.R. 2007. Fatty acid and sugar composition, and nutritional value of five wild edible mushrooms from Northest Portugal. Food Chem. 105:140-145.

Barros L., Cruz T., Babtista P., Estevinho L.M. and Ferreira C.F.R. 2008. Wild and commercial mushrooms as source of nutritient and nutraceuticals. Food Chem. Toxicol. 46:2742-2747.

Diez V.A. and Alvarez A. 2001. Compositional and nutritional studies on two wild edible mushrooms from North West Spain. Food Chem. 75:417-422.

Gałgowska M., Pietrzak-Fiećko R. and Felkner-Poźniakowska B. 2012. Assessment of the chlorinated hydrocarbons residues contamination in edible mushrooms from the North-Eastern part of Poland. Food Chem. Toxicol. 50:4125-4129.

Gawęcki J. and Hryniewiecki L. 2000. Human nutrition. The basics of food science (tome 1). Warszawa, Wydawnictwo Naukowe PWN (in Polish).

Hunter J.E., Zhang J. and Kris-Etherton P.M. 2010. Cardiovascular disease risk of dietary stearic acid compared with trans, other saturated, and unsaturated fatty acids: a systematic review. Am. J. Clin. Nutr. 91:46-63.

Innis S.M. 2005. Essential fatty acid transfer and fetal development. Placenta 26(19):70-75.

Kalač P. 2009. Chemical composition and nutritional value of European species of wild growing mushrooms: A review. Food Chem. 113:9-16.

Kalač P. 2013. A review of chemical composition and nutritional value of wild-growing and cultivated mushrooms. J. Sci. Food Agric. 93(2): 209–18.

Kalogeropoulos N., Yanni A.E., Koutrotsios G. and Aloupi M. 2013. Bioactive microconstituents and antioxidant properties of wild edible mushrooms from the island of Lesvos, Greece. Food Chem. Toxicol. 55:378-385.

Kanu P.J., Zhu K., Kanu J.B., Zhou H., Qian H. and Zhu K. 2007. Biologically active components and nutraceuticals in sesame and related products: A review and prospect. Trends Food Sci. Technol. 18:599-608.

Kavishree S., Hemawathy J., Lokesh B.R., Shashirekha M.N. and Rajarathnam S. 2008. Fat and fatty acids of Indian edible mushrooms. Food Chem. 106:597-602.

Kris-Etherton P.M. and Etherton T.D. 2003. The impact of the changing fatty acid profile of fats on diet assessment and health. J. Food Compos. Anal. 16:373-378.

Lee K.J., Yun I.J., Kim H.Y., Lim S.H., Ham H.J., Eum W.S. and Joo J.H. 2011. Amino acid and fatty acid compositions of *Agrocybe chaxingu*, an edible mushroom. J. Food Compos. Anal. 24:175-178.

Moioli B., Contarini G., Avalli A., Catillo G., Orru L., De Matteis G., Masoero G. and Napolitano F. 2007. Effect of stearoyl-coenzyme A desaturase polymorphism on fatty acid composition of milk. J. Dairy Sci. 90: 3553-3558.

Motard-Belanger A., Charest A., Grenier G., Paquin P., Chouinard Y., Lemieux S., Couture P. and Lamarche B. 2008. Study of the effect of trans fatty acids from ruminants on blood lipids and other risk factors for cardiovascular disease. Am. J. Clin. Nutr 87: 593-599.

Pedneault K., Angers P., Gosselin A., Tweddell R.J. 2006. Fatty acid composition of lipids from mushrooms belonging to the family *Boletaceae*. Mycol. Res. 110:1179-1183.

Peisker K. 1964. A rapid semi-micro method for preparation of methyl esters from triglycerides using chloroform, methanol, sulphuric acid. J. Am. Oil Chem. Soc. 41: 87-88.

PN-68/A-78508-1968 Mushrooms And Mushroom Products – collection and sample preparation. Polish Committee for Standardization(PN) p. 1-10 (in Polish).

PN A-78509-2007 Fresh Mushrooms And Mushroom Products - Methods Of Testing. Polish Committee for Standardization(PN) p.1-24 (in Polish).

Przysławski J. and Bolesławska I. 2006. Food lipids- therapeutic or pathogenic factor. Tłuszcze Jadalne 41:179-192 (in Polish).

Ribeiro B., Guedes de Pinho P., Andrade P.B., Baptista P. and Valentão P. 2009. Fatty acid composition of wild edible mushrooms species: A comparative study. Microchem. J. 93:29-35.

Sanmee R., Dell B., Lumyong P., Izumori K. and Lumyong S. 2003. Nutritive value of popular wild edible mushroom from northern Thailand. Food Chem. 82:527-532.

Vaz J.A., Barros L., Martins A., Santos-Buelga C., Vasconcelos M.H. and Ferreira I.C.F.R. 2011. Chemical composition of wild edible mushrooms and antioxidant properties of their water soluble polysaccharidic and ethanolic fractions. Food Chem. 126:610-616.

Von Schacky C. and Harris W.S. 2007. Cardiovascular benefits of omega-3 fatty acids. Cardiovasc. Res. 73:310-315.

Williams C.M. 2000. Dietary fatty acids and human health. Ann. Zootech. 49:165-180.

Yilmaz N., Solmaz M., Türkekul I. and Elmastas M. 2006. Fatty acid composition in some wild edible mushrooms growing in the middle Black Sea region of Turkey. Food Chem. 99:168-174.

Paper Received January 20, 2015 Accepted December 12, 2015