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Fatty Acid Profiling in Selected Cultivated Edible and Wild Medicinal Mushrooms in Southern United States

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Abstract

The fatty acid composition was determined in the cultivated edible mushroom *Agaricus bisporus* (white), and the wild medicinal mushrooms, Turkey-tail (*Trametes versicolor*), Artist Conk (*Ganoderma applanatum*) and Tinder Polypore (*Fomes fomentarius*). The most prominent fatty acids present in all of the species studied were palmitic (C16: 0), stearic (C18: 0), oleic (C18: 1), and linoleic acid (C18: 2n6). The amount of linoleic acid in the cultivated species was 75.35 ± 1.54%; compared to 16.80 ± 1.54 to 30.30 ± 1.54% in the wild medicinal mushrooms. Unsaturated fatty acids were the most abundant in both the cultivated edible and the wild medicinal mushrooms studied, which varied from 80.51 ± 1.75% and 58.35 ± 1.75 to 69.61 ± 1.75% respectively. The saturated fatty acid amounts ranged from 29.22 ± 1.73 to 41.65 ± 1.73% in the wild mushrooms and 19.49 ± 1.73% in the cultivated mushrooms. Oleic acid was the most abundant fatty acid in the wild mushrooms and varied from 20.66 ± 0.87 to 37.21 ± 0.87%. The n-6: n-3 ratios was (28.45 ± 7.38% in cultivated edible compared to 16.19 ± 7.38 to 55.42 ± 9.03% in the wild medicinal mushrooms) generally higher than the recommended value of 2:1 or 3:1 in human diets.

Keywords: Wild edible; Medicinal mushroom; Cultivated; *Agaricus bisporus*; Fatty acid methyl esters; Omega 3 and 6

Introduction

Wild mushrooms are distributed worldwide, and consumption of both cultivated edible mushrooms and wild edible mushrooms has drawn much public interest due to their nutritional characteristics, medicinal properties and economic potential. The number of mushroom species estimated to exist is approximately 140,000 and of these only about 14,000 to 22,000 are characterized. This indicates that only about 10% to 15% have been well-characterized [1,2]. Supposing that mushrooms of nutritional and medicinal usefulness among those unidentified and uncharacterized constitute only 5%, this implies that about 7000 undiscovered species could be beneficial to humans [1,2].

In many countries mushrooms serve as a natural food resource because of their high nutritional, medicinal and economic value [2-4]. Fungus collecting in certain parts of the world is often seen as a hobby but several studies have illustrated that mushrooms are an essential source of nutrients and pharmaceutical raw materials, and therefore are a source of income generation in both developed and underdeveloped nations [4,5].

More recently, attention has been focused on both cultivated and wild mushrooms to exploit the nutritional and medicinal applications in regard to improving health. Studies in Africa [6], Italy [7], U.S [8], India [9], Canada [10], Russia [11], France [12], Japan [13] and Pakistan [14] have investigated this issue further.

The nutritional and medicinal compositions in mushrooms are well documented. For instance, some mushrooms (e.g. *Agaricus bisporus* [15,16] and *Tricholoma matsutake* [17], have been appreciated because of their therapeutic activity such as, reduction of hypercholesterolemia, antherosclerosis, hypertension and immune therapy in cancer [2,18,19]. Clinical studies have also documented that some mushrooms have medicinal potential in lowering serum cholesterol levels (*Tricholoma matsutake, G. applanatum, Trametes Versicolor, Fomes fomentanus*), can act as antitumor and antiviral agents (*Trametes Versicolor, Fomes fomentaus*), and have antithrombotic and immunomodulating effects (*Tricholoma matsutake, Trametes Versicolor*) [2,15,19-21]. The ability of mushrooms to exert hypocholesterolemic effects have been reported in rats [22-26]. Wild mushrooms have demonstrated some pharmacological characteristics such as antitumor [20,22].

It is, therefore, vital to study the fatty acid and other chemical composition of mushrooms in southern US to document their chemical profile(s) as a preliminary means to further study their biochemical and physiological implications to human health.

In recent studies, unsaturated fatty acids (UFs), particularly polyunsaturated fatty acids (PUFAs), have been reported in many wild mushrooms and are believed to have important contributions in nutritional and medicinal application [15,27]. Linoleic (LA) and α-linolenic (ALA) acids are essential fatty acids that are fundamental in human nutrition and serve as important precursors for the biosynthesis of other long chain fatty acids [28]. In most studies conducted in fungi, n-3 content and n-6 to n-3 ratios have not been given much attention. However, the n-3 levels and its ratio factor with the n-6 FAs may be a crucial factor in the reduction of cardiovascular, inflammatory, immunomodulating and cancer diseases. In this perspective, determination of fatty acid profile(s) and n-6 to n-3 ratios in cultivated and wild medicinal mushrooms will aid consumers in

selecting dietary components that offer better nutritional balance and good health functional compounds.

Although, mycological studies have reported the fatty acid profiles and other essential nutrients of cultivated edible and some wild medicinal mushrooms from some regions in the United States, there is limited information regarding the fatty acid composition and lipid health biomarkers of wild medicinal mushrooms located in the Southern region of the United States. These mushrooms were selected based on their abundance in the county and previous biological activity claims reported in other countries [2,15,19,20]. Hence, the present study was conducted to compare the fatty acid compositions, n6: n3 ratio and fatty acid biomarkers of wild medicinal mushrooms species in this region and compare them to well characterized cultivated edible mushroom (*Agaricus bisporus*).

Materials and Methods

Sample collection

In this study four mushrooms were sampled; one (1) cultivated edible mushroom *Agaricus bisporus* (white) was purchased from a local supermarket in Tuskegee, AL, USA, and three (3) wild medicinal mushrooms were collected from tree logs on the campus of Tuskegee University in Tuskegee, in Macon County of Alabama, USA between spring and summer session (May and August, 2009). Soil pH, pressure, nutrients, moisture content, ions and electrical conductivity were not measured because there was no information regarding these conditions stated in the cultivated mushrooms species purchased. All samples were washed thoroughly with deionized water and immediately put into jars and stored under nitrogen at -20°C for later analyses.

Fatty Acid Methyl Ester synthesis

A modified procedure [29] was adopted for the analysis. Ten grams (10.0 g) of mushroom was weighed and placed into a 16 × 125 mm screw-cap Pyrex culture tube. Forty microliters (40 µl) of a C19: 0 internal standard (IS) (1, 2 Dinonadecanoyl-syn-glycero-3-phosphocholine, came from Avanti Polar Lipids Inc) of concentration 0.5 mg/ml, followed by 0.7 ml of 5M KOH (ACS grade) in water, and 5.3 ml of MeOH (HPLC grade, Fisher Scientific) were added to the culture tube and the mixture incubated for 90 min at 55°C in water bath vigorously shaking to ensure total hydrolysis of samples. Following the incubation period, the mixture was cooled for 5 min in an ice bath and 0.58 ml of 24N H_2SO_4 in water was added. Tubes were inverted several times-mixed properly to breakdown the presence of K_2SO_4 precipitate formed after the addition of the acid and reincubated as indicated above to generate fatty acid methyl esters (FAMEs). After FAME synthesis, tubes were cooled in ice bath for 5 min, 3 ml of hexane was added, then vortex-mixed for 5 min, then centrifuged for 5 min using a clinical tabletop centrifuge (IEC Centra CL 2). The organic phases containing the FAMEs were filtered using a 0.2 µm PTFE filter into gas chromatography (GC) vials. Vials were capped and stored at -20°C until GC analysis.

Gas chromatography (GC) separation and quantitation of individual fatty acids

An Agilent GLC 6890N equipped with a flame ionization detector (FID) was used for the separation and quantification of fatty acids methyl esters (FAMEs). Samples were injected into the column via a split injector. The split ratio was 5:1. Separations were done using a DB23 capillary column (Model No.122-2362, 60.0 µm × 250 µm × 0.25 µm, J and W Scientific). The initial oven temperature was maintained at 130°C, held for 1 min, subsequently increased to 170°C at a rate of 6.50°C/min, then moved to 215°C and held for 12 min at a rate of 2.75°C/min then increased to 230°C at 40°C/min. Helium was used as a carrier gas at a flow rate of 2.6 ml/min with average velocity 40 cm/sec, and the column head pressure was set at 48.27 kpa. Both injector and detectors were set at 250°C. Fatty acid methyl esters were identified by comparison with 54 fatty acid methyl esters standard GLC463 (obtained from Nu-Chek Prep Inc., Elysian, Minnesota) retention times. Fatty acids were also reported in percentage of total identified peaks.

The degree of unsaturation of C18 FA(Δ/mol C18) was estimated using the relationship; Δ/mol C18=[(1 × 18:1) + (2 × 18:2) + (3 × 18:3)]/Σ(C18 FA) [30] as indicators for nutritional, medicinal, taxonomical and technological applications.

Statistical analysis

Data for this study were analyzed using a one-way analysis of variance. When differences among mushrooms were detected at $p<0.05$, Fisher's LSD was used to compare means. Results are reported as means in % total of fatty acids identified.

Results

This study identified 31 individual fatty acids in each mushroom species that are presented as the % of total FA identified in the cultivated edible and wild medicinal mushrooms (Table 1).

Fatty acids observed at greater than 2% in at least one species were C10:0, C16:0, C16:1, C18:0, C18:1, C18:2n6, C18:3n3, C22:4n6, C22:6n3 and C22:5n3 in the two classes studied shown in table 1. An important notable difference between species was that in the cultivated species C16:1, C17:0, C17:1, C18:1, C18:1t and C18:3n3 were not detected, whereas for most of the wild medicinal mushrooms species these FAs were observed, except for Tinder polypore and Artist conk where C18:3n3 was absent and C18:1t was not detected in the Turkey-tail mushrooms. The C16:0 and C18:0 levels were higher in only Turkey-tail and Artist Conk of the wild medicinal mushrooms than the cultivated species.

The monounsaturated fatty acid (C18: 1) was absent in the cultivated species, whereas in the wild medicinal mushrooms, it constituted 20.66 ± 0.87% to 37.21 ± 0.87% of the total fatty acids identified. In the cultivated mushrooms (*Agaricus bisporus* white) the dominant fatty acid was linoleic acid (C18:2n6) with 75.35 ± 1.54%, whereas in the wild medicinal mushrooms oleic acid (C18:1) with 20.66 ± 0.87% (Turkey-tail), 32.21 ± 0.87% (Artist conk) and 37.21 ± 0.87% (Tinder polypore) was most prevalent. This percent is very important because oleic acid play crucial roles in the biochemical and physiological pathways in cells accumulation of cholesterol in the human body. This conjecture is supported by Grundy, [31] that Oleic acid (C18:1) can lower serum cholesterol concentrations because it acts as a good substrate for liver enzyme which converts cholesterol deposits into an inactive form known as Acyl CoA transferase:cholesterol acyltransferase. The richest amounts of oleic acid are in olive, canola and peanut oils and even some beef [32].

%FA	Turkey tail	Tinder polypore	Artist conk	*Agaricus bisporus* (white)
C8:0	-	-	-	0.35 ± 0.18^{a}
C9:0	0.99 ± 0.18^{b}	1.77 ± 0.18^{a}	1.83 ± 0.18^{a}	0.40 ± 0.22^{b}
C10:0	1.75 ± 0.44^{b}	3.16 ± 0.44^{b}	6.00 ± 0.44^{a}	0.51 ± 0.54^{c}
C13:0	1.06 ± 0.10^{a}	-	-	-
C13:1	-	0.56 ± 0.03^{a}	-	-
C14:0	1.59 ± 0.13^{a}	-	0.89 ± 0.13^{b}	-
C14:1	0.96 ± 0.21^{a}	0.58 ± 0.21^{a}	-	0.39 ± 0.21^{a}
C15:0	1.74 ± 0.27^{a}	-	0.83 ± 0.27^{b}	0.65 ± 0.27^{b}
C15:1	-	0.61 ± 0.004^{a}	-	0.35 ± 0.004^{b}
C16:0	20.27 ± 0.95^{a}	15.87 ± 0.95^{b}	20.22 ± 0.95^{a}	12.90 ± 0.95^{b}
C16:1	3.07 ± 0.10^{a}	1.43 ± 0.10^{b}	1.61 ± 0.10^{b}	-
C16:1t	1.65 ± 0.32^{a}	0.79 ± 0.39^{a}	1.06 ± 0.32^{a}	0.96 ± 0.32^{a}
C17:0	0.72 ± 0.10^{b}	0.71 ± 0.10^{b}	1.10 ± 0.10^{a}	-
C17:1	3.00 ± 0.19^{a}	1.58. ± 0.19^{b}	1.61 ± 0.19^{b}	-
C18:0	6.76 ± 0.27^{c}	5.91 ± 0.27^{c}	10.78 ± 0.27^{a}	3.70 ± 0.27^{b}
C18:1	20.66 ± 0.87^{c}	37.21 ± 0.87^{a}	32.00 ± 0.87^{b}	-
C18:1t	-	1.86 ± 0.11^{a}	1.09 ± 0.14^{b}	-
C18:1n7	2.07 ± 0.25^{a}	0.72 ± 0.25^{b}	-	0.89 ± 0.25^{b}
C18:2n6	30.30 ± 1.54^{a}	23.86 ± 1.54^{b}	16.80 ± 1.54^{c}	75.35 ± 1.54^{d}
C18:3n3	3.42 ± 0.58^{a}	-	-	-
C20:0	-	1.42 ± 0.13^{a}	-	1.29 ± 0.13^{a}
C20:2n6	-	-	-	-
C20:3n6	-	-	-	-
C20:4n6	-	-	5.40 ± 0.35^{a}	-
C20:5n3	-	-	-	1.21 ± 0.27^{a}
C22:2n6	-	-	1.43 ± 0.11^{b}	-
C22:4n6	-	-	-	-
C24:0	-	0.58 ± 0.06^{a}	-	-
C22:5n3	-	-	-	-
C22:6n3	-	0.45 ± 0.43^{a}	-	2.24 ± 0.43^{b}
C24:1	-	0.55 ± 0.07^{a}	-	-

Table 1: Fatty acids composition (% of total FAs) of cultivated edible (*Agaricus bisporus* white) and wild medicinal mushrooms (Turkey-tail, Tinder polypore, and Artist conk) in Southern Region of the United States using direct FAMEs synthesis. Values are least significant means plus standard errors with triplicate determination (n=3), Means sharing the same superscript across rows are not significantly different at p<0.05. -not detected.

The C22:5n3 and C22:6n3 were found in the cultivated edible mushrooms with DHA content around 2.24 ± 0.43%. Conversely, in the wild medicinal mushroom DHA was present only in the Tinder polypore species in a small amount (0.45 ± 0.43%).

The results for total unsaturated fatty acids (UFA), total saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), n-6, n-3, MUFA:SFA, PUFA:SFA, UFA:SFA, linoleic to oleic ratio (L:O), n-6:n-3 and the degree of unsaturation of C18 (Δ/mol C18) were calculated as indicators for nutritional, medicinal and technological purposes are shown in table 2. The study depicted an interesting trend with respect to the PUFA and MUFA content within the wild medicinal mushrooms and between the cultivated edible mushrooms. It was observed that the MUFA content in the wild medicinal mushrooms accounted for 45.44 ± 0.86% in (Tinder polypore), 37.00 ± 0.86% in (Artist conk), and 31.41 ± 0.86% in (Turkey-tail), whereas in the cultivated species (*Agaricus bisporus* white) constituted 2.47 ± 0.86 %. The PUFA amounts in the wild medicinal mushrooms were in order of highest to lowest Turkey-tail >Tinder polypore> Artist conk. The PUFA was substantially higher (p<.05) in the Turkey-tail compared to the rest of the wild medicinal mushroom.

Ratios	Turkey tail	Tinder polypore	Artist conk	*Agaricus bisporus* (white)
MUFA	31.41 ± 0.86^{a}	45.44 ± 0.86^{b}	37.00 ± 0.86^{c}	2.47 ± 0.86^{d}
PUFA	33.72 ± 1.76^{b}	24.16 ± 1.76^{c}	21.34 ± 1.76^{c}	78.04 ± 1.76^{a}
SFA	34.88 ± 1.73^{b}	29.22 ± 1.73^{c}	41.65 ± 1.73^{a}	19.49 ± 1.73^{d}
UFA	65.13 ± 1.75^{b}	69.61 ± 1.75^{b}	58.35 ± 1.75^{c}	80.51 ± 1.75^{a}
MUFA/SFA	0.92 ± 0.06^{b}	1.56 ± 0.06^{a}	0.89 ± 0.06^{b}	0.13 ± 0.06^{c}
PUFA/SFA	0.99 ± 0.20^{b}	0.83 ± 0.20^{b}	0.52 ± 0.20^{b}	4.02 ± 0.20^{a}
UFA/SFA	1.91 ± 0.22^{bc}	2.38 ± 0.22^{b}	1.41 ± 0.22^{c}	4.14 ± 0.22^{a}
n-3	3.42 ± 1.22^{c}	0.30 ± 1.22^{b}	nd	2.70 ± 1.21^{c}
n-6	30.30 ± 1.77^{a}	23.86 ± 1.77^{d}	21.34 ± 1.77^{d}	75.35 ± 1.77^{b}
n-6/n-3	16.19 ± 7.38^{b}	55.42 ± 9.03^{a}	nd	28.45 ± 7.38^{b}
Linoleic/Oleic	1.48 ± 0.08^{a}	0.64 ± 0.08^{b}	0.53 ± 0.08^{b}	nd
Δ/mol C18	1.15 ± 0.03^{b}	0.72 ± 0.03^{c}	0.57 ± 0.03^{d}	1.89 ± 0.03^{a}

Table 2: Percentage ratio of MUFA, PUFA & SFA, n 6 and n3, Δ/mol C18 and Linoleic and Oleic acid of cultivated edible and wild medicinal mushrooms (n=3). PUFA-Polyunsaturated fatty acids, SFA-

Saturated fatty acids, n-3 and n-6-Omega 3 & 6 polyunsaturated fatty acids, and not determined , Δ/mol C18-degree of unsaturation of C18 FAs. Mean values on the same row followed by a same letter not significantly different according to least significant (LS) means (at $p<0.05$). Values are reported as least significant means plus standard error (LSMean ± SE) of triplicate determination.

The MUFA and UFA: SFA varied significantly among the wild medicinal mushroom at $p<0.05$. The SFA content was greater in the wild medicinal mushrooms than the cultivated species. The MUFA: SFA were observed to differ only in the Tinder Polypore out of the three wild medicinal mushrooms considered, and is lower in the *Agaricus bisporus* (white) considered for the study. Another interesting observation was that the total fatty acids identified were basically full of n -6 constituting about 21.34% to 75.35%, whereas the n-3 only made up of 0.30% to 3.42%. The n6/n3 ratio ranged between 55.42 with a statistically difference in only Tinder polypore medicinal mushrooms. The linoleic: oleic ratio differs only in the Turkey-Tail mushroom compared to other wild medicinal mushrooms. The Δ/mol C18 were significant different in the wild medicinal species, whereas in the cultivated edible type no differences were detected.

There was only one slight significant variation in MUFA, SFA, UFA and MUFA: SFA with one of the wild medicinal mushroom (i.e. Tinder polypore) compared to all of the other species. For the ratio of UFA: SFA variation was observed in the Turkey-tail and the Artist conk species compared to the other species. There were no differences between inter-species in terms of the ratios of PUFA: SFA in the cultivated species, as well as that of the wild medicinal mushrooms at the $p<0.05$. However, differences were detected between the cultivated species and the wild mushrooms. The degree of unsaturation (Δ/mol C18) in the wild medicinal mushrooms differs from the cultivated edible species (Table 2).

Discussion

The identified fatty acids in these analyses of the cultivated edible species (*Agaricus bisporus*) ranged from (C8:0 to C24:1) which agreed with what has been reported in most cultivated species, and (C9:0 to C24:1) in the wild medicinal mushrooms [33-37].

The most abundant fatty acids identified were C16:0, C18:0, C18:1 and C18:2n6 and the rest in smaller amounts in cultivated categories of mushrooms. This was in agreement with what has been reported in *Agaricus bisporus* sp [12,36,38,39] and some wild edible mushrooms (Table 2) [30,36,39,40].

Fatty Acid	*Agaricus bisporus*a	*L. deliciosus*a	*Lentinus sajor-cajub*	*Lactarius deliciosus*b	*Macrolepiota procerab*	*Ganoderma applanatumc*	*Suillus grevilleic**	*Schizophyllum communed*	*Lentinues edodesd*	*T. texensee*	*A. bisporus*‡
C16:0	4.34	12.08	15.4	16.3	4.6	18.3	8.9	20.8	19.2	11.4	15.1
C16:1	-	0.92	0.1	0.9	-	-	1.01	-	-	-	Trace
C18:0	1.79	25.33	-	6.1	-	3.31	1.49	2.5	2.7	3.4	15.6
C18:1	21.47	41.26	23.5	33	17.2	22.5	43.9	10.4	8.3	45.9	13.6
C18:2n6	44.19	17.06	54.9	37.1	47	28.8	40.1	61.3	68.8	38	55.1
C18:3n3	-	0.26	-	-	15.6	0.4	0.63	4.8	0.6	-	Trace
C18:3n6	-	-	-	-	-	-	-	-	-	-	-
C20:0	-	0.44	-	-	5.6	0.26	0.18	0.2	0.4	<0.2	-
SFA	6.13	37.85	15.4	22.4	10.2	21.87	10.57	23.5	22.3	14.4	30.7
UFA	65.66	59.5	78.5	71	79.8	51.7	85.64	76.5	77.7	83.9	68.7
UFA:SFA	10.71	1.57	5.09	3.17	7.82	2.36	8.1	3.26	3.48	5.83	4.05
L/O	2.06	0.41	2.34	1.12	2.73	1.28	0.91	5.89	8.29	0.83	2.24

Table 3: Some common fatty acids composition (%) of selected cultivated edible and wild mushrooms in Portugala, Pakistana*, Indiabd, Canadacc* and USe‡. Source: *a- Sadiq et al., 2008 Iran.J.Chem.Chem.Eng. a-Barros et al., 2007 Food Chemistry, b-Kavishree et al., 2008. Food Chemistry c- Pedneault et al., 2006 and 2008* mycological Research. d-Longvah & Deosthale, 1998. Food Chemistry, e-Beuchat et al., 1993, Food Chemistry.‡- Holtz et al., 1972 .Plant physiology.‡ and e are from U.S.A.

The chief unsaturated fatty acid was linoleic acid which constituted 75.35% of the total fatty acids identified for all the cultivated edible species. These results are in agreement with previous literature on *Agaricus bisporus* FAs reported by Hughes, (1962) to range between 63% to 74%, 68.4 % in [35], 66% to 79% in [12] and 53% to 79% by [39].

However, the linoleic acid level in this study was higher than other values in literature of 55.1 % [38], 44.19% [41] and absent or not detected [37]. These differences may be attributed to methodological, geographical, instrumental and environmental factors.

The UFA content ranged from 58.35% to 69.61% and 80.51% in the wild medicinal mushrooms and the cultivated edible mushrooms

respectively, which is in line with previously reported data on *Agaricus bisporus* [27,39] and some wild edible mushrooms [30,37,40-43].

The (%) FAs range reported in this study, in the cultivated *Agaricus bisporus* brown and white brand agrees with previous studies [12,27,32,34-36,39]. However, in the wild medicinal mushroom, the trend was different with oleic acid showing as the dominant unsaturated fatty ranging from 20.66% to 37.21% (Table 1). These results suggest that predominance of individual fatty acids varies from species to species although they could belong to same phylum and family.

In general FAs significantly varied between the cultivated edible and the wild medicinal mushrooms. This may be attributed to the intrinsic nature of some mushroom species in the production of greater amounts of some unique FAs compared to others species within the environment [37]. In addition, the trend could possibly be ascribed by the geographical location of the fungus, soil pH, pressure, nutrients, moisture content, ions and chemical interaction between the host, age of the mushrooms, enzymatic activities in the mushroom itself and its symbiotic agents (like insects). This is supported by previous studies [44-46] that FAs composition in most eukaryotic microorganisms tends to be influenced by environment factors, like pH, temperature, aeration, enzymatic activities and media component. However, since this current study did not include data from environmental parameters (soil pH, Moisture, humidity, conductivity), caution must be exercised when interpreting these factors with this current study.

The n-6, n-3 and their ratios have not been given much attention in previous fungi fatty acid studies, although, they contribute greatly to human nutrition and health. In general, the wild medicinal and cultivated edible mushrooms species were higher in n-6 than n-3. These trends may attribute to the high linoleic acid amounts in the mushrooms studied.

The ratio of n-6: n-3 is higher than the 15:1 ratio reported in the typical western diet by Simopoulos, (2002), and also the 10:1 ratio in the typical American diet [47-49]. The ratio of n-6: n-3 was also well above the recommended values of 3:1 or 2:1 [50-52]. This unfavorable n-6: n-3 ratio, should not be viewed, however, to detract from the overall healthful benefits of consuming mushrooms. The total amount of fat in mushroom is very low about 1 mg/g for every 100g of servicing cup, and therefore consuming a regular serving of mushrooms would only add (about 1 mg) of n-6: n-3 fatty acid. The high ratio is not necessarily a health detriment.

The ratio of PUFA:SFA and linoleic:oleic were in agreement with previous literature in some edible wild fungus, such as *T. claveryi, P. juniperi* [53] and *Agaricus arvensis* and *G. applanatum* [30].

The linoleic:oleic ratio was similar to those obtained in *T. claveryi* and *P. juniperi* [53], in *G. arinarius, Boletus edulis, and Helvella crispa* [43] in some edible mushrooms. The UFA: SFA ratio in both the wild medicinal and the cultivated edible mushrooms were similar to what was reported in studies of *T. claveryi*, and *P. juniperi; G. arinarius, Boletus edulis*, and *Helvella crispa* [43]; *Agaricus arvensis*, and *G.applanatum* [30]; *Agaricus bisporus* [39]. However, the ratios were lower than what was reported in some Basidiomycota, in the family Boletaceae e.g. *Boletus edulis, Boletus erythropus*, and *Boletus variipes* [37].

Some of the fatty acids detected are considered as bio-indicators for soil fungi characterization in the environment [48]. For instance, the linoleic acid (18:2n6) content in the various mushrooms can be used as an indicator for the determination of the number of fungi and its biomass content in soils [48].

The linoleic acid to oleic acid ratio and some of the identified unsaturated FAs such as; C16:1, C16:1t, C18:1, C18:1n7, C18:1n9t, and C18:2n6 may be useful as biomarkers for physiological, taxonomical and cell differentiation studies in two similar or different species of mushrooms, plants, algae and bacteria within the same family [48,54-60].

The degree of unsaturation for C18 FA (Δ/mol C18) in the cultivated species (*Agaricus bisporus*, white) was 1.89. With regards to the wild medicinal mushrooms C18 FA (Δ/mol C18) of unsaturation varied from 0.57 ± 0.03 to 1.15 ± 0.03%. The Δ/mol C18 results were similar to what has been reported in higher Basidiomycetes indigenous mushrooms in eastern Canada [30]. This may be used as indicators for nutritional, medicinal, and taxonomical purposes.

Conclusion

In summary, the studies have determined the fatty acid composition of selected wild medicinal mushrooms (Turkey-tail, Tinder polypore and Artist conk) in the Southern region of United States. The fatty acid compositions vary considerable among these wild medicinal mushrooms and the cultivated edible species *Agaricus bisporus*. Both wild medicinal mushrooms and cultivated edible mushrooms had high unsaturated fatty acids than saturated fatty acids. The wild mushrooms had mainly lower linoleic acid content (1/2 to 1/5 of the cultivated species). In all species the n-6/n-3 ratios were higher than the recommended ratio 3:1 but not substantially different from many common vegetable products. The fatty acid health biomarkers were within the values reported in some wild and cultivated edible mushrooms in literature.

Hence, nutritional, medicinal and economic studies should be encouraged into cultivated edible and wild mushrooms in the Southern region of United States because few studies have been conducted that evaluate and characterize mushrooms for their potential usefulness.

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