

PHENOLIC COMPOUNDS IN SOME WIDELY DISTRIBUTED
MEDICINAL MUSHROOM SPECIES IN ARMENIA

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Polyphenols constitute one of the most numerous and ubiquitous groups of fungal metabolites and are an integral part of the human diet. These molecules can be met as simple phenolic compounds or highly polymerized compounds. Recent interest in phenolic compounds has increased, owing to their antioxidant capacity. Besides, these compounds can have possible beneficial implications in human health, such as in the treatment and prevention of cancer, cardiovascular diseases, and other pathologies. Since there is little research done in Armenia, the data is scattered. This review aims to combine domestic and abroad papers on this matter.

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Introduction. Polyphenolic compounds are one of the largest distributed secondary metabolites. These compounds possess different properties and biological activity ranging from toxin inhibition to antioxidant, antitumor, anti-inflammatory, vasoprotective and other beneficial properties [1–12].

In nature these compounds serve to their hosts for protection against diseases, predators, or as metabolism and growth regulators [6, 11].

There is little research done in Armenia to determine the identity of polyphenolic compounds in some widely distributed medicinal fungi species [1–5]. However, there is some research on this topic in the international literature. *Cerioporus squamosus*, *Calvatia gigantea*, *Ganoderma lucidum*, *Fomes fomentarius*, and *Scleroderma verrucosum* medicinal fungi are widely distributed in Armenia. Since the ancient times the above-mentioned fungi have been used in food and drug production and are of great importance to our everyday life [6, 7, 8, 11].

The data published about the above-mentioned fungi is described below.

1. *Calvatia gigantea* (Batsch) Lloyd, 1904.

C. gigantea (Puffball mushroom) fruit bodies are round, up to 50 cm in diameter, rarely over 90 cm. Fruit bodies are found on ground. Young fruit bodies are white, edible. Mature fruit bodies are greenish brown, often can cause poisonings when consumed. It occurs in all floristic regions throughout Armenia [9, 13].

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Biochemical Content. A study carried out in 2016 showed high antioxidant activity, mainly linked to the polyphenolic compounds found in fungus. The most abundant phenolic compound is reported to be gentisic acid (23.26 $\mu\text{g/g}$). These findings are making the species a promising source for secondary metabolites. It has great potential to be a healthy food and food supplementary product. It was shown that ethanolic and methanolic extracts contain myristic acid, myristoleic acid, pentadecanoic acid, palmitic acid, palmitoleic acid, heptadecanoic acid, stearic acid, elaidic acid, oleic acid, linoleic acid, behenic acid, as well as aroma compounds such as 3-methyl-butanal, pentanal, 1-pentene, 2-methyl-pentanal, 1-pentanol, hexanal, isovaleric acid, 2-methylene-hexanall, 1-hexanol, benzaldehyde, 1-octen-3-one, 1-octen-3-ol, 2-pentyl-furan, 2-octenal. These extracts showed high antioxidant and radical scavenging activity as well [14].

There is no data published in Armenia regarding this species yet, but since *C. gigantea* can be found in every floristic region in Armenia, studying the fungus can prove to be very useful in understanding of fungal secondary metabolites.

2. *Cerioporus squamosus* (Huds.) Quél. 1886 syn. *Polyporus squamosus* (Huds.) Fr. 1821. *C. squamosus* (Dryad's Saddle) fruit bodies are annual. Mushroom is commonly found on dead logs or branches. Fruit bodies are up to 30 cm across and 10 cm thick, yellowish or brownish. Young fruit bodies are edible. Spore print is white. Can be found in all floristic regions throughout Armenia [9, 13].

Fruit bodies are rich in proteins, essential amino acids as well as fibers, but they are poor in fats. The young edible fruit bodies are considered vital sources of many vitamins including vitamin B₁, B₂, B₁₂, C, D, and E. They also possess a great importance due to their valuable bioactive compounds such as phenolic compounds, as well as unsaturated fatty acids, carotenoids and terpenoids. Thus, mushrooms have been used in many nutritional and pharmaceutical products [12, 15].

Polyphenolic Content. Fruit bodies collected from Serbia and Portugal showed high antioxidant activity and were rich in nutrients such as tocopherols, organic acids, and phenolic compounds. Portugal samples contained the highest amount of beta-tocopherol and gamma-tocopherol was not found in the extracts. Meanwhile Serbian samples contained the highest amount of gamma-tocopherol. The tocopherol content of Portugal samples were more than 15 times higher than the Serbian were. Serbian samples had higher overall antioxidant and radical scavenging activities (up to 2.3 times depending on the assays used) [16].

Research performed by our team earlier showed that the specimens collected from Armenian broad leaf forests showed high phenolic content (104 mg/L of gallic acid equivalent) [2].

3. *Ganoderma lucidum* (Curtis) P. Karst. 1881. *G. lucidum* (Reishi) fruit bodies are commonly found on dead logs or branches in different forests. Fruit bodies almost always have tawny stripe that is 1.5 times the diameter of cap. Mushroom is rusty brownish, edible, often used to make teas. Can be found in all floristic regions throughout Armenia [9, 13].

G. lucidum is widely known as the “mushroom of immortality” and is a symbol of traditional Chinese medicine owing to its high therapeutic potential and efficacy. *G. lucidum* has been used in herbal medicine for many years to treat human diseases, including cancer, viral hepatitis, and bronchitis, and more. Previous studies

worldwide have reported that the *G. lucidum* extract could elicit innate immune responses, control cell proliferation, and cause cancer cell migration [17].

Polyphenolic Content. 42 constituents were identified in the essential oil of *G. lucidum* [18]. Among the most important compounds ergosterol (1), ergosta-7,22-diene-3b-ol (2), lanosta-8(9), 24(28)-diene-3b-ol (3), ergosterol peroxide (4) and 5,8-epi-dioxy-24-methylcholesta-6,9(11),22-triene-3b-ol (5), eburicoic acid (6) as well as two new triterpenes, (+)-23-oxo-3,4-seco-lanosta-4(28),7(8),9(11),24(31)-tetraene-3,26-dicarboxylic acid (7) and (+)-20-hydroxy-23-oxo-3,4-seco-lanosta-4(28),7(8),9(11),24(31)-tetraene-3,26-dicarboxylic-acid (8), can be mentioned. Compound 5 was tested and showed potential for its anticarcinogenic activity and compound 7 for its antimicrobial activity [18].

Meanwhile, 109 compounds were detected in the crude extract of the fungus. Furthermore, it has been shown that the drying method of the fresh fungal specimens before the extraction has a huge effect on the amount of compounds in the crude extract. The heat-dried extract was differentiated due to a high level of amino acids (L-Alanine, L-Serine, L-Asparagine, L-Proline, and L-Threonine); alcohols and derivatives (D Mannitol, glycerol, ethylene glycol and silanol) and monosaccharides (D(-)-fructose, D(+)-mannose and D(-)-ribofuranose). In the freeze-dried samples, the organic acids were found to be significantly higher [17].

4. *Fomes fomentarius* (L.) Fr. 1849. *F. fomentarius* (Hoof fungus or Tinder fungus) fruit bodies are up to 45 cm across, 25 cm thick. Fruit bodies are found on dead logs or branches in various broad leaf forests. Underside has round pores often colored cinnamon brown. Color and size can vary depending on the substrate. Can be found in all floristic regions throughout Armenia [9, 13].

Polyphenolic Content. *F. fomentarius* have significant antioxidant activity mainly due to the antioxidant enzymes, as well as digestive enzymatic activity, antimicrobial activity: antifungal, antibacterial, antiviral, anti-inflammatory properties, antitumor, DNA protective activity [19].

Research showed that these activities are exhibited by extracts or isolated compounds from *F. fomentarius* fermentation broth, mycelia and fruiting bodies. As a result of its perceived health benefits, *Fomes fomentarius* has gained wide popularity as an effective medicine and has become one of the valuable mushrooms [15, 19, 20].

Another research shows that antiviral substances with systemic effects produced by basidiomycetes such as *F. fomentarius* mushroom modulates the immune system, inhibits tumour growth, has anti-inflammatory, activities and lowers blood lipid concentrations and prevents high blood pressure. Several polysaccharides were identified and purified that are responsible for these properties [21].

F. fomentarius fruit bodies show high phenolic content (157 mg/L of gallic acid equivalent). Alcoholic extracts are good radical scavengers. It was shown that methanolic extracts of these fungi contain a little bit more (~10%) phenolic compounds than ethanolic extracts. Phenolic compounds found in the fruit bodies of the mushroom do not dissolve in the cold distilled water very well because cold distilled water extracts only contain around 60% of alcoholic extracts' phenolic content [22, 23].

5. *Scleroderma verrucosum* (Bull.) Pers. 1801. *S. verrucosum* (Warted earth ball) fruit bodies are roughly spherical with flattened top, up to 7 cm across. Fruit

bodies are ochre or dingy brown, surface is covered with warts. The base is smooth. *S. verrucosum* is ectomycorrhizal, grows in broad leaf forests. Can be found in all floristic regions throughout Armenia [9, 13].

Biochemical Content. *S. verrucosum* is not a well-studied species. There is not much information about structure and content of low molecular secondary metabolites published, however research carried out in Brazil in 2022 shows promising results. The fungus contains high amount of polyphenolic compounds (309.14 g per 100 g of extract gallic acid equivalent) as well as being a highly potent radical scavenger (5.97 $\mu\text{g/mL}$).

S. verrucosum was used as a traditional medicine against cancer and in low amounts several cultures are using it as a spice in culinary. Thus, it is important to carry out research to identify all the secondary metabolites in *S. verrucosum* fruit bodies. Studies will expand our knowledge about secondary metabolites [24].

Fungal metabolites with great diversity and preapproved biocompatibility can be a potential source for new antiviral drug lead. Considering, very small fraction of fungal species has been discovered and only few percent of these extracts are tested for various diseases. Small-molecule fungal metabolites due to their vast diversity, stereochemical complexity, and preapproved biocompatibility always remain an attractive source for new drug discovery [25].

Conclusion. The above-mentioned species are highly distributed in Armenia and contain a large amount of different biochemical compounds. *C. gigantea*, *C. squamosus*, *G. lucidum*, *S. verrucosum*, and *F. fomentarius* possess antioxidant, anticancer, immunomodulatory activities. As it was shown, the same species grown on different substrates, under different ecological conditions accumulated different amounts of secondary metabolites. It is a matter of great importance to make long-term research to identify all the medicinal fungal secondary metabolites that grow in different parts of Armenia, not to miss the ideal composition of accumulated secondary metabolites as a treatment for different diseases.

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ՀԱՅԱՍՏԱՆՈՒՄ ՀԱՆԴԻՊՈՂ ՈՐՈՇ ԼԱՅՆ ՏԱՐԱԾՈՒՄ ՈՒՆԵՑՈՂ ԴԵՂԱՍՆԿԵՐԻ ՖԵՆՈԼԱՅԻՆ ՄԻԱՑՈՒԹՅՈՒՆՆԵՐԸ

Ֆենոլային միացությունները սնկերի երկրորդային մետաբոլիտներից ամենաբազմազանն են և մարդկանց սննդակարգի անբաժանելի մասն են: Այս մոլեկուլները սնկերում կարող են հանդիպել ինչպես ցածրամոլեկուլային՝ պարզ ֆենոլներ, այնպես էլ բարդ՝ պոլիմերիզացված ձևերով: Վերջին ժամանակներում ֆենոլային միացություններն ավելի հաճախ են հայտնվում ուշադրության կենտրոնում շնորհիվ իրենց դրական հատկությունների, ինչպիսին է հակաօքսիդանտային ակտիվությունը և մի շարք հիվանդությունների հավանական բուժման եղանակ, օրինակ քաղցկեղ, սրտանոթային հիվանդություններ: Հայաստանում այս ոլորտի հետազոտությունները քիչ են, տվյալները՝ ցրված: Այս աշխատանքի նպատակն է համախմբել Հայաստանում և արտասահմանում հրատարակված գրականությունը այս թեմայի շուրջ:

В. С. ГЕВОРГЯН

ФЕНОЛЬНЫЕ СОЕДИНЕНИЯ НЕКОТОРЫХ ШИРОКО РАСПРОСТРАНЕННЫХ МЕДИЦИНСКИХ ГРИБОВ В АРМЕНИИ

Фенольные соединения – одни из наиболее широко распространенных вторичных метаболитов грибов, являются неотъемлемой частью рациона человека. В грибах эти соединения могут встречаться как в виде низкомолекулярных соединений, например простые фенолы, так и в виде сложных полимеров. В последнее время фенольные соединения чаще оказываются в центре внимания благодаря полезным свойствам, таким как антиоксидантная активность, и используются в качестве лекарственных средств при лечении таких болезней, как рак и сердечно-сосудистые заболевания. Медицинские грибы в Армении мало изучены, а имеющиеся данные разрознены. Цель работы – обобщение литературных данных относительно фенольных соединений некоторых широко распространенных медицинских грибов.