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AGARICOMYCETES MUSHROOMS DISTRIBUTED IN ARMENIA – SOURCE OF COSMETIC BIOINGREDIENTS

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Currently, the cosmetic industry is in a constant search for valuable bioingredients with anti-aging (antioxidant, anti-inflammatory, anti-collagenase, anti-elastase, anti-hyaluronidase and anti-tyrosinase) properties. Edible and medicinal Agaricomycetes mushrooms (macrofungi) as unlimited source of bioactive compounds and enzymes have mainly been studied for their nutritional value and medicinal properties. They have also been included in cosmetic formulations for topical and oral administration however there is slow progress in their usage as cosmeceuticals.

We described 19 medicinal, including 12 edible mushrooms belonging to 18 genera of Agaricomycetes fungi distributed in Armenia – as potential cosmeceuticals. Further evaluation of mushrooms resources in Armenia will revealed new species and promote their biotechnological exploitation not only as mushroom-derived nutraceuticals and pharmaceuticals, but also cosmeceuticals. Advances in biology and biotechnology of Agaricomycetes will further assist development of myco-cosmetology in Armenia.

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Introduction. Aging is a result of oxidative stress in human body and naturally derived cosmetic skin and hair care formulations (cosmeceuticals) with antioxidant and anti-inflammatory effects are highly in demand by consumers. Cosmeceuticals are products between cosmetics and pharmaceuticals containing bioingredients, which can be extracted from different organisms, including mushrooms and plants or obtained biotechnologically (cultivation, fermentation, enzymatic synthesis, etc.).

Currently the cosmetic industry is in search for low toxicity bioingredients to develop novel formulations and cosmeceuticals. Mushrooms are valuable source of bioactive compounds with antioxidant, anti-inflammatory, photoprotective, wound-healing and other effects [1–13]. Mushrooms-derived multifunctional cosmetic bioingredients are currently exploiting in production of anti-aging skin and hair care cosmetic products [9–11, 14, 15].

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Several bioactive compounds such as glucans, phenolics, polysaccharides and terpenoids with anti-inflammatory, antioxidant, anti-collagenase, anti-elastase, anti-hyaluronidase, anti-tyrosinase and other activities isolated from agaricomycetous fungi are incorporated in cosmetic products. The mushroom-derived cosmeceuticals (applied topically as creams, lotions and ointments) and nutracosmetics (administered *per os*) currently available in the market are safe [15].

Mushroom-derived Bioactive Cosmetic Ingredients. Bioactive compounds with different origin are increasingly used as cosmeceutical ingredients. Scientific data showed that fatty acids, bioactive peptides, phenolics, polysaccharides, terpenoids, vitamins, and volatile compounds isolated from extracts of different medicinal and edible agaricomycetous mushrooms possess anti-aging, anti-inflammatory, antioxidant, anti-pigmentation, antimicrobial, anti-wrinkle, wound-healing, skin-whitening and moisturizing effects. They also inhibit the activity of collagenase, elastase, hyaluronidase and tyrosinase enzymes. Therefore, mushrooms, along with plants, potentially could be used as natural cosmetic ingredients.

Polysaccharides, triterpenes, and fungal immunomodulatory proteins (FIPs) found in *Ganoderma* species have been exploited for potential ingredients in the cosmetic industry to develop new cosmeceuticals, nutri- and nutracosmetics with antioxidant, antibacterial, anti-inflammatory and melanin-inhibitory effects [16]. The extract from Reishi or Ling Zhi mushroom (*Ganoderma lucidum*) was found to have potent anti-tyrosinase activity against melanin formation and used in skin-lightening beauty products in China [17–19]. *G. lucidum* also contains α- and β-D-glucans, alkaloids, triterpenoids, such as ganoderic acids, ganoderol, and lucidenic acids, as well as ergosterol and proteins (LZ-8, LZ-9) with different pharmacological activities. *G. lucidum* together with edible medicinal oyster mushroom *Pleurotus ostreatus* incorporated into base of several cosmetic creams with antioxidant and antibacterial effects [11, 20, 21].

The chemical constituents isolated from medicinal bracket fungi *Phellinus igniarius* possess anti-inflammatory effect and have also been reported as bioingredients to develop cosmetic products [22]. Medicinal mushroom *Schizophyllum commune* contains phenolics, polysaccharides and β-glucans beneficial to skin health [23, 24]. Polysaccharides isolated from edible mushroom *Tremella fuciformis* has attracted attention due to its ability efficiently reduce water and collagen losses of the skin and used to develop skin-protective cosmeceuticals [25]. Edible medicinal winter mushroom *Flammulina velutipes* has showed antioxidant activity and was suggested as the best source for biocosmetics [26]. Antibacterial and antioxidant activities with high sun protective factor (SPF) (34.02 at 200 $\mu g/mL$) were revealed in ethyl acetate extracts of mycelia and cultural broth of *F. velutipes* and *P. ostreatus.* Both species are considered as promising cosmeceuticals [9, 14, 25].

Anti-melanogenesis and anti-inflammatory activity were detected in hot water extracts of several agaricoid and polyporoid medicinal mushrooms (*Agaricus bisporus, G. lucidum, Hypsizygus marmoreus, Pleurotus floridanus* and *Pleurotus pulmonarius*) [27]. Extract from *Trametes versicolor* was reported as suppressor of cellular senescence in HaCaT cells possibly through augmenting Sirtuin 1 (SIRT1) protein expression [28].

Mushroom-derived Enzymes Activity Inhibitors. Mushrooms are producers of anti-aging bioactive compounds with anti-tyrosinase, anti-hyaluronidase, anti-collagenase and anti-elastase effects and, therefore, are incorporated in many cosmetic products [10, 11, 13, 14].

Well-known edible medicinal button mushroom *A. bisporus* is rich in nutrients and minerals, and possesses potential anticancer, antioxidant, anti-obesity and anti-inflammatory properties. The observed anti-tyrosinase activity and the presence of ergothioneine with skin-whitening properties have shown that this fungus is not only a source of nutraceuticals and pharmaceuticals, but also cosmeceuticals [8]. The tyrosinase-inhibitory, anti-inflammatory, antibacterial, and antioxidant activities of ethanolic extracts from *A. bisporus* and *P. ostreatus* showed their significant cosmeceutical potential. The phenolic acids and ergosterol isolated from these species were suggested as basic ingredients for cream [14, 29].

The polysaccharide extracts from *G. lucidum* have been screened for their antioxidant activity, collagenase and elastase inhibitory effects. Smaller quantities of proteins, phenolics and flavonoids were detected in the extracts, as well. Inhibition of tyrosinase activity and antioxidant effect of tested extract could provide a skin-lightening effect, while anti-collagenase and anti-elastase activities can help to restore the skin elasticity. *G. lucidum* is presented as a promising source of cosmetic bioingredients [30]. The chemical content (phenolic acids and sterols), cosmetic properties (anti-tyrosinase and anti-hyaluronidase) and SPF values of mycelial extracts derived from *Ganoderma applanatum, Laetiporus sulphureus* and *T. versicolor* have been reported. The SPF value of *G. applanatum* extract was ~ 9. The screened species may be used as bioingredients in the formulation of novel cosmeceuticals [31].

Study of chemical contents and assessment of cosmeceutical potential of water extracts from fruiting bodies of medicinal mushrooms *Auricularia polytricha, G. lucidum, P. ostreatus* and *S. commune* revealed total phenolics, polysaccharides and glucans, as well as antioxidant activity. The total polysaccharide content of *P. ostreatus* extract was the highest, while the extract obtained from *G. lucidum* contained the lowest level of glucans. The extract from *S. commune* exhibited 98.15% anti-tyrosinase and 94.82% antioxidant activities. *G. lucidum* extract showed the strongest anti-hyaluronidase activity (72.78%). The cosmeceutical properties of these mushrooms can mainly be attributed to the combination of polysaccharides and phenolics. The extracts of *S. commune* and *G. lucidum* were suggested for further study as potential cosmeceuticals [32].

Mushrooms with Cosmeceutical Potential Growing in Armenia. The forest regions in Armenia are rich with mushroom biodiversity and are mainly distributed in the northeastern (Ijevan and Lori floristic regions) and southeastern (Zangezur floristic region) parts of Armenia. The biotic, climatic and edaphic environmental conditions are favorable for the development of rich mushroom biodiversity [33]. Around 850 agaricoid and polyporoid Agaricomycetes species, forms and variations from 13 orders (Agaricales, Boletales, Polyporales, Hymenochaetales, etc.), largely corresponding to the classical group of Homobasidiomycetes, have been described in Armenia. They belong to different ecological groups (xylotrophs, soil and litter saprotrophs, mycorrhizal, etc.).

Mushrooms distributed in different floristic regions of Armenia as potential source of cosmeceuticals

Species	Floristic Region	Bioactive compounds	Cosmetic effects	Ref.
Abortiporus biennis (Bull.) Singer ●	IJ, ZG	Exopolysaccharides	AOA	[38]
Agaricus bisporus (J.E. Lange) Pilát* # ●	YE, GG	Caffeic, chlorogenic, cinnamic, ferulic, gallic, *p*-hydroxybenzoic, *p*-coumaric and protocatechuic acids, alkaloids, polyphenols	AOA, AIA, ABA, anti-tyrosinase	[8, 9, 27]
Amanita muscaria (L.) Lam. ●	AP,IJ	β-D-glucan, FMG	AIA	[39]
Boletus edulis Bull. # ●	AP, IJ, LR, ZG	Ergothioneine, glutathione	AOA	[40]
Calocybe gambosa (Fr.) Donk # ●	AP,YE, IJ, SV	Ascorbic acid (vitamin C)	Anti-radiation, stimulating collagen synthesis	[41]
Coprinus comatus (O.F. Muller) * # ●	YE, IJ, LR, SV ZG	Tocopherols (vitamin E)	Reducing UV damage to skin	[41]
Flammulina velutipes (Curtis) Singer * # ●	YE, IJ, LR	Glycosides	AIA, AOA	[9, 25, 26]
Ganoderma lucidum (Curtis) P. Karst. * ●	AP, IJ, LR ZG	α/β-D-glucans, alkaloids, triterpenoids (ganoderic acids, ganoderenic acids, ganoderol, ganoderiol, lucidenic acids), sterols/ergosterol, proteins (LZ-8, LZ-9), FIPs, nucleosides (adenosine, inosine, uridine), and nucleotides (adenine, guanine)	Anti-tyrosinase, melanin inhibitory, AIA	[11, 19, 21, 22, 27, 30]
Inonotus obliquus (Fr.) Pilát ●	LR	Protein-bound polysaccharides, xylogalactoglucan, lanostanoid triterpenoids, steroids (betulin flanosterols, inotodiol, inostiols, vitamin B, lactones, melanin	Antioxidant, skin moisturizer	[42]
Laccaria amethystine Cooke # ●	AP, IJ, LR	Laccaridiones A, B	Anti-collagenase	[43]
Laetiporus sulphureus (Bull.) Murrill * # ●	YE, IJ, LR, MG, ZG	Phenolic acids	Anti-hyaluronidase, anti-tyrosinase	[31]
Macrolepiota procera (Scop.) Singer # ●	DG, IJ, LR, SV, ZG	Lanostane triterpenoids	Inhibition of NO production	[44]
Neolentinus lepideus (Fr.) Redhead & Ginns [= *Lentinus lepideus* (Fr.) Fr.] # ●	IJ, LR	1,3- Dihydroisobenzofuran-4,5,7-triol,5-methoxy-1,3-dihydroiso-benzofuran-4,7-diol, lepidepyrone	Anti-tyrosinase, anti-hyaluronidase	[45]
Pleurotus eryngii (DC.) Quél. * # ●	YE	Cinnamic, *p*-coumaric and *p*-hydroxyphenylacetic acids, ergosterol, nicotinic acid, pleurone, (24E)-3β-hydroxy- cucurbita-5,24--diene-26-oic acid	AOA, anti-elastase	[25, 46, 47]
Pleurotus ostreatus (Jacq.) P. Kumm. * # ●	YE, IJ, LR, ZG	Alkaloids, phenolics, gallic acid	AMA, AOA, AIA, anti-pigmentation, anti-tyrosinse,	[9, 14, 20, 21, 25]
Phellinus igniarius (L.) Quél. * ●	All	Nepetidin, betulic acid	NF-κB inhibitory	[22, 36]
Schizophyllum commune Fr.* ●	AP, YE, IJ, ZG	Phenolics, ß-glucans	Anti-pigmentation, AOA	[23, 24]
Trametes versicolor (L.) Lloyd * ●	All	Protein SIRT1, phenolic acids	Anti-tyrosinase, anti-hyaluronidase, AOA	[28, 31]
Volvariella bombycina (Schaeff.) Singer * # ●	YE	Isodeoxyhelicobasidin, alkaloids	Anti-elastase, AMA, AIA, AOA	[1, 3, 9]

Note: * – cultures are available in the FCC-YSU [37]; # – edible species; ● – medicinal species; AOA – antioxidant activity; AIA – anti-inflammatory activity; ABA – antibacterial activity; AMA – antimicrobial activity. All – all floristic regions of Armenia: AG – Aragats; AP – Aparan; DG – Daralegez; GG – Geghama; IJ – Ijevan; LR – Lori; MG – Meghri; SH – Shirak; SV – Sevan; UA – Upper Akhuryan; YE – Yerevan; ZG – Zangezur [33].

Among them, around 80 species are known as medicinal; more than 50 species are edible, including highly priced edible mushrooms *Boletus edulis, Calocybe gambosa, Cantharellus cibarius, F. velutipes, Lactarius deliciosus, P. ostreatus* and *Suillus luteus* with excellent culinary properties [34–36].

The studies of biotechnological potential of edible and medicinal Agaricomycetes fungi and comprehensive evaluation of their bioresources in the territory of Armenia are in demand [34–37]. Further advances in biology and biotechnological cultivation of these organisms will open up new perspectives for their usage in production of novel myco-pharmaceuticals, nutraceuticals and cosmeceuticals [10, 12].

In the current review 19 medicinal mushrooms, including 12 edible species from 18 genera (*Abortiporus, Agaricus, Amanita, Boletus, Calocybe, Coprinus, Flammulina, Ganoderma, Inonotus, Laccaria, Laetiporus, Macrolepiota, Neolentinus, Pleurotus, Phellinus, Schizophyllum, Trametes* and *Volvariella*) distributed almost in all floristic regions of Armenia have been reported as potential source of cosmeceuticals (see Table). Among them 105 strains of 9 species are preserved in the culture collections of the Yerevan State University (FCC-YSU) [37].

Nowadays several species, such as *G. lucidum, T. versicolor, L. sulphureus* and *C. comatus* distributed also in Armenian are widely incorporated in the cosmetic products available in the world market (Figs. 1 and 2).

Fig. 1. Mushrooms collected in Armenia as potential source of cosmetic bioingredients:
a – *Trametes versicolor* (Hanqavan, beech tree stump);
b – *Laetiporus sulphureus* (Erevan, asch tree);
c – *Ganoderma lucidum* (Tavush, beech tree stump);
d – *Coprinus comatus* (Erevan, on soil).

a b c d e

Fig. 2. Mushroom-derived cosmetic products:
a – hairs strengthening shampoo and balm from Ling Zhi (*Ganoderma lucidum*);
b – mushroom cosmetics from “WEIL” for Origins;
c – Skin relief face cleanser contain *G. lucidum*, Mico-Lift anti-wrinkle cream;
d – Mico-Soap from *Trametes versicolor;*
e – anti-wrinkle cream from Chaga mushroom *(Inonotus obliquus)*.

Conclusion. Edible and medicinal Agaricomycetes mushrooms growing in Armenia are regarded as a traditional source of valuable food and myco-pharmaceuticals, however their exploitation as potential ingredients in the cosmetic industry was not assessed. Meanwhile several mushrooms are successfully used as bioingredients in formulations of anti-aging organic cosmetic products with anti-wrinkle, moisturizing, wound-healing, anti-collagenase, anti-elastase, anti-hyaluronidase, anti-tyrosinase, anti-pigmentation, anti-inflammatory and antioxidant effects.

We described 19 medicinal mushrooms, including 12 edible species from 18 genera of Agaricomycetes fungi distributed in Armenia as potential sources of cosmeceuticals. Further evaluation of mushrooms resources will promote their biotechnological exploitation not only as nutraceuticals and pharmaceuticals, but also cosmeceuticals. Advances in fungal biology and biotechnology will further assist development of myco-cosmetology in Armenia.

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ՀԱՅԱՍՏԱՆՈՒՄ ՏԱՐԱԾՎԱԾ ԱԳԱՐԻԿՈՄԻՑԵՏԱՅԻՆ ՍՆԿԵՐԸ՝ ԿՈՍՄԵՏԻԿ ԿԵՆՍԱԲԱՂԱԴՐԱՄԱՍԵՐԻ ԱՂԲՅՈՒՐ

Ագարիկոմիցետային սնկերը վաղուց հայտնի են մարդկությանը իրենց սննդային արժեքով և դեղաբանական հատկություններով, սակայն կոսմետիկ միջոցների արտադրության մեջ նրանց կիրառումը գրանցել է դանդաղ առաջընթաց: Ներկայումս կոսմետիկ արտադրությունը հակածերացնող հակակոլագենազային, հակաէլաստազային, հակահիալուրոնիդազային, հակապիգմենտային, հակաբորբոքային, հակաօքսիդանտային և հակաթիրոզինազային հատկություններով բնական բաղադրիչների մշտական որոնման մեջ է: Aգարիկոմիցետային ուտելի սնկերը և դեղասնկերը որպես արժեքավոր սննդի և կենսաակտիվ միացությունների աղբյուր կարող են լայնորեն կիրառվել զանազան կենսատեխարտադրանքների, ներառյալ կոսմետիկ միջոցների արտադրության մեջ:

Նկարագրվել է Հայաստանում տարածված ագարիկոմիցետային սնկերի 18 ցեղերին պատկանող 19 տեսակ, որոնք հանդիսանում են կոսմետիկ կենսաբաղադրամասերի պոտենցիալ աղբյուր: Սնկային ռեսուրսների հետագա գնահատումը Հայաստանում կբացահայտի նոր տեսակներ և կնպաստի դրանց կենսատեխնոլոգիական կիրառմանը ոչ միայն որպես

առողջարար սննդի և սնկային դեղապատրաստուկների, այլև կոսմետիկ միջոցների արտադրության մեջ: Սնկերի կենսաբանության և կենսատեխնոլոգիայի առաջընթացը կխթանի միկոկոսմետոլոգիայի հետագա զարգացումը Հայաստանում:

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АГАРИКОМИЦЕТОВЫЕ ГРИБЫ, РАСПРОСТРАНЕННЫЕ В АРМЕНИИ – ИСТОЧНИК КОСМЕТИЧЕСКИХ БИОИНГРЕДИЕНТОВ

Пищевая ценность и лекарственные свойства агарикомицетовых грибов (класс Agaricomycetes) всесторонне исследованы, однако прогресс в области их биотехнологического применения в косметической промышленности незначительный. В настоящее время косметическая промышленность находится в постоянном поиске источников ценных природных ингредиентов против старения с антиколлагеназным, антиэластазным, антигиалуронидазным, антипигментационным, антитирозиназным, противовоспалительным и антиоксидантным эффектами. Съедобные и лекарственные грибы являются природным источником нутрицевтиков и фармацевтиков. Их можно использовать и в качестве биоингредиентов для разработки органических космецевтиков (нутрацевтиков и нутрицевтиков).

Нами были описаны 19 лекарственных видов, включая 12 съедобных из 18 родов агарикомицетовых грибов, произрастающих на территории Армении, как потенциальных биоингредиентов для получения космецевтиков. Дальнейшая оценка их ресурсного потенциала в Армении позволит выявить новые виды, которые могут быть использованы не только в качестве продуктов питания и лекарственных препаратов, но и космецевтиков. Достижения в области биологии и биотехнологии агарикомицетов будут способствовать развитию микокосметологии в Армении.