European Food Science and Engineering

Eur Food Sci Eng 2021, 2 (2), 46-51

https://dergipark.org.tr/tr/pub/efse

A review on fatty acid profiles of edible wild mushrooms from Turkey

Sanem Bulam[1*], Nebahat Şule Üstün[2] and Aysun Pekşen[3]

[1] Department of Food Engineering, Faculty of Engineering, Giresun University, Giresun, Turkey
[2] Department of Food Engineering, Faculty of Engineering, Ondokuz Mayıs University, Samsun, Turkey
[3] Department of Horticulture, Faculty of Agriculture, Ondokuz Mayıs University, Samsun, Turkey

ARTICLE INFO

Review Article
Article History:
Received: 4 October 2021
Accepted: 24 November 2021
Available Online: 04 December 2021
Keywords:
Edible wild mushroom
Fatty acid composition
Health
Omega-6
Turkey

ABSTRACT

Edible wild mushrooms (EWM) are called “healthy foods” in terms of nutritional value due to their low energy, fat, and saturated fatty acids (SFA) content, high unsaturated fatty acids (UFA) level, and being cholesterol-free. EWM mostly contain crude fat as 2-6 g 100 g^{-1} DW and this fat mainly consists of UFA. In terms of polyunsaturated (PUFA) and monounsaturated fatty acids (MUFA) composition, linoleic (C18:2, ω-6) and oleic acids (C18:1, ω-9) represent more than two-thirds weight of all fatty acids found in EWM. Palmitic acid (C16:0) as one of SFA ranks third with a large difference in content. In Turkey, fatty acid compositions of EWM mostly consist of linoleic, oleic, palmitic, and stearic acids (C18:0) with a higher ratio of ΣUFA than ΣSFA. Essential UFA including linoleic and linolenic acids (C18:3, ω-3), which cannot be synthesized by human body, can be obtained from EWM. UFA are important for cardiovascular health, lowering blood cholesterol, and preventing obesity. ω-3 PUFA including EPA and DHA can modify structures of cell membranes, cell protein functions, and patterns of gene expression. Due to increasing interest in EWM as “functional foods”, this review highlights recently determined fatty acid profiles of EWM growing in vegetation of Turkey.

1. Introduction

Mushrooms, which are taxonomically placed in two phyla, the Ascomycota and Basidiomycota in subkingdom Dikarya, are widely distributed worldwide. Today, about 7000 mushroom species are known which have diverse degrees of edibility and more than 3000 species from 231 genera are regarded as prime edible wild mushrooms (EWM) (Badalyan et al., 2019). Functional EWM are classified as saprophytic, mycorrhizal, and parasitic species (Díaz-Godínez and Téllez-Téllez, 2021) which produce an extensive diversity of high- and low-molecular-weight bioactive compounds (alkaloids, bioelements, ergosterols, ergothioneine, glucans, glutathiones, lectins, lipids, lovastatins, peptidoglycans, phenolics, polyketides, polysaccharides, polysaccharide-proteins/peptides, proteins, ribosomal and non-ribosomal peptides, steroids, terpenoids, etc.) and have therapeutic effects (analgesic, antibacterial, anticancer, antifungal, anti-inflammatory, antioxidant, antitumor, antiviral, cytotoxic, hepatoprotective, hypocholesterolemic, hypoglycemic, hypotensive, immunomodulatory, immunosuppressive, mitogenic/regenerative, prebiotic, probiotic, etc.) (Bulam et al., 2018a, 2018b; Kothari et al., 2018; Badalyan et al., 2019; Bulam et al., 2019a, 2019b; Abdelshafy et al., 2021; Podkowa et al., 2021). The highest levels of mycophilia have been stated in numerous regions of Southern and Eastern Europe, Turkey, parts of Africa, Mexico, and most of Asia since ancient times (Kotowski et al., 2019). Fresh or dried EWM and mushroom-based bio-products have been utilized as an ethnomedicine against cancer, anemia, eye infections and diseases, cough, cold, fatigue, and for increasing fertility and wound healing for ages (Akyüz et al., 2017; Azeem et al., 2020). EWM are also considered as a “gourmet food” due to their unique taste, aroma and flavor based on their eight-carbon derivatives, soluble sugars, and diverse volatile organic compounds. In terms of nutritional value, EWM are “healthy foods” containing essential minerals, trace elements, vitamins, high levels of water, dietary fiber (chitin), carbohydrates, high biological value proteins, unsaturated fatty acids with low fat and low energy value, and nearly free of cholesterol (Badalyan et al., 2019; Sande et al., 2019).

On the other hand, EWM are among the most valuable bioeconomic non-wood forest products which are widely known and used as natural, cultural/traditional, and spiritual sources of food/nutrition and income by both rural households and recreational, hobby and professional collectors in Europe as well as in Turkey. Folk taxonomic and DNA barcoded

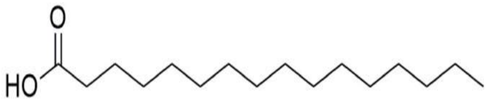
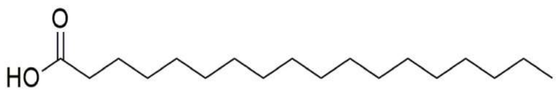
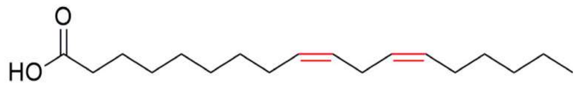
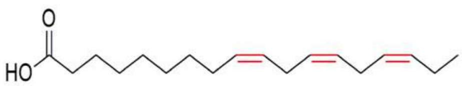
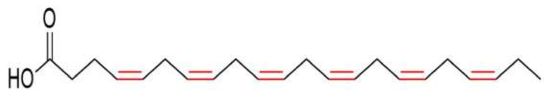
*Corresponding author
E-mail address: sanem.bulam@giresun.edu.tr

Penny Buns, Chanterelles, Milk Cups, Yellowroots, Morels, Caesar's Mushrooms, Hedgehog Mushrooms, Black Trumpets, Truffles, and other EWM are the most collected species as 1017 billion kg year^{-1} with a total economic value of 8.1 billion € year^{-1} which are not only daily consumed as raw, fresh cooked, grilled, roasted, and fried with a high edible quality but also preserved as dried, pickled, cooled, and frozen by the indigenous people. Moreover, they are sold as fresh or processed with a sale value of 1.7 billion € year^{-1} throughout Europe including Turkey by the local collectors (Akyüz et al., 2017; Bulam et al., 2018c; Kotowski et al., 2019; Lovrić et al., 2020; 2021; Arslan et al., 2021). In addition, there is a growing demand for EWM by vegetarians and vegans for substitution of meat-based foods (Lang, 2020), which are used by highly educated adult women as fresh and processed (Boin and Nunes, 2018), and other consumers or researchers who prefer them for mycotherapy (Elkhateeb and Daba, 2021), seasonal mycotourism (Latorre et al., 2021), dye and traditional/modern culinary recipes (Erdem et al., 2018; Kotowski et al., 2019), cultivation and healthier, processed, value-added bio-tech products (Badalyan et al., 2019; Mingyi et al., 2019; Singhal et al., 2019; Gonzales et al., 2020), and novel industrial applications in ready-to-eat and ready-to-cook food, agricultural, and product development sectors (Bulam et al., 2019c; Kumar et al., 2021).

EWM contain oleic, linoleic, and linolenic acids as major constituents of essential and non-essential unsaturated fatty acids (UFA) (70% of the total fatty acids) in their lipid profiles and low fat about 0.1-16.3 g 100 g^{-1}. EWM lipids mainly consist of mono (MUFA) and polyunsaturated fatty acids (PUFA) in comparison to saturated fatty acids (SFA), and the ratio of UFA to SFA is often suitable to categorize them as a healthy resource of lipids. Palmitic (16:0), oleic (18:1), and linoleic (18:2) acids are the most dominant fatty acids in the species of Basidiomycota. Mammals can convert saturated stearic acid (C18:0) into a MUFA called as oleic acid (C18:1, ω-9) via desaturase enzymes. They also produce arachidonic acid (AA) as a ω-6 PUFA, and eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) as ω-3 PUFA with other desaturase enzymes metabolizing linoleic (C18:2; ω-6) and linolenic (C18:3; ω-3) fatty acids to these longer-chain fatty acids with 20 and 22 carbon atoms (Sande et al., 2019). Nevertheless, human metabolism lacks enzymes which are essential for ω-3 desaturation, so it is not able to synthesize linoleic and linolenic acids. Therefore, the human diet must involve foods containing essential UFA such as EWM. As a part of the daily diet, all the fatty acids join into the bloodstreams, cells, and tissues of human beings.

The consumption of essential UFA in balanced ratios (1:1 or 2:1 ω-6/ω-3) may help to prevent obesity while an unbalanced ω-6/ω-3 ratio has been related to adipogenesis. Essential UFA also join in high-density lipoprotein (HDL) composition, which carries fat from blood to liver, where it can be metabolized by decreasing blood cholesterol and risk of cardiovascular disorders. In addition, PUFA are precursors for the synthesis of eicosanoids such as prostaglandins and resolvins, which are important for cardiovascular health, inflammation decrease, and various bioactivities. EPA and DHA as ω-3 PUFA can modify structures of cell membranes, cell protein functions, production of lipid mediators, and patterns of gene expression promoting to human welfare improving (Sande et al., 2019; Işık et al., 2020; Çayan et al., 2020; Kaşık et al., 2020; Acay et al., 2021; Bengü et al., 2021; Taşkın et al., 2021). Formations of abundant and beneficial fatty acids of EWM were given in Table 1.

Table 1. Important saturated and unsaturated fatty acids of edible wild mushrooms (Sande et al., 2019)

Saturated fatty acids	 Palmitic acid C16:0	 Stearic acid C18:0
Unsaturated fatty acids	 Oleic acid C18:1, Δ^{9} (ω-9)	 Linoleic acid C18:2, $\Delta^{9,12}$ (ω-6)
	 Linolenic acid C18:3, $\Delta^{9,12,15}$ (ω-3)	 Docosahexanoic acid (DHA) C22:6, $\Delta^{4,7,10,13,16,19}$ (ω-3)
	 Eicosapentaenoic acid (EPA) C20:5, $\Delta^{5,8,11,14,17}$ (ω-3)	

In the rich vegetation of Turkey due to suitable climatic conditions (Üstün et al., 2019), 2728 species of Ascomycota and 2782 species of Basidiomycota including EWM were previously identified (Sesli et al., 2020). EWM are collected mostly with traditional information, consumed, and sold as fresh or processed in local markets or sold to mushroom exporting companies, mushroom processing plants, marketers, and restaurants through intermediaries, or directly to factories and hotels by the locals (Akyüz et al., 2017; Bulam et al., 2018c; Arslan et al., 2021). Turkey gained about 171 million $ income from foreign trade of edible mushrooms belonging to 13 genera and mushroom products in 2007-2017 period (Bulam et al., 2018c). However, EWM are not commonly consumed by urban people and gastronomy chefs because of supply/continuity problems, inability to provide the same quality and standard, unrecognition of species, dislike of mushroom taste, and fear of poisoning in Turkey (Erdem et al., 2018; Gürgen et al., 2018; Sesli et al., 2020; Arslan et al., 2021). Therefore, this review highlights the recent fatty acid compositions of EWM growing in Turkey to introduce species and stimulate their usage for a healthier daily diet in terms of prevention and therapy of obesity, hypercholesterolemia, and cardiovascular diseases.

2. Fatty Acid Composition Studies of Edible Wild Mushrooms From Mycobiota of Turkey

In Turkey, the most common fatty acids previously determined were linoleic and oleic acids as UFA, and palmitic and stearic acids as SFA. In addition, the total ΣMUFA and ΣPUFA were found higher than ΣSFA in diverse EWM of Turkey. The up-to-date study results of fatty acid compositions of EWM from Turkey were given in Table 2. In a recent study, Acay et al. (2021) determined main fatty acids in phospholipid (PL), total lipid (TL) and triacylglycerol (TG) parts of *Pleurotus eryngii* collected from Hakkari including C8:0, C12:0, C13:0, C14:0, C15:0, C16:0, C17:0, C18:0 and C20:0 as SFA, C16:1n-7, C18:1n-9 and C20:1n-9 as MUFA, and C18:2n-6, C18:3n-3 as PUFA. C8:0 was identified only in the TG part at a trace amount. ΣMUFA ratio (44.5%) was higher than ΣSFA (18.25%) and ΣPUFA (37.2%) in TL part. In PL part, ΣPUFA ratio (50.14%) was significantly the highest when compared with ΣSFA (17.87%) and ΣMUFA (31.95%). The ΣMUFA (52.95%) percentage was found higher than ΣSFA (11.28%) and ΣPUFA (29.71%) in TG part. Linoleic (C18:2n-6), oleic (C18:1n-9) and palmitic (C16:0) acids were found as major fatty acids in all parts of *P. eryngii*.

Bengü et al. (2021) studied five EWM growing in Tokat and Yozgat. The most dominant fatty acid in *Agaricus benesii* and *Macrolepiota phaeodisca* was linoleic acid as 62.58 and 45.02%, respectively. The most abundant fatty acid in *Amanita vaginata*, *Leccinum aurantiacum* and *Sarcodon imbricatus* was oleic acid as 54.32, 46.98 and 48.67%, respectively. The highest rate of ΣSFA was found in *M. phaeodisca* with 43.11% due to the high levels of palmitic acid (30.70%), while the lowest ΣSFA was found in *L. aurantiacum* with 21.65%. The highest rate of ΣUFA was determined in *L. aurantiacum* with 78.35% due to the high levels of oleic acid (46.98%) and linoleic acid (31.37%), while the lowest of ΣUFA was determined in *M. phaeodisca* with 56.89%. ΣUFA in all of species was higher than ΣSFA. ΣPUFA was higher in *A. benesii* and *M. phaeodisca*, and ΣMUFA was higher in *A. vaginata* and *S. imbricatus*. Major fatty acid was linoleic acid in *A. benesii* and *M. phaeodisca* as 62.58, 45.02%, respectively. The dominant fatty acid was oleic acid in *A. vaginata, L. aurantiacum* and *S. imbricatus* as 54.32, 46.98 and 48.67%, respectively.

Taşkın et al. (2021) investigated fatty acid profiles of six *Morchella* species (*Morchella deliciosa* (HT682), *M. dunalii* (HT562), *M. esculenta* (HT704), *M. importuna* group (HT667, HT681), *M. mediterraneensis* (HT698), and *M. purpurascens* group (HT565, HT592, HT662, HT699)) collected from Adana, Balıkesir, Çanakkale, Edirne, Isparta, İzmir, and Osmaniye. Linoleic acid was detected to be the most abundant fatty acid in HT565 (69.61%), HT592 (69.17%), HT704 (67.57%), HT662 (58.18%), HT682 (52.09%) and HT667 (50.82%) and it was followed by oleic acid except HT565. For the rest of the collected samples numbered as HT681 (64.54%), HT698 (63.29%), HT699 (63.14%) and HT562 (56.17%), oleic acid was dominant and followed by linoleic acid in the same samples. ΣUFA/SFA ratios were found as 10.79 in HT562, 4.78 in HT565, 6.80 in HT592, 8.09 in HT662, 6.67 in HT667, 4.35 in HT681, 8.70 in HT682, 8.64 in HT698, 7.90 in HT699 and 7.43 in HT704 all of which were higher than 1.6 value recommended by WHO (2003).

In another study, seven fatty acids of *Rhizopogon luteolus* and ten fatty acids of *R. roseolus* growing in Tokat were detected in different ratios (Işık et al., 2020). In *R. luteolus*, the highest fatty acid was linoleic acid (50.30%), while oleic acid was the highest (42.07%) in *R. roseolus*. Other fatty acids with a high ratio were oleic (26.16%) and palmitic acid (15.48%) in *R. luteolus*, linoleic (35.20%) and palmitic acid (9.82%) in *R. roseolus*. In both mushrooms, ΣUFA ratio was higher than ΣSFA ratio.

Çayan et al. (2020) determined oleic (6.76-59.25%), linoleic (6.45-61.63%), palmitic (3.57-28.09%) and stearic acids (0.90-19.77%) as the abundant fatty acids in 17 samples collected from Muğla. Moreover, palmitoleic (0.47-9.60%), pentadecanoic (0.30-5.69%), arachidic (0.29-4.57%), myristic (0.15-1.53%), tetracosanoic (0.11-15.90%), and azelaic (0.08-5.45%) acids were determined in small amounts in almost all investigated samples. The total fatty acid amounts for SFA, MUFA, and PUFA ranged from 9.51 to 74.31%, 8.52 to 59.72%, 6.45 to 61.63%, respectively. The amounts of UFA were more than SFA in all analyzed species apart from *Daedalea quercina*, *Gloeophyllum trabeum* and *Schizophyllum commune*. Due to the high content of linoleic acid and oleic acid, UFA level was higher than SFA. The highest concentration of UFA was detected in *Trametes pubescens* (90.49%) and *Hydnum repandum* (77.50%). The linoleic:oleic acid ratios regarded as an important chemo-taxonomic parameter and helpful for taxonomic differentiation among the species of the same genus were smaller than 1.00 for eight mushrooms and the highest value of 7.14 was observed in *Omphalotus olearius*.

It was determined that oleic, linoleic, and linolenic acid contents of *Picoa lefebvrei*, *Teresia clavery* and *Terfezia* spp. collected from Konya province ranged from 16.86 to 21.32%, 58.03 to 60.63% and 12.97 to 19.00%, respectively (Şahin et al., 2020). Erucic acid content of *Picoa lefebvrei* (9.51%) was detected higher than the other two species.

Kaşık et al. (2020) investigated 15 EWM collected from Konya. The most dominant fatty acid was linoleic acid in 12 mushrooms, palmitic acid in *Lepista nuda* and *Lactarius vellereus* and oleic acid in *Boletopsis leucomelaena*. ΣUFA ratios of different species were found between 44.82 and 79.76%. The highest UFA ratio was found in *Terfezia* spp. while the lowest ratio was determined in *L. nuda* and *L. vellereus*. While linoleic acid was the most common fatty acid in species of Ascomycota, the second was oleic acid and the third was palmitic acid. In eight species of Basidiomycota the

Table 2. Fatty acid profiles of some edible wild mushrooms from Turkey (%)[a]

Species	C16:0	C18:0	C18:1	C18:2	C18:3	ΣSFA	ΣMUFA	ΣPUFA	Reference
Agaricus benesii	19.95	12.59	4.88	62.58	ND	32.54	4.88	62.58	Bengü et al., 2021
Agaricus campestris	10.45	13.60	14.60	34.30	3.60	-	-	-	Kaşık et al., 2020[b]
Agaricus silvicola	21.61	8.23	4.21	60.03	ND	32.81	7.16	60.03	Isik, 2020
Cantharellus cibarius	14.86	11.86	28.62	38.64	ND	29.13	32.33	38.54	Bengu, 2020
Coprinus comatus	19.59	2.05	10.66	61.63	ND	23.05	15.27	61.63	Çayan et al., 2020
Hydnum repandum	14.75	3.41	47.85	28.61	ND	22.46	48.89	28.61	Çayan et al., 2020
Lactarius deliciosus	6.40	9.27	7.90	35.60	2.01	-	-	-	Kaşık et al., 2020[c]
Macrolepiota procera	23.32	10.95	8.93	48.85	ND	38.33	12.23	48.55	Bengu, 2020
Morchella deliciosa	7.83	2.23	36.15	52.09	ND	10.21	36.71	52.09	Taşkın et al., 2021[d]
Morchella esculenta	9.48	2.14	19.13	67.57	ND	11.74	19.70	67.57	Taşkın et al., 2021[e]
Pleurotus eryngii	11.58	4.31	43.57	37.03	0.17	18.25	44.5	37.2	Acay et al., 2021
Rhizopogon luteolus	15.48	4.75	26.16	50.30	ND	21.26	-	-	Işık et al., 2020[f]
Rhizopogon roseolus	9.82	2.87	42.07	35.20	ND	14.46	-	-	Işık et al., 2020[g]
Sarcodon imbricatus	15.95	8.93	48.67	26.45	ND	24.88	48.67	26.45	Bengü et al., 2021
Terfezia boudieri	22.34	4.29	23.75	33.75	1.17	-	-	-	Kaşık et al., 2020 [h]
Terfezia clavery	-	-	21.32	58.03	19.00	-	-	-	Şahin et al., 2020

ND: not detected, -: not given. [a]Data are means of three replicates, [b]ΣUFA: 57.82%, [c]ΣUFA: 54.65%, [d, e]: Data are %, in DW, [f]ΣUFA: 78.72%, [g]ΣUFA: 84.72%, [h]ΣUFA: 66.73%.

most common fatty acid was linoleic acid whereas palmitic acid was the most abundant in two species and oleic acid was in other mushroom. Qualitative and quantitative similarities were determined in the fatty acid compositions of taxonomically related species.

Çınar Yılmaz et al. (2020) studied edible *Cyclocybe aegerita* and *Hygrophorus eburneus* collected from Tokat. Palmitic, stearic, oleic, and linoleic acids were found in *C. aegerita* as 22.15, 9.62, 13.90, 54.33%, respectively. In *H. eburneus* myristic, palmitic, stearic, palmitoleic, oleic, linoleic, and nervonic acids were determined as 0.32, 21.93, 3.15, 1.14, 47.80, 24.88, 0.41%, respectively. While the major fatty acid was linoleic acid in *C. aegerita* with 54.33%, it was oleic acid in *H. eburneus* with 47.80%. The most common SFA kind in samples was palmitic acid ranging from 22.15% (*C. aegerita*) to 21.93% (*H. eburneus*). Myristic, palmitoleic and nervonic acids could only be determined in *H. eburneus* as 0.32, 1.14 and 0.41%, respectively. In both species, ΣUFA were higher than ΣSFA.

In a study conducted with three EWM collected from Tokat and Yozgat provinces, the dominating fatty acid was C18:1 in *Pleurotus eryngii* and C18:2 in *Agaricus silvicola* and *Hydnum repandum* (Isik, 2020). Among the found SFA, the content of C16:0 was higher than other ones. C15:0 and C24:0 were determined only in *P. eryngii* with ratios of 1.41 and 0.34%, respectively. C18:3 was just detected in *H. repandum* with ratio of 1.15%. C20:0 was found in *H. repandum* and *A. silvicola* with ratios of 0.42 and 2.04%, respectively. C24:1 was determined in *P. eryngii* and *H. repandum* with ratios of 0.49 and 1.81%, respectively. In *H. repandum*, the most dominant fatty acid was found to be C18:2, followed by C18:1 and C16:0. Among species, *A. silvicola* contained the highest amount of C18:2 with a ratio of 60.03%. ΣUFA ratios were found to be higher than ΣSFA ratios in all samples.

Bengu (2020) studied economically important nine EWM collected from Tokat and Yozgat. The dominant fatty acids determined in species were linoleic acid and oleic acid, followed by palmitic acid and stearic acid. ΣUFA/SFA ratio was detected as the highest in *Helvella lacunosa* and the lowest in *Morchella elata*. Nervonic acid was determined as 7.22% in just *Pleurotus ostreatus*. Lignoceric acid was found as 0.71% in just *Macrolepiota procera*. The highest SFA was 46.24% in *Agaricus bisporus* and the lowest SFA was 29.13% in *Cantharellus cibarius*. The highest MUFA was detected as 46.94% in *H. lacunosa*, while the lowest MUFA was found as 4.02% in *A. bisporus*. The highest PUFA was 53.61% in *Bovista plumbea* and the lowest PUFA was 22.49% in *H. lacunosa*. While the highest ΣUFA was determined in *C. cibarius* (70.87%), the lowest ΣUFA was detected in *M. elata* (51.27%). The highest ΣUFA/SFA was 2.43 in *C. cibarius*, while the lowest ΣUFA/SFA was 1.05 in *M. elata*. ΣUFA levels were higher than ΣSFA in all of nine mushrooms.

3. Conclusions

EWM are considered as "functional foods" due to their high-quality nutrients, bioactive compounds, and biological activities. They are also potential natural sources of essential UFA. EWM have beneficial effects on human health due to their fatty acid composition including the higher content of MUFA and PUFA compared to SFA. They can be consumed for cardiovascular health, low cholesterol levels, and in low-calorie diets by the humans. Moreover, they can be potentially used in the production of novel functional foods such as mushroom-based meat, dairy, bakery products and beverages, and dietary supplements and skincare formulations as an ingredient by the food, pharmaceutical, and cosmeceutical industries due to their low fat and SFA content, and high essential UFA level.

In Turkey, indigenous EWM are mainly supplied from forests and barren areas, consumed, and sold in both domestic and foreign trade. They are preferred for natural, healthy nutrition, and livelihood not only in rural areas but also in urban lifestyles with less demand. In the current studies, various EWM species from different regions of Turkey have been investigated and linoleic, oleic, palmitic, and stearic acids were determined as the most abundant fatty acids compared to other ones with a higher ratio of ΣUFA than ΣSFA. In addition, linolenic acid of another essential UFA, which is also important for human being health, was detected in some mushroom species. Fatty acid profiles of EWM varied depending on species and even in the same species because of ecologic parameters such as forest structure, soil, climate, elevation in addition to maturity stage of samples and extraction procedure. Further studies should be conducted to introduce and determine the fatty acid compositions of EWM growing in the rich mycobiota of Turkey and the benefits of their UFA on human organism to enhance the consumption of EWM in the daily diet of people and their usage in the development of novel functional products.

Declaration of competing interest

The authors declare no conflict of interest.

Acknowledgments

The part of this review study was presented in the International Online Conferences on Engineering and Natural Sciences (IOCENS'21), which was held online in Gümüşhane, Turkey on 05-07 July 2021 and the abstract of this study was published in the Abstract Book (Bulam et al., 2021).

References

Abdelshafy, A. M., Belwal, T., Liang, Z., Wang, L., Li, D., Luo, Z. & Li, L. (2021). A comprehensive review on phenolic compounds from edible mushrooms: Occurrence, biological activity, application and future prospective. *Critical Reviews in Food Science and Nutrition.* 1-21. doi: https://doi.org/10.1080/10408398.2021.1898335

Acay, H., Dündar, A., Kaçar, S., Baran, M. F. & Keskin, C. (2021). Investigation of nutritional content, antioxidant anticancer and antimicrobial activities of *Pleurotus eryngii* (DC. Ex Fr.) Quel, extract obtained by different solvents. *KSU Journal of Agriculture and Nature*, *24*, 267-277. doi: https://doi.org/10.18016/ksutarimdoga.vi.742646

Akyüz, M., Akyüz, H. E. & Kırbağ, S. (2017). Ethnomycological aspects of traditional usage and indigenous knowledge about the arid-semi arid truffles consumed by the residents of the Eastern Anatolia Region of Turkey. *Gazi University Journal of Science, 30*, 57-70.

Arslan, M., Kaba, H., Yılmaz, T., Okan, T., Köse, C. & Hilesiz, H. (2021). Yenilebilir yabani mantar ticaretinde toplayıcı ve aracıların rolü: İstanbul Orman Bölge Müdürlüğü örneği. *Turkish Journal of Forest Science, 5*, 165-186.

Azeem, U., Hakeem, K. R. & Ali, M. (2020). Ethnomycology. Fungi for Human Health (pp. 23-39). Switzerland: Springer. doi: https://doi.org/10.1007/978-3-030-58756-7_4

Badalyan, S. M., Barkhudaryan, A. & Rapior, S. (2019). Recent progress in research on the pharmacological potential of mushrooms and prospects for their clinical application. D. C. Agrawal, M. Dhanasekaran (Eds.), Medicinal Mushrooms (pp. 1-70). Singapore: Springer. doi: https://doi.org/10.1007/978-981-13-6382-5_1

Bengu, A. S. (2020). The fatty acid composition in some economic and wild edible mushrooms in Turkey. *Progress in Nutrition, 22*, 185-192. doi: https://doi.org/10.23751/pn.v22i1.7909

Bengü, A. Ş, Işık, H., Türkekul, İ. & Çınar Yılmaz, H. (2021). Some minerals and fatty acid compositions of five different wild edible mushrooms species collected in Tokat and Yozgat provinces in Turkey. *Anatolian Journal of Botany, 5*, 58-64. doi: https://doi.org/10.30616/ajb.890955

Boin, E. & Nunes, J. (2018). Mushroom consumption behavior and influencing factors in a sample of the Portuguese population. *Journal of International Food & Agribusiness Marketing, 30*, 35-48. doi: https://doi.org/10.1080/08974438.2017.1382420

Bulam, S., Üstün, N. Ş. & Pekşen, A. (2018a). β-Glucans: An important bioactive molecule of edible and medicinal mushrooms. 1. International Technology Sciences and Design Symposium (ITESDES), Giresun, Turkey.

Bulam, S., Üstün, N. Ş. & Pekşen, A. (2018b). *Polyporus squamosus* (Huds.) Fr. in the Black Sea Region. *Turkish Journal of Agriculture - Food Science and Technology, 6*, 183-188. doi: https://doi.org/10.24925/turjaf.v6i2.183-188.1546

Bulam, S., Üstün, N. Ş. & Pekşen, A. (2018c). Mushroom foreign trade of Turkey in the last decade. International Congress on Engineering and Life Science (ICELIS 2018), Kastamonu, Turkey.

Bulam, S., Üstün, N. Ş. & Pekşen, A. (2019a). Evaluation of nutritional and medicinal values of edible wild and cultivated *Pleurotus ostreatus*. *Turkish Journal of Agriculture - Food Science and Technology, 7*, 2054-2061. doi: https://doi.org/10.24925/turjaf.v7i12.2054-2061.2730

Bulam, S., Üstün, N. Ş. & Pekşen, A. (2019b). Nutraceutical and food preserving importance of *Laetiporus sulphureus*. *Turkish Journal of Agriculture - Food Science and Technology, 7*, 94-100. doi: https://doi.org/10.24925/turjaf.v7isp1.94-100.2729

Bulam, S., Pekşen, A. & Üstün, N. Ş. (2019c). Yenebilir ve tıbbi mantarların gıda ürünlerinde kullanım potansiyeli. *Mantar Dergisi, 10*, 137-151. doi: https://doi.org/10.30708.mantar.644367

Bulam, S., Üstün, N. Ş. & Pekşen, A. (2021). A review on fatty acid profiles of edible wild mushrooms from Turkey. International Online Conferences on Engineering and Natural Sciences (IOCENS'21) Abstract Book, Gümüşhane, Turkey.

Çayan, F., Deveci, E., Tel-Çayan, G. & Duru, M. E. (2020). Chemometric approaches for the characterization of the fatty acid composition of seventeen mushroom species. *Analytical Letters, 53*, 2784-2798. doi: https://doi.org/10.1080/00032719.2020.1759082

Çınar Yılmaz, H., Işık, H., Bengü, A. Ş. & Türkekul, İ. (2020). Fatty acid contents of two edible mushroom species (*Cyclocybe aegerita* and *Hygrophorus eburneus*) collected from Tokat region. *Middle East Journal of Science, 6*, 37-43.

Díaz-Godínez, G. & Téllez-Téllez, M. (2021). Mushrooms as edible foods. X. Dai, M. Sharma, J.-Y. Chen (Eds.). Fungi in Sustainable Food Production (pp. 143-164). Switzerland: Springer. doi: https://doi.org/10.1007/978-3-030-64406-2

Elkhateeb, W. A. & Daba, G. M. (2021). Mycotherapy of the good and the tasty medicinal mushrooms *Lentinus*, *Pleurotus*, and *Tremella*. *Journal of Pharmaceutics and Pharmacology Research, 4*, 1-6. doi: https://doi.org/10.31579/2693-7247/29

Erdem, Ö., Bayram F., Çiftçi, B. & Kemer, A. K. (2018). Mutfak şeflerinin yöresel mantarları tanıma ve kullanım durumlarına ilişkin keşifsel bir araştırma. *Journal of Tourism and Gastronomy Studies, 6*, 225-239. doi: https://doi.org/10.21325/jotags.2018.250

Gonzalez, A., Cruz, M., Losoya, C., Nobre, C., Loredo, A., Rodríguez, R., Contrerasa, J. & Belmares, R. (2020). Edible mushrooms as a novel protein source for functional foods. *Food & Function, 11*, 7400-7414. doi: https://doi.org/10.1039/d0fo01746a

Gürgen, A., Yıldız, S. & Yıldız, Ü. C. (2018). Determination of mushroom consumption preferences by using fuzzy analytic hierarchy process. *Eurasian Journal of Forest Science, 6*, 25-34. doi: https://doi.org/10.31195/ejejfs.433353

Isik, H. (2020). Fatty acid contents of three wild edible mushroom species. *Chemistry of Natural Compounds, 56(6)*, 1114-1116 doi: https://doi.org/10.1007/s10600-020-03239-0

Işık, H., Bengü, A. Ş., Çınar Yılmaz, H., Yılmaz, N. & Türkekul, İ. (2020). A study on mineral contents and fatty acid profiling of two *Rhizopogon* species. *Acta Biologica Turcica, 33*, 237-243.

Kaşık, G., Nurullahoğlu, Z. U., Öztürk, C., Öztürk, R., Eroğlu, G., Aktaş, S. & Özcan, M. M. (2020). Oil content and fatty acid compositions of some edible macrofungi. *Journal of Agroalimentary Processes and Technologies, 26*, 217-222.

Kothari, D., Patel, S. & Kim, S. K. (2018). Anticancer and other therapeutic relevance of mushroom polysaccharides: A holistic appraisal. *Biomedicine & Pharmacotherapy, 105*, 377-394. doi: https://doi.org/10.1016/j.biopha.2018.05.138

Kotowski, M. A., Pietras, M. & Łuczaj, Ł. (2019). Extreme levels of mycophilia documented in Mazovia, a region of Poland. *Journal of Ethnobiology and Ethnomedicine, 15*, 1-19. doi: https://doi.org/10.1186/s13002-019-0291-6

Kumar, H., Bhardwaj, K., Sharma, R., Nepovimova, E., Cruz-Martins, N., Dhanjal, D. S., Singh, R., Chopra, C., Verma, R., Abd-Elsalam, K. A., Tapwal, A., Musilek, K., Kumar, D. & Ku˘ca, K. (2021). Potential usage of edible mushrooms and their residues to retrieve valuable supplies for industrial applications. *Journal of Fungi, 7(6)*, 427. doi: https://doi.org/10.3390/jof7060427

Lang, M. (2020). Consumer acceptance of blending plant-based ingredients into traditional meat-based foods: Evidence from the meat-mushroom blend. *Food Quality and Preference, 79*, 103758. doi: https://doi.org/10.1016/j.foodqual.2019.103758

Latorre, J., de-Magistris, T., de Frutos, P., García, B. & Martinez-Peña, F. (2021). Demand for mycotourism products in rural forest areas. A choice model approach. *Tourism Recreation Research,* 1-17. doi: https://doi.org/10.1080/02508281.2021.1926749

Lovrić, M., Da Re, R., Vidale, E., Prokofieva, I., Wong, J., Pettenella, D., Verkerk, P. J. & Mavsar, R. (2020). Nonwood forest products in

Europe – A quantitative overview. *Forest Policy and Economics, 116*, 102175. doi: https://doi.org/10.1016/j.forpol.2020.102175

Lovrić, M., Da Re, R., Vidale, E., Prokofieva, I., Wong, J., Pettenella, D., Verkerk, P. J. & Mavsar, R. (2021). Collection and consumption of non-wood forest products in Europe. *Forestry: An International Journal of Forest Research, 94*, 757-770. doi: https://doi.org/10.1093/forestry/cpab018

Mingyi, Y., Belwal, T., Devkota, H. P., Li, L. & Luo, Z. (2019). Trends of utilizing mushroom polysaccharides (MPs) as potent nutraceutical components in food and medicine: A comprehensive review. *Trends in Food Science & Technology, 92*, 94-110. doi: https://doi.org/10.1016/j.tifs.2019.08.009

Podkowa, A., Kryczyk-Poprawa, A., Opoka, W. & Muszyńska, B. (2021). Culinary–medicinal mushrooms: A review of organic compounds and bioelements with antioxidant activity. *European Food Research and Technology, 247*, 513-533. doi: https://doi.org/10.1007/s00217-020-03646-1

Sande, D., de Oliveira, G. P., e Moura, M. A. F., de Almeida Martins, B., Lima, M. T. N. S. & Takahashi, J. A. (2019). Edible mushrooms as a ubiquitous source of essential fatty acids. *Food Research International, 125*, 108524. doi: https://doi.org/10.1016/j.foodres.2019.108524

Sesli, E., Asan, A. & Selçuk, F. (Eds.). (2020). Türkiye Mantarları Listesi (The Checklist of Fungi of Turkey). İstanbul: Ali Nihat Gökyiğit Vakfı.

Singhal, S., Rasane, P., Kaur, S., Garba, U., Singh, J., Raj, N. & Gupta, N. (2019). Mushroom cultivation, processing and value-added products: A patent based review. *Recent Patents on Food, Nutrition & Agriculture, 10*, 3-19. doi: https://doi.org/10.2174/2212798410666180604101353

Şahin, A., Kaşık, G., Alkan, S. & Özcan, M. M. (2020). Total phenol, antioxidant activity, fatty acid composition and mineral contents of the species of fungi known as domalan. *Journal of Agroalimentary Processes and Technologies, 26*, 149-154.

Taşkın, H., Süfer, Ö., Attar, Ş. H., Bozok, F., Baktemur, G., Büyükalaca, S. & Kafkas, N. E. (2021). Total phenolics, antioxidant activities and fatty acid profiles of six *Morchella* species. *Journal of Food Science and Technology, 58*, 692-700. doi: https://doi.org/10.1007/s13197-020-04583-3

Üstün, N. Ş., Pekşen, A., Bulam, S. & Duran, H. (2019). Edible wild herbaceous plants consumed in Giresun province. *Acta Biologica Turcica, 32*, 84-89.

WHO. (2003). Diet, nutrition and the prevention of chronic diseases. World Health Organization Technical Report Series, 916, 1-149. Geneva.