ISSN: 2287-688X

Annals of
Plant Sciences

Volume 12, Issue 06 (2023) pp. 5877-5883

Review Article

Growing Gold of Mountains: Morchella esculenta—A Review

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Abstract

Mushrooms are fungus that may be both poisonous and beneficial to humans. There are many different kinds of mushrooms in the globe. *Morchella esculenta* is one of these mushrooms. It is the costliest mushroom known to date, and it belongs to the morel species. It is usually found in hilly terrain. Carbohydrates, proteins, lipids, carotenoids, phenolic compounds, and aromatic compounds like aldehydes, ketones, and other bioactive elements make up the fruiting body. It possesses a wide range of pharmacological and therapeutic effects, including antioxidant, anti-inflammatory, antibacterial, and hepatoprotective qualities, among others.

Keywords: *Mushroom, Morchella, Morel, bioactive constituents, pharmacological action.*

Introduction

Mushrooms have been eaten since time immemorial. They play a significant role in minor forest products. Mushrooms are macro fungi with a distinct fruiting body that can be epigeal and hypogeal. Mushrooms were thought to bring power to warriors in combat by the ancient Greeks. Nicknamed "Food of the Gods" by the Romans, the Chinese have considered mushrooms for millennia as a "vital elixir" and a therapeutic meal. Mushrooms have a wide range of uses, including medicine and food, in addition to their important ecological responsibilities. For thousands of years, they have been a part of human civilization., and their sensory traits have piqued the curiosity of some of history's most prominent civilizations; they've also been lauded for their delectable gastronomic qualities.Mushrooms have a variety of nutraceutical qualities, including the prevention and treatment of Parkinson's disease, Alzheimer's disease, hypertension, and stroke risk. Because of their antitumor properties, they are also used to lower the risk of cancer invasion and metastasis. Mushrooms have antimicrobial, immune-boosting, and cholesterol-lowering properties, as well as being rich in bioactive chemicals. Some mushroom extracts are used to improve human health and are available as dietary supplements as a result of these qualities. Mushrooms belonging to Morchella spp. are edible mushrooms renowned all over the world for their savoury flavour. Morchella is linked to cup fungi that have a simpler anatomical structure. The upper half of these unique mushrooms is made up of a network of ridges with holes between them, giving them a honeycomb-like appearance. Morels have been used in traditional medicine for generations because of their health advantages, and recent study has revealed that they contain anti-oxidant and anti-inflammatory bioactivities, as well as immunostimulatory and anti-tumor capabilities. *Morchella conica, Morchella angusticeps, Morchella elata, Morchella vulgaris* are black morels, whereas *Morchella esculenta, Morchella crassipes, and Morchella deliciosa* are yellow morels. Due to their widespread consumption, the yellow morel *Morchella esculenta* and the black morel *Morchella conica* are the most researched species in terms of nutritional and phytochemical content (Kumar, *et al*., 2018).

Morchella esculenta is one of the world's most expensive mushrooms. The cost of dried ascocarp is Rs. 5000 per kilogram, making

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DOI: http://dx.doi.org/10.21746/aps.2023.12.6.2

Morchella mushroom one of the most expensive edible fungi on the planet. It's one of the most significant and commercially beneficial wild mushroom species. Other names for it include Gucchi, morel, common morel, true morel, morel mushroom, yellow morel, sponge morel, and so on. The name "*esculenta*" is derived from the Latin whose meaning is "edible". It thrives in dense coniferous forests with loamy, humus-rich soil. It grows on a steep height with a cold climate naturally. From March until July, the plant is in full bloom. The woodlands of Jammu and Kashmir and Himachal Pradesh in India are home to this mushroom (Kumar, *et al*., 2018). It has been found in temperate climates, Asia, the Himalayan Mountains, Europe, Mediterranean nations, and North America as a mycorrhizal or saprobic connection with hardwood and coniferous trees at altitudes of 2500-3500m (Sud, *et al*., 2017). Ascocarps are cooked with rice and vegetables and are thought to be as healthy as meat. It is also widely employed in health difficulties, cures, and therapeutic purposes, and is free of any linguistic, cultural, or geographical limitations. *Morchella esculenta* is widely renowned for its nutritional properties all over the world. It is high in carbs, proteins, fibre, vitamins, minerals, and aromatic components (Sharma, *et al*., 2016). Table 1 shows the *Vernacular names of M.esculenta.*

Table 1: Vernacular names of M.esculenta

Region/Language	Vernacular Name
India	Guchhi
Nepal	Guchihyau
French	Morille
Pakistan	Gujae, Guchhi, Spina Guchhi, Kerkichoke, Khosay

Systemic Classification of *M. esculenta* (Ajmal, *et al*., 2015):
Kingdom – Fungi
Phylum – Ascomycota
Class – Discomycetes
Order – Pezizales
Family – Morchellaceae
Genus – Morchella
Species – *Morchella esculenta* (L.) Pers

Figure 1: Morchella esculenta

Life Cycle of *M. esculenta:*

The sporophyte produces a haploid ascospore, which initiates the life cycle. Ascospores have been observed to germinate practically quickly after being discharged. Multinucleate hyphae begin to develop once the ascospores germinate. The life cycle of *M. esculenta* can follow two distinct paths based on multinucleate hyphae development; the decisive element on which path the life cycle will take is when plasmogamy occurs (Volk, *et al*., 1990). Without plasmogamy, the first route will continue to expand. To protect the nucleus, the main mycelia will circle up and build thicker cell walls. Sclerotia, a structure with extremely thick cell walls that allows the fungus to live under hard environments, will arise as a result of this sort of growth (Leonard, *et al*., 1992).

The sclerotia can store energy during the winter and produce fruiting hyphae in the spring. When the environment around the fungus does not allow for continued vegetative growth, this is the path to take. This could be due to a lack of nutrients, unsuitable growing temperatures, or a lack of water. When specific nutrients are present, such as sheep manure, the fungus has been proven to follow this pattern. When conditions are ideal for further growth and there is an interaction between two compatible primary mycelia, the fungus will take the second path. Another sclerotium is generated when the two primary mycelia have experienced plasmogamy and joined to form a secondary mycelium. The cycle of the sclerotium can then adopt one of two paths: myceliogentic germination or carpogenic germination. The sclerotium transforms into a secondary mycelium during myceliogenic germination and waits for optimum growth circumstances to continue its life cycle. When the sclerotium goes through carpogenic germination, the fruiting body emerges, immediately forming asci containing ascospores, and the cycle begins again (Volk, *et al*., 1990).

Morphological Characters:

In the early stages, the hue is creamy white, but when mature, it becomes yellow. Its size ranges from 2 cm to 25 cm while fresh, but shrinks to 0.1 to 10 cm when dried (Hamayun, *et al*., 2006).

Up to 7-9cm long, and 4-5cm broad pileus with no discernible longitudinal ridges. Round, uneven, or longitudinally elongated pits are common.ridges with uneven anastomosing, rounded edges, lighter than pits. At the base, the stipe is just slightly extended (Negi, 2006).

Bioactive Constituents:

M. esculenta's fruiting body contains various bioactive substances such as organic acids, phenolic compounds, and tocopherols, as well as a lot of carbs (including free sugars), carotenoids and proteins. Mono and unsaturated fatty acids were also outnumbered by polyunsaturated fatty acids, p-Coumaric acid, p-Hydroxybenzoic acid, and protocatechuic acid are the most prevalent phenolic chemicals found in this yellow morel (Helano, *et al*., 2013). MEP-1, MEP-2, and MEP-3 were produced from M. esculenta polysaccharide fractions. MEP-1 was an odourless, water-soluble polysaccharide with a specific rotation of + 257.0. MEP-1 has glucose, mannose, galactose, and arabinoser, according to early findings. The carbohydrate was a heteropolysaccharide with a glycosidic linkage, and the average molecular quality was 43.625 kDa (Yang, *et al*., 2015). Mannitol, treholose and fructose are also found (Heleno, *et al*., 2013). Linoleic acid (C18:2n6), oleic (C18:1n9), and palmitic (C16:0) acids were found to be the fatty acids with the highest percentages. There were up to 24 different fatty acids found and measured. α-, γ- and δ-tocopherols were discovered in *M.esculenta*. In *M.esculenta*, only lycopene- a carotenoid, a well-known antioxidant, was found (Heleno, *et al*., 2013). Mannose (62.9 percent) and galactose (20 percent) are the glycosyl components of this galactomannan, which makes up roughly 2.0 percent of the dry fungal material weight (Ducan, *et al*., 2002). Aldehydes, acids, ketones, esters, and terpenes are among the aromatic chemicals found in yellow morel.Morchelline, an amino acid, has been isolated from M. esculenta

culture broth (Tsubaki K. *et al*., *Patent*). Table 2 shows various pharmacological properties of active constituents of *M.esculenta*. Table 3 indicates Volatile/Aromatic compounds present in *M.esculenta* detected by Headspace Gas Chromatography-Mass Spectrometry.

Table 2: Pharmacological properties of active constituents of M.esculenta (Ajmal, *et al*., 2015)

Active constituents	Pharmacological properties
Phenolic compounds	Antioxidant, antimicrobial, antiallergenic, antiinflammatory and antineoplastic
Polysaccharides	Antioxidant
Organic acids	Antioxidant, neuroprotectant, anti-inflammatory, and antibacterial properties
Tocopherols	antioxidant
Galactomannan	Immunostimulant

Table 3: Volatile/Aromatic compounds present in M.esculenta detected by Headspace Gas Chromatography-Mass Spectrometry (TAŞKIN H., 2013)

ALCOHOL	1-Octen-3-ol,1-Octadecanol ,Cyclooctylalcohol, Trans-2-Undecen-1-ol
ESTER	Butanoic acid, butyl ester (CAS) ,Carbamic acid, methyl ester, 2-Ethylhexyl-2-ethylhexanoate, Phthalic acid, decyl isobutyl ester, 2,2,4-Trimethyl-1,3-pentanediol diisobutyrate
ACID	Propanoic acid
ALDEHYDE	Decanal ,Nonanal
KETONE	7,9-Di-tert-butyl-1-oxaspiro(4.5)deca-6,9-diene-2,8-dione 2,5-Cyclohexadiene-1,4-dione,2,6-bis(1,1-dimethylethyl) 2,6-Di-T-butyl-4-methylene-2,5-cyclohexadiene-1-one
TERPENE	Trans-alpha-bisabolene
PHENOL	phenol, 2,6-bis(1,1-dimethylethyl)-4-methyl

Elemental Analysis: Mushrooms are noted for their ability to gather elements at various amounts depending on the substrate's concentration. The amounts of Fe, Cu, Zn, Pb, Ni, Mn, Co, and Cd in the body of M. esculenta were measured. (Eraslan, *et al*., 2021)

Table 4: Elemental Analysis (Eraslan, *et al*., 2021)

Elements	*M. esculenta* (mg.kg-1)
Fe	264.57 ±17.27
Zn	7.82 ±0.34
Cu	14.77 ±0.14
Pb	12.59 ±0.89
Ni	0.53 ±0.08
Mn	19.45 ±0.97
Co	3.82 ±0.13
Cd	2.45 ±0.02

Pharmacological Activities

Hepatoprotective Activity

Ethanolic extract of *M.esculenta* mycelium can protect the liver from CCL4-induced damage and boost the production of antioxidant enzymes including superoxide dismutase and catalase. The extract's capacity to prevent liver damage is demonstrated by its considerable effect on serum transaminases (SGOT and SGPT) and Alkaline Phosphatase (ALP) levels (Ravikumar and Kalidoss, 2014). Aqueous-ethanolic extract of M. esculenta mycelium possessed significant hepatoprotective activity against CCl4 and ethanol induced chronic hepatotoxicity. Treatment with extract decreased the elevated serum GOT, GPT and

ALP activities in a dose dependent manner. The extract also replenished the depleted levels of antioxidants in liver consequent to CCl_4 and ethanol challenge (Nitha, *et al*., 2013).

Anti-inflammatory Potential

In mice, a mycelium extract of *M. esculenta* dramatically decreased acute inflammation generated by carrageenan and dextran, as well as chronic inflammation caused by formalin. At a dosage of 500 mg/kg body weight, the extract outperformed the reference medicine, Diclofenac (Nitha, *et al*., 2007). According to researchers, M. esculenta polysaccharide FMP-1 might protect NR8383 cells against PM2.5-induced inflammation and inhibit the activation of the NF-B pathway. Sulfatation and carboxymethylation were discovered to be effective methods of enhancing the protective benefits (Li, *et al*., 2019)

Anti-tumor Activity

An ethanolic extract of *M. esculenta* mycelium was discovered to have substantial antitumor efficacy against both ascites and solid tumors. According to the findings, the extract has both therapeutic and preventative capabilities against solid tumors in a dose-dependent manner (Nitha, *et al*., 2007). The extract's effectiveness against ascites tumor is likewise rather high. These findings imply that *M. esculenta* mycelia contain substances that may affect carcinogenesis at various stages or may operate at the same stage. It has been reported that a polysaccharide extracted from *M. esculenta's* fruiting bodies exhibits immunostimulatory properties. (Lata Manju, 2022)

Nephroprotective Activity

Acute renal damage was generated in Swiss albino mice by cisplatin and gentamicin can be treated by an aqueous-ethanol extract of cultivated M. esculenta. Treatment with the extract at 250 and 500 mg/kg body weight reduced a rise in serum creatinine and urea levels while also restoring the antioxidant defence system, which had been depleted. In the kidneys, the activity of superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx) was much higher (Nitha, *et al*., 2008).

Miscellaneeous

Morchella esculenta extracts in methanol, ethyl acetate, and hot and cold water were tested against a variety of microorganisms. Antibacterial activity was measured using disc diffusion tests, while antifungal activity was measured using the well diffusion method. Hot water extract was shown to be more efficient against bacterial strains, with a maximal zone of inhibition of 90% against Bacillus atrophaeus. While cold water extract shown significant effectiveness against the majority of tested fungal strains, including *Trichophyton rubrum, Trichoderma citrinoviride,* and *Alternaria alternata*. M. esculenta ethyl acetate extract has the least antibacterial activity against the investigated microorganisms (Khan, *et al*., 2019). At a concentration of 50 µg/mL, the EtOH extract of M. esculenta had the maximum antibacterial activity against S. aureus, E. faecalis, and E. coli. At a dosage of 50 µg/mL, mushroom extract was similarly efficient against P. aeruginosa. The mushroom extract's MIC values for antifungal activity against Candida albicans and Candida tropicalis were reported to be 200 µg/mL (Eraslan, *et al*., 2021).

Further, *M. esculenta* activity with a molecular weight of roughly 1.0 million Da has been reported to **possess** Immunostimulatory The galactomannan polysaccharide boosted NF-kappa B directed luciferase expression in THP-1 human monocytic cells to 50% of the maximum activation dose (10 g/mL) of lipopolysaccharide in THP-1 human monocytic cells when used at 3.0 g/mL (Ducan, *et al*., 2002).

Morchella esculenta has a big and diverse home range that have the capacity to interact with a wide range of creatures in their environment (Mihail, *et al*., 2007). Morels are capable of acting as both prey and predator. Trees such as elms, ash trees and apple trees have been reported to degrade in the presence of M. esculenta. This may appear to be the morel preying on the tree, and it can be viewed in

that light on an energy pyramid, but this is a contentious notion. Many people consider this to be predation because the mushroom is the only one that gains from this connection (Harbin, *et al*., 1999). The tree is eaten and broken down, while the mushroom receives the nutrients it requires to thrive; yet, because the tree is already dead, it is categorized as a decomposer. Morels, on the other hand, must keep an eye out for predators such as animals that eat them. M. esculenta are pleasant and nutritious, therefore not only do animals who dwell in the forest like to eat them, but humans also hunt them. Deer, squirrels, and elk are some of the creatures that reside in the forest near M. esculenta and appear to interact the most with this fungus (Dahlstrom, *et al*., 2000).

Conclusion

Morchella esculenta, a Morchella spp. member, is also known as "growing gold of the mountains" since it is one of the costly edible morels that belongs to hilly terrain as its primary habitat. The fruiting body of *M.esculenta* contains a variety of bioactive constituents, that possesses a wide range of medicinal and pharmacological qualities, including antioxidant, hepatoprotective, anti-inflammatory, antitumor, antibacterial, immunostimulatory, and nephroprotective activities, among others. Hence, it can be concluded that a deep research is required to explore more potential of *M.esculenta* .

Acknowledgement

I wish to express my sincere gratitude to S. Gurvinder Singh Bahra, Hon'ble Chancellor and Chairman, Rayat Bahra University, Mohali, who gave me a platform for pursuing masters work in this esteemed University. I am greatly indebted to Prof. (Dr.) Parvinder Singh, worthy Vice Chancellor, for graciously permitting me to carry on the research work.

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Source of support: Nil;
Conflict of interest: The authors declare no conflict of interests.

Cite this article as:
Tamber, S.S., Palak, B., Shradha, M. and Ramica, S. "Growing Gold of Mountains*: Morchella esculenta*—A Review." *Annals of Plant Sciences*.12.06 (2023): pp. 5877-5883.