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REVIEW ARTICLE

Exploring the Nutritional, Medicinal and Economic Significance of *Morchella Esculenta*: A Comprehensive Review

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Abstract

This overview summarises the nutritional profile, medicinal properties, economic significance and traditional uses of *Morchella esculenta* (Guchhi). It also highlights research gaps to guide future studies. Information from multiple sources was synthesised to explore the mushroom's nutritional composition, bioactive compounds, pharmacological activities, ethnobotanical relevance and economic role. *M esculenta* provides proteins, fibre and micronutrients such as zinc, selenium and iron, which contribute to immune support, antioxidant defence and blood health. Its pharmacological potential includes antioxidant, antitumour, antimicrobial and anti-inflammatory effects, largely attributed to polysaccharides (β-glucans, galactomannan) and phenolic compounds. Traditional uses for arthritis, fatigue and gastrointestinal disorders align with modern pharmacological findings. Economically, it remains one of the world's most valuable wild fungi, supporting rural livelihoods. *M esculenta* is a nutritionally and pharmacologically significant mushroom with cultural and economic value. Further toxicological studies, clinical trials and cultivation research are needed to realise its full potential.

Key words: *Morchella esculenta*; Phytotherapy; Toxicological phenomena; Nutrition assessment.

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Introduction

Morels, a type of mushroom (Figure 1) in the Morchella genus, are highly prised for their distinctive flavour and texture. They have a unique appearance, featuring a honeycomb like cap atop stem, with hollow interior.[1] Known for their savoury, meat-like taste, morels are consumed both fresh and as a flavouring ingredient. These fungi are nutritionally dense, containing high levels of protein, fibre, vitamins and minerals, while being low in carbohydrates and fat.[2] They are particularly rich in potassium, zinc and selenium compared to other common mushrooms.[3] Morels also contain bioactive compounds such as polysaccharides, phenolics, tocopherols and ergosterols, which contribute to their potential health benefits. These supporting immune function and providing antioxidant protection, aiding cardiovascular health and promote digestive wellness.[4] Morels are primarily found in the Northern Hemisphere, with harvests occurring in spring and summer.[5] Major wild morel sources include China, Pakistan, India, Turkey and North America.

Morel mushrooms, particularly six distinct species, are commonly found in the Indian Himalayas.6 Among these species - *Morchella crassipes, deliciosa, esculenta, conica, angusticeps* and *hybrida* - only *M esculenta* possesses medicinal properties.[7, 8] Research institutions worldwide, including both academic and commercial organisations, have focused their studies on *M esculenta*'s potential pharmaceutical and biochemical applications. The species contains a unique compound with therapeutic properties that makes it valuable in treating serious illnesses, including various types of cancer and tumours.[9] Their life cycle follows typical ascomycete stages, including mycelium, ascocarp, sclerotia, knots or pinheads, primordia and fruiting bodies. Cultivating morels has historically been challenging due to their specific environmental requirements.[10, 11] However, since the development of outdoor farming techniques in the 1980s, commercial cultivation has become more prevalent, with production increasing. For instance, China's annual dried morel exports have grown significantly in recent years, reaching 900,000 kg at an average pricing of $160 USD/kg.[12]

Providing their economic value and growing demand, research on morels has intensified, covering areas such as distribution, life cycle cytology, cultivating artificially, functionality and product development.[13] This review aimed to provide a comprehensive overview of morels, including their life cycle, cultivation methods, nutritional value, bioactive compounds and health-promoting effects, to support further development in morel cultivation and applications in the pharmaceutical and food industries.[14]

Figure 1: Fruiting body of morel mushroom Morchella esculenta (Gucchi)

Nutritional aspect

M esculenta is a nutrient-dense mushroom, providing proteins (~32 %), carbohydrates (~38 %), fibre (~18 %) and minimal fat (~2 %). It is rich in B-complex vitamins, with smaller amounts of vitamins A, C and D. Essential minerals include iron, zinc, copper, manganese, potassium and selenium. These nutrients contribute to its therapeutic value: zinc supports immune function, selenium provides antioxidant defence and iron prevents anaemia.[15 16]

The mineral profile is impressive, containing various essential elements: Iron: 195 mg/g, Zinc: 98.9 mg/g, Copper: 62.6 mg/g, Manganese: 54.7 mg/g, Potassium: 23.5 mg/g, Phosphorus: 3.49 mg/g, Magnesium: 1.82 mg/g, Calcium: 0.85 mg/g and Sodium: 0.18 mg/g.[17] The protein found in *M esculenta*'s mycelium is comparable to plant-based proteins and is more digestible than most vegetables, making it an excellent protein supplement. Its B-complex vitamins and minerals can help address various health concerns, including fatigue, sleep issues, high cholesterol, anaemia and blood sugar regulation.[18]

While prised for its culinary value, it's important to note that consuming large quantities of fresh *Morchella esculenta* can be toxic. This toxicity may be due to an unstable or volatile neurotoxin present in small amounts. Proper cooking time is essential to eliminate any potential toxins.[19] The Gucchi mushroom is characterised by its cylindrical structure, with two main parts. The upper portion, called the pileus, makes up the majority (70-80 %) of the mushroom's total weight. This pileus features either round or irregular pits and measures 3-9 cm in length and 2.5-4.8 cm in width. Its colour can vary from yellow to brown, pale, or black.[20, 21]

Identification

The lower portion, known as the stipe or a stalk, accounts for 20-30 % of the mushroom's total

weight.[22] This hollow stem ranges from 1.0 to 4.0 cm in length with a thickness of one to three centimetres. The stipe undergoes a colour transformation as it matures, starting from white or pale grey and developing into a greyish brown.[23] It has a slightly enlarged base that provides support to the pileus. While fresh specimens can measure between 2-25 cm in length, they significantly shrink upon drying to just 0.1-1 cm. The vertical dissection of *Morchella esculenta* is shown in Figure 2.

Plant kingdom is presented in Table 1.

The lifecycle of *Morchella esculenta* from ascospores to primordia and ascocarp is shown in Figure 3.

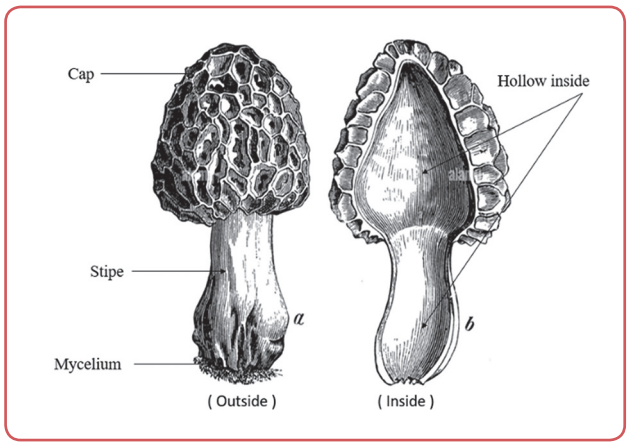


Figure 2: Vertical section of Morchella esculenta fruiting body

Table 1: Taxonomical classification of Morchella esculenta

Kingdom	Fungi
Phylum	Ascomycota
Class	Discomycetes
Order	Pezisales
Family	Morchellaceae
Genus	Morchella
Species	*Morchella esculenta* (L) Pers

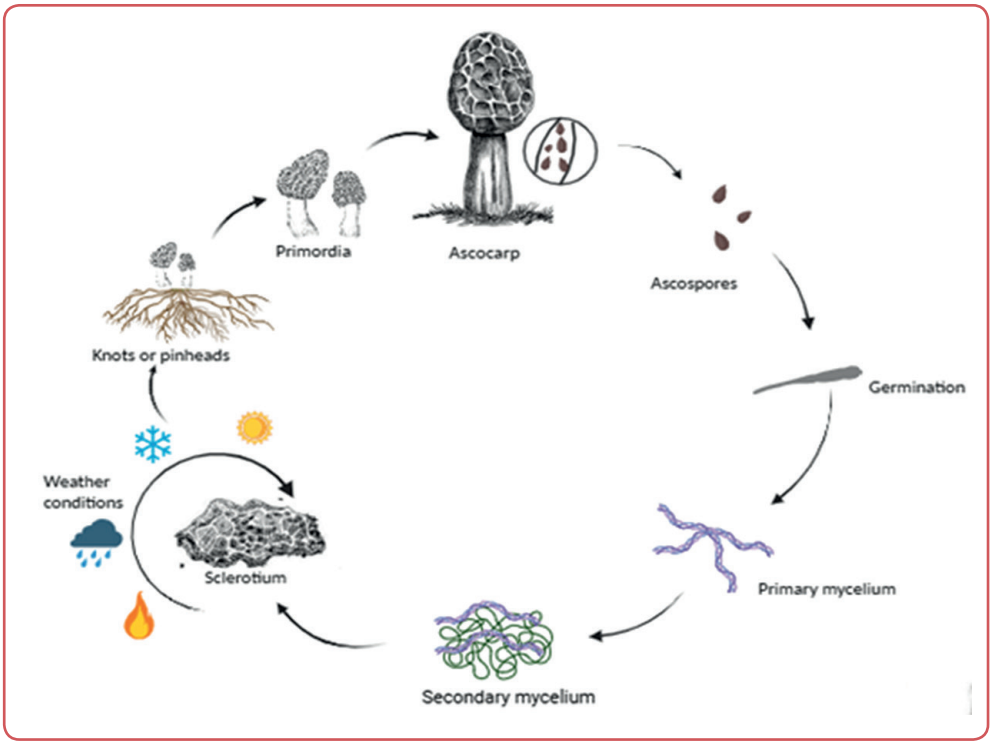


Figure 3: Lifecycle of Morchella esculenta

Ethno-mycological and sociobiological aspects

The inhabitants of Himachal Pradesh have interesting cultural beliefs about wild Morchella mushrooms. There's a widespread belief that these mushrooms only appear after lightning strikes and thunder. Experienced villagers, especially older folks, return to spots where they've successfully found these mushrooms before. Local tradition says that once you spot a Morchella mushroom, it won't grow any bigger, so people collect them while they're still small.[24] While these mushrooms have been gathered for food from ancient times due to their unique appearance, taste and nutrition, nowadays many people collect them to sell because they fetch a high price.[25] Different communities have their own ways of cooking these mushrooms. A popular dish is 'Pulao,' which combines the mushrooms with rice or vegetables. In the Kullu district, locals have a special preparation method where they boil the mushrooms in cow milk before eating them.[26]

Communities in the Himalayas and Central Asia use *M esculenta* both as food and medicine. It is consumed fried in ghee for arthritis, immune weakness (Table 2) and general fatigue; powdered for stomach disorders and wound healing; and prepared in dishes such as pulao for cultural and nutritional purposes.[27-29]

Linking traditional uses with pharmacological evidence:

- **Arthritis and inflammatory conditions:** Supported by quercetin, gallic acid, catechol and polysaccharides with anti-inflammatory effects.[30]
- **Digestive health and stomach problems:** Validated by polysaccharides that improve gut microbiota and reduce gut inflammation.[31]
- **General weakness and tonic effects:** Explained by micronutrient richness (iron, zinc, B-vitamins, selenium).[32]
- **Immune disorders:** Supported by immunostimulatory β-glucans and galactomannan.[33]
- By aligning ethnobotanical practices with bioactive compounds and pharmacological studies, it is evident that the long-standing traditional reputation of *M esculenta* has a strong scientific basis.

Ethnopharmacological use of *Morchella esculenta*

Morel, is an edible fungus belonging to the *Ascomycota phylum* that was initially classified in 1822. These mushrooms thrive in pristine environments with low sulphide and nitrogen levels and serve as valuable food sources.[34] They contain exceptional nutritional content, including amino acids, vitamins (particularly vitamin D_2, which is rarely present in other edible fungi), polysaccharides and essential trace minerals like zinc, magnesium and selenium. Morels also demonstrate significant medicinal properties, such as liver protection, anti-cancer effects, anaesthetic qualities, anti-HIV activity, antioxidant capabilities and antibacterial action.[35, 36]

Morchella has been extensively utilised in traditional Tibetan herbal medicine throughout history. These mushrooms are employed to treat numerous ailments, particularly chronic gastritis, with *Morchella*-based treatments showing therapeutic success in 61.1 % of chronic gastritis patients. In northern Xinjiang, indigenous Kazak communities utilise *Morchella* medicinally for treating diarrhoea, dysentery and fever, while Tibetan populations use it to address asthma and coughing. The dried mushroom's stems and caps are characterised by finger-sized, bright yellow-brown crusts, contrasting with Chinese morel or spring mushroom varieties that typically display small dark brown crusts on their stems. Various *Morchella* species are associated with distinct therapeutic benefits.[37]

Morchella angusticeps enjoys worldwide distribution and ranks as the most sought-after vegetarian delicacy globally due to its distinctive flavour and

Table 2: Ethnobotanical uses of Morchella esculenta

Plant use	Disease	Use and mode of utilisation
Fruiting body	Hallucinogenic, immunoregulatory, arthritis and general weakness	Fried with cow ghee and taken after meal
Whole plant	Intestinal problem, wound healing and stomach problems	Powder form

culinary significance. This species is traditionally indicated for treating external wind-cold headaches and chronic childhood convulsions. Local Tibetan and Uyghur traditional healers possess specialised knowledge regarding Morel applications and document their prescriptions in medical texts. While pharmacological research examining the medicinal and toxicological properties, as well as the chemical kinetics of these edible and medicinal mushrooms, is critically needed, progress remains gradual. There is particular urgency in studying compound prescriptions derived from ancient healers' empirical knowledge.

Bioactive compounds

The *Morchella esculenta* mushroom contains many beneficial compounds, including polysaccharides (*Morchella esculenta* polysaccharide 1 (MEP-1), MEP-2, MEP-3, tocopherols, carotenoids, organic acids and phenolic compounds (quercetin, rutin, protocatechuic acid, gallic acid, etc). The most usual phenolic compounds found in it are p-coumaric acid, p-hydroxybenzoic acid and protocatechuic acid (Table 3). The yellow morel variety contains many aromatic compounds like aldehydes, acids, ketones, esters and terpene.

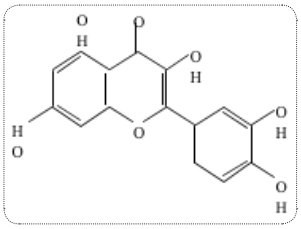
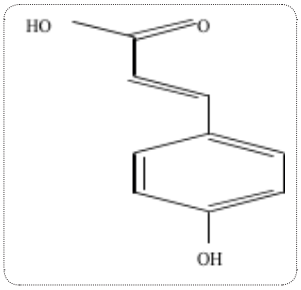
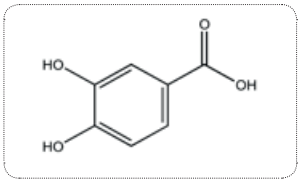
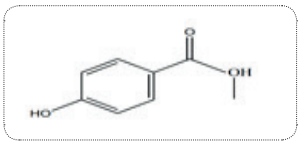
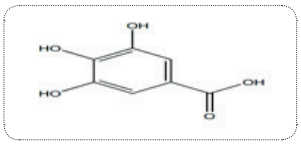
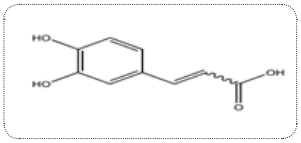
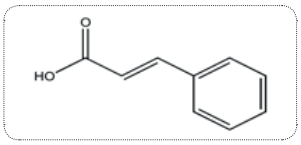
When extracted with methanol, this mushroom shows properties that can fight mutations and cell division.[42] The main aromatic compound is phenol, which consists of alcohol (50.9 %), ester (15.6 %) and carbamic acid (11.37 %). The mushroom's mycelia (fungal threads) contain very high levels of lovastatin (1438.42 mg/kg). Scientists have isolated three types of polysaccharides from this mushroom (MEP-1, MEP-2 and MEP-3, which are made up of mannose, glucose, galactose and arabinose sugars, with average molecular weight of 43,625 Daltons.[3, 43, 44] *Morchella esculenta* holds significant economic value in Jammu and Kashmir. Its price fluctuates throughout the harvesting season and varies based on quality. The dried morels command extraordinary prices, ranging from 4,000 to 20,000 rupees per kilogram, making them among the world's most expensive fungi. The supply chain involves collectors selling to wholesalers through middlemen, with collectors earning 8,000-10,000 rupees per kg. Middlemen sell at 12,000-14,000 rupees per kg to wholesalers, who then sell at around 15,000 rupees per kg. The mushrooms fetch up to 20,000 rupees per kg in national markets and approximately 30,000 rupees per kg in international markets (Table 4).[44]

Table 3: Phenolic composition of Morchella esculenta from different geographic regions[38-41]

Specie and region	Phenolic composition	Content	Pharmacological properties
India	Quercetin	169.8 mg/kg extract	Anti-inflammatory, Antioxidant
	p-Coumaric	94.7 mg/kg extract	Antioxidant
	Rutin	80.0 mg/kg extract	Antioxidant
	Tocopherol	42.6 mg/kg extract	Antioxidant
	Catechol	40.1 mg/kg extract	Anti-inflammatory
	Hyperoside	20.3 mg/kg extract	Anti-viral, Anti-inflammatory
	Ellagic acid	13.5 mg/kg extract	Antioxidant
	Cinnamic acid	7.0 mg/kg extract	Anti-inflammatory, Anti-diabetic
Turkey	Protocatechuic acid	1,715.2 mg/100 g DW	Antioxidant
	p-Hydroxybenzoic acid	345.8 mg/100 g DW	Anti-microbial
	Quercetin	198.9 mg/100 g DW	Antioxidant, Anti-inflammatory
	Gallic acid	78.2 mg/100 g DW	Anti-inflammatory, Anti-diabetic
	Chlorogenic acid	17.3 mg/100 g DW	Antioxidant
	Epicatechin	12.9 mg/100 g DW	Anti-inflammatory
	Ferulic acid	7.5 mg/100 g DW	Antioxidant
	p-Coumaric acid	0.53 mg/100 g DW	Antioxidant

DW: dry weight;

Table 4: Summary of phenolic compounds found in Morchella esculenta and their properties

Compound	Natural sources	Key properties	Mechanism / notable findings	Chemical structure
Quercetin[45, 46]	Apples, berries, onions, capers	Antioxidant, anti-apoptotic, anti-inflammatory, anticancer, antithrombotic, vasorelaxant	Activates Nrf2 pathway; increases superoxide dismutase to protect mitochondria from oxidative damage	
p-Coumaric acid[47-51]	Fruits, vegetables, cereal grains	Strong antioxidant	Neutralises ROS and free radicals; proven effective in endothelial cells exposed to glucose and fatty acids	
Protocatechuic acid[52]	Various plants (not explicitly listed)	Antioxidant	Compared with related phenolic acids; less effective than 3,4,5-trihydroxyphenylacetic acid and 3,4-dihydroxyphenylacetic acid in lipid peroxidation assays	
p-Hydroxybenzoic acid[53]	Fruits and vegetables (exact sources not listed)	Antimicrobial (effective against bacteria, fungi, yeasts)	Active against *E coli, S aureus, Candida albicans, Lactobacillus spp, Fusarium, Listeria, Saccharomyces*	
Gallic acid[54-57]	Fruits, vegetables, nuts, various plants	Anti-inflammatory, antioxidant, anticancer, antibacterial, antidiabetic, anti-obesity, cardioprotective	Tri-phenolic compound with wide-ranging therapeutic effects	
Caffeic acid[58-60]	Olives, coffee beans, fruits, potatoes, carrots, propolis	Antibacterial, antiviral	Most consumed hydroxycinnamic acid in diet; multiple health benefits	
Aromatic acids (non-phenolic)				
Cinnamic acid[61, 62]	Naturally occurring aromatic acid (source plants not specified)	Antioxidant, antimicrobial, anticancer, neuroprotective, anti-inflammatory, antidiabetic	Antioxidant effect due to electron-donating properties that stabilise radicals	

Nrf2: Nuclear factor erythroid 2–related factor 2; ROS: reactive oxygen species;

Pharmacological activities of *Morchella esculenta*

Antioxidant potential

While oxidation is vital for life, too many oxygen-based free radicals can harm cells and tissues, leading to serious diseases like atherosclerosis, diabetes and cancer. Although our bodies have natural defences against oxidative damage, they're not always enough. This is where antioxidant-rich foods come in - they can help reduce this damage. While many herbs contain antioxidants, mushrooms, especially *Morchella esculenta*, are particularly valuable.[63] Research shows that *Morchella esculenta* contains many compounds with strong antioxidant properties.[64] Its fungal threads (mycelia) contain beta-carotene and linoleic acid, which help fight oxidation. The mushroom's polysaccharides and steroids also work as antioxidants.[65] Additionally, it's rich in fatty acids and phenolic compounds that are excellent at neutralising harmful free radicals. When *Morchella esculenta* is extracted with methanol, it shows impressive antioxidant properties, eliminating 90 % of harmful free radicals.[66] Similarly, when extracted with ethanol, it can reduce superoxide generation by 83 % at a concentration of 100 mg/mL. The mushroom's polysaccharides naturally help reduce oxidative stress in the body. The mushroom's mycelia (fungal threads) show promise as a source of natural antibiotics and can help protect against various diseases.[67]

Scientists have found that both water-based and methanol-based extracts of these mushrooms might help protect kidneys from damage. Interestingly, even the leftover soybean material after fermenting *Morchella esculenta* can be used as a healthy food ingredient rich in antioxidants.[68] Beyond its antioxidant properties, this mushroom also shows the ability to fight against harmful microorganisms.[69]

Anti-tumour activity

Studies have shown that the extract obtained from *M esculenta* mushroom mycelium demonstrates powerful anticancer properties, effectively fighting both ascites (fluid-filled) and solid tumours. The extract's effectiveness against solid tumours varies with dosage, offering both therapeutic and preventive benefits.[70] It has also proven particularly effective in treating ascites tumours. The findings indicate that *M esculenta* mycelium contains substances that might influence tumour development at various stages, or possibly work at a specific stage. Studies found that polysaccharides extracted from *M esculenta*'s fruiting bodies can boost immune system function.[71, 72]

Digestive health protection

Rehman and colleagues investigated the effects of *M esculenta* polysaccharides on gut microbiota in mice suffering obesity with diet-induced gut dysfunction.[73, 74] When mice were supplemented with 200 and 400 mg/kg of these polysaccharides over 12 weeks, the researchers observed significant improvements in bacterial diversity.[75, 76] The supplementation led to a reduction in *Firmicutes* populations and an increase in *Bacteroidetes*, which potentially mitigates obesity and metabolic disorder risks. At the genus level, the study also demonstrated a notable increase in *Lactobacillus*, a beneficial bacteria associated with enhanced short-chain fatty acid (SCFA) production.[77, 78]

Immunostimulatory properties

Research has demonstrated that high molecular weight of galactomannan and polysaccharides extracted from the fruiting body of *Morchella esculenta* exhibit potent immunostimulatory characteristics, as documented by multiple scientific studies.[79-81]

Anti-microbial activity

Studies have revealed significant antimicrobial properties of *M esculenta*, particularly in combating several drug-resistant pathogens including *E faecium, S epidermidis, K pneumoniae* (multi-drug resistant - MDR), *P vulgaris* (MDR) and *S pneumoniae* (MDR).[82] Similarly, *T versicolor* showed notable effectiveness against *E faecium, S odorifera* (MDR) and *S pneumoniae* (MDR). When comparing these findings with earlier research by Kalyoncu et al 2010, who tested *M esculenta* ethanol extract against 11 microorganisms, their results showed minimal antimicrobial effects against only *S aureus, S lutea, S typhimurium* and *C albicans.* The discrepancy between these studies' results likely stems from variations in sample collection locations and differences in the specific microbial strains tested.[83, 84]

Anti-inflammatory activity

The formalin-induced paw oedema test is considered an excellent method for evaluating chronic anti-inflammatory medications because it closely mimics the conditions of human arthritis.[85] For-

malin produces pain in two distinct phases: an initial neurogenic response followed by a subsequent tissue-mediated phase.[86] Based on the experimental results, *M esculenta* extract shows promise as a potential treatment for inflammatory conditions, particularly arthritis.[87-89]

Nutraceutical potential of *Morchella esculenta*

Nutraceuticals refer to substances or compound combinations that demonstrate significant potential for development as dietary supplements, offering preventive and therapeutic benefits for various human ailments without adverse effects. Mushroom-based nutraceuticals consist of refined or semi-refined extracts derived from mycelium, basidium, or ascoma, typically consumed as capsules or tablets rather than regular food, serving as dietary supplements with therapeutic potential. Micronutrients which are mainly present in *Morchella esculenta* are: Iron 195 mg/g, Zinc 98.9 mg/g, Copper 62.6 mg/g, Manganese 54.7 mg/g, Potassium 23.5 mg/g, Phosphorus 3.49 mg/g) Magnesium 1.82 mg/g, Calcium 0.85 mg/g and Sodium 0.18 mg/g; as reported by Du et al in 1988.[10, 89]

Research has examined the nutraceutical potential of morels, revealing favourable comparisons with other mushroom species.[73] Morels demonstrate superior content of polysaccharides, dietary fibre, nucleic acids and essential minerals including selenium, zinc, potassium, copper, sodium and calcium. They also contain multiple vitamins (B1, B2, C, A, D and K), complete proteins with all essential amino acids and are cholesterol-free, making them excellent nutraceutical candidates. Their fatty acid profile shows predominance of polyunsaturated fats over monounsaturated and saturated varieties, with linoleic, oleic and palmitic acids being most abundant, along with notable α-linolenic acid content. Various tocopherols (α-, γ- and δ-forms) were also identified.[90] Organic acids including oxalic, fumaric, malic, quinic and citric acids were detected, along with phenolic compounds such as protocatechuic acid, p-hydroxybenzoic acid and p-coumaric acid. These mushrooms exhibit diverse biological and medicinal properties encompassing antioxidant, antitumor, anticancer, antimicrobial, immunomodulatory and anti-inflammatory activities.

Drying, storage and marketing

The preservation of these mushrooms, which are harvested during the rainy period, requires proper drying techniques. Communities in Himachal Pradesh employ two main traditional drying methods: sun-drying and suspension over traditional cooking hearths ("chulhas"). Both ap-

Figure 4: Different drying process of fruiting bodies of Morels

proaches aid in preserving the mushrooms for extended periods while protecting them from insect infestation and mold growth.[29] One distinctive traditional practice involves creating garlands from the fruiting bodies and hanging them from walls or roof beams. Similar drying practices are observed in Jammu and Kashmir, where locals dry the collected mushrooms using various methods - placing them on dung and mud-plastered floors, stone surfaces, or straw mats, as well as drying them on terraces, in balconies, or stringing them under roofs.[91] Under suitable weather conditions, the complete drying process typically requires 10-15 days to complete (Figure 4).[92]

Economic and sociobiological aspects

Ethnobiology

In the rural areas of Himachal Pradesh, local folklore associates *Morchella* mushrooms with lightning and thunderstorms. Elderly residents traditionally revisit previous collection sites, guided by a persistent belief that these mushrooms emerge only during intense atmospheric electrical activity.[93] A prevalent myth suggests that once spotted, the mushroom's sporophore remains static in size, prompting immediate harvesting when the specimens are still small.[94]

Economics

The discovery of *Morchella* (morel mushrooms) is considered a sign of great fortune in local communities. These mushrooms are typically found growing near walnut trees (Juglans regia), oak trees (Quercus), grasses and Himalayan pine (*Pinus wallichiana*).[95] Traditional medicinal uses include treating digestive issues, boosting immunity and serving as a hallucinogenic substance. When fried in clarified butter (ghee), it's consumed as a general health tonic. The mushroom also has practical uses in making baskets, fodder and thatching materials.

Morchella esculenta holds significant economic value in Jammu and Kashmir. Its price fluctuates throughout the harvesting season and varies based on quality.[96] The dried morels command extraordinary prices, ranging from 4,000 to 20,000 rupees per kilogram, making them among the world's most expensive fungi.

Trade chain

The supply chain involves collectors selling to wholesalers through middlemen, with collectors earning 8,000-10,000 rupees per kg. Middlemen sell at 12,000-14,000 rupees per kg to wholesalers, who then sell at around 15,000 rupees per kg. The mushrooms fetch up to 20,000 rupees per kg in national markets and approximately 30,000 rupees per kg in international markets.[97]

Traditional and modern uses

People have long valued morels both as food and medicine, believing they offer health benefits and good nutrition. Old writings mention people eating them to help strengthen their immune systems. These mushrooms are still prised today and are considered a delicacy in fine dining (Table 5).[27,98,99]

Table 5: Traditional and modern uses of Morchella esculenta

Traditional uses	Modern uses
Laxative	Obesity
Body tonic	Insomnia
Emollient	Anaemia treatment
Wound healing	Control blood sugar level

Cultivation of *Morchella esculenta*

The edible mushroom *Morchella esculenta* forms dense mycelial networks on humus-rich forest floors when nutrients are abundant. Its ascocarps emerge after rainfall, typically appearing extensively in March with collection occurring April-June.[100] The fungus thrives in forests dominated by specific trees like *Rhododendron species, Taxus baccata*, various pines and cedars and *Betula utilis*. These areas also host important medicinal plants including *Podophyllum hexandrum, Picrorhisa kurrooa* and various *Aconitum* species.[101] Local inhabitants burn the ground during October/November, believing this practice enhances *Morchella* yields.[102]

However, The Indian Councils of Agricultural Researches (ICAR)-Directorate of Mushroom Research in Solan, Himachal Pradesh, initially attempted to cultivate Gucchi mushrooms (*Morchella esculenta*) but achieved limited success.[103] In 2019, following recommendations from the Research Advisory Committee (RAC), they shifted their focus to exploring Morel cultivation possibilities in India.[104] Dr VP Sharma, who directs ICAR Directorate of Mushroom Research (DMR), assigned this project to scientist Dr Anil Kumar.

Under Dr Kumar's leadership, a research project titled "Standardisation of *Morchella* mushroom growing technique" was initiated. The research team selected Morchella genus cultures specifically for their high sclerotial formation potential. They successfully developed a standardised substrate preparation method for Gucchi mushroom (*Morchella esculenta*) cultivation. Through extensive laboratory experiments focused on inducing fruit bodies (ascoma) in *Morchella*, they managed to produce three small ascomata measuring between 0.5 to 1 cm.[15, 105, 106]

Future prospective

Although various studies have documented the biological activities of this mushroom, research on its potential harmful or toxic effects is lacking. This gap highlights a significant opportunity for future researchers to undertake comprehensive toxicological investigations. Furthermore, the existing literature shows limited exploration of the mushroom's therapeutic applications, suggesting another key area for study. Current evidence indicates that the species is likely safe for consumption, as no toxic compounds have been identified to date. Therefore, prioritising thorough toxicological assessments should be a central focus of future research efforts.

Conclusion

M esculenta is a nutritionally rich, pharmacologically active and economically important mushroom. Its traditional uses are increasingly validated by modern pharmacology, highlighting its potential as both food and medicine. However, future research must address toxicology, clinical relevance and cultivation to fully realise its therapeutic and economic promise.

Ethics

This study was a secondary analysis based on the currently existing data and did not directly involve with human participants or experimental animals. Therefore, the ethics approval was not required in this paper.

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Conflicts of interest

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Data access

The data that support the findings of this study are available from the corresponding author upon reasonable individual request.

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