



# Boletus edulis

***Boletus edulis*** (English: **cep**, **penny bun**, **porcino**) is a basidiomycete fungus, and the type species of the genus *Boletus*. It is prized as an edible mushroom.

The fungus produces spore-bearing fruit bodies above ground in summer and autumn. The fruit body has a large brown cap which on occasion can reach 30 cm (12 in), rarely 40 cm (16 in) in diameter and 3 kg (6 lb 10 oz) in weight. Like other boletes, it has tubes extending downward from the underside of the cap, rather than gills; spores escape at maturity through the tube openings, or pores. The pore surface of the *B. edulis* fruit body is whitish when young, but ages to a greenish-yellow. The stout stipe, or stem, is white or yellowish in colour, up to 20 cm (8 in), rarely 30 cm (12 in) tall and 10 cm (4 in) thick, and partially covered with a raised network pattern, or reticulations.

The fungus grows in deciduous and coniferous forests and tree plantations, forming symbiotic ectomycorrhizal associations with living trees by enveloping the tree's underground roots with sheaths of fungal tissue. Widely distributed in the Northern Hemisphere across Eurasia and North America, it does not occur naturally in the Southern Hemisphere, although it has been introduced to southern Africa, Australia, New Zealand, and Brazil. Several closely related European mushrooms formerly thought to be varieties or forms of *B. edulis* have been shown using molecular phylogenetic analysis to be distinct species, and others previously classed as separate species are conspecific with this species. The western North American species commonly known as the California king bolete (*Boletus edulis* var. *grandedulis*) is a large, darker-coloured variant first formally identified in 2007.

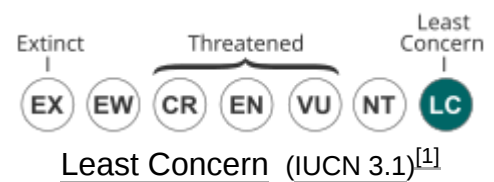
*B. edulis* is held in high regard in many cuisines, and is commonly prepared and eaten in soups, pasta, or risotto. The mushroom is low in fat and digestible carbohydrates, and high in protein, vitamins, minerals and dietary fibre. Although it is sold commercially, it is very difficult to cultivate. Available fresh in autumn throughout Europe and

## Boletus edulis



In the northern Apennine Mountains,  
Abetina Reale forest, Italy

## Conservation status



## Scientific classification

Kingdom: Fungi  
Division: Basidiomycota  
Class: Agaricomycetes  
Order: Boletales  
Family: Boletaceae  
Genus: Boletus  
Species: ***B. edulis***

## Binomial name

***Boletus edulis***

Bull. (1782)

Russia, it is most often dried, packaged, and distributed worldwide. It keeps its flavour after drying, and it is then reconstituted and used in cooking. *B. edulis* is also one of the few fungi sold pickled.

## Taxonomy

*Boletus edulis* was first described in 1782 by the French botanist Pierre Bulliard and still bears its original name.<sup>[3]</sup> The starting date of fungal taxonomy had been set as January 1, 1821, to coincide with the date of the works of the 'father of mycology', Swedish naturalist Elias Magnus Fries, which meant the name required sanction by Fries (indicated in the name by a colon) to be considered valid, as Bulliard's work preceded this date. It was thus written *Boletus edulis* Bull.:Fr. A 1987 revision of the International Code of Botanical Nomenclature set the starting date at May 1, 1753, the date of publication of Linnaeus' work, the *Species Plantarum*.<sup>[4]</sup> Hence, the name no longer requires the ratification of Fries' authority. Early alternate names include *Boletus solidus* by English naturalist James Sowerby in 1809,<sup>[5]</sup> and Gray's *Leccinum edule*.<sup>[6]</sup> Gray's transfer of the species to *Leccinum* was later determined to be inconsistent with the rules of botanical nomenclature, and he apparently was unfamiliar with the earlier works of Fries when he published his arrangement of bolete species.<sup>[7]</sup>

*Boletus edulis* is the type species of the genus *Boletus*. In Rolf Singer's classification of the Agaricales mushrooms, it is also the type species of section *Boletus*, a grouping of about 30 related boletes united by several characteristics: a mild-tasting, white flesh that does not change colour when exposed to air; a smooth to distinctly raised, netted pattern over at least the uppermost portion of the stem; a yellow-brown or olive-brown spore print; white tubes that later become yellowish then greenish, which initially appear to be stuffed with cotton; and cystidia that are not strongly coloured.<sup>[8][9]</sup> Molecular analysis published in 1997 established that the bolete mushrooms are all derived from a common ancestor, and established the Boletales as an order separate from the Agaricales.<sup>[10]</sup>

## Synonyms<sup>[2]</sup>

- *Ceratomyces crassus* Battarra (1775)
- *Boletus solidus* Sowerby (1809)
- *Leccinum edule* (Bull.) Gray (1821)
- *Dictyopus edulis* (Bull.) Forq. (1890)

### *Boletus edulis*



#### Mycological characteristics



Pores on hymenium

Cap is **convex**

Hymenium is **adnate**

Stipe is **bare**

Spore print is **brown**

Ecology is **mycorrhizal**

Edibility is **choice**



Pierre Bulliard first described *B. edulis* in 1782.

The generic name is derived from the Latin term *bōlētus* "mushroom", which was borrowed in turn from the Ancient Greek βωλίτης, "terrestrial fungus".<sup>[11]</sup> Ultimately, this last word derives from *bōlos*/βῶλος "lump", "clod", and, metaphorically, "mushroom".<sup>[12]</sup> The βωλίτης of Galen, like the *boletus* of Latin writers like Martial, Seneca and Petronius,<sup>[13]</sup> is often identified as the much prized *Amanita caesarea*.<sup>[14]</sup> The specific epithet *edulis* in Latin means "eatable" or "edible".<sup>[15]</sup>

## Common names

Common names for *B. edulis* vary by region. The standard Italian name, *porcino* (pl. *porcini*), means *porcine*;<sup>[16]</sup> *fungo porcino*, in Italian, echoes the term *suilli*, literally "hog mushrooms", a term used by the Ancient Romans<sup>[17]</sup> and still in use in southern Italian terms for this species.<sup>[18]</sup> The derivation has been ascribed to the resemblance of young fruit bodies to piglets, or to the fondness pigs have for eating them.<sup>[19]</sup> It is also known as "king bolete".<sup>[20]</sup> The English *penny bun* refers to its rounded brownish shape. The German name *Steinpilz* (stone mushroom) refers to the species' firm flesh.<sup>[21]</sup> In Austria, it is called *Herrenpilz*, the "noble mushroom",<sup>[19]</sup> while in Mexico, the Spanish name is *panza*, meaning "belly".<sup>[22]</sup> Another Spanish name, *rodellon*, means "small round boulder", while the Dutch name *eeekhoortjesbrood* means "squirrel's bread".<sup>[23]</sup> Russian names are *belyy grib* (ру:белый гриб; "white mushroom" as opposed to less valuable "black mushrooms") and *borovik* (ру:боровик; from *bor*—"pine forest"). The vernacular name *cep* is derived from the Catalan *cep* or its French name *cèpe*, although the latter is a generic term applying to several related species. In France, it is more fully *cèpe de Bordeaux*, derived from the Gascon *cep* "trunk" for its fat stalk,<sup>[24]</sup> ultimately from the Latin *cippus* "stake".<sup>[25]</sup> *Ceppatello*, *ceppatello buono*, *ceppatello bianco*, *giallo leonato*, *ghezzo*, and *moreccio* are names from Italian dialects,<sup>[26][27]</sup> and *ciurenys* or *surenys* is another term in Catalan.<sup>[28]</sup> The French-born King Charles XIV John popularised *B. edulis* in Sweden after 1818,<sup>[29]</sup> and is honoured in the local vernacular name *Karljohanssvamp*, as well as the Danish name *Karl Johan svamp*. The monarch cultivated the fungus about his residence, Rosersberg Palace.<sup>[30]</sup> The Finnish name is *herkkutatti*, from *herkku* 'delicacy', and *tatti*, 'bolete'.

## Description

The cap of this mushroom is 7–30 cm (3–12 in) broad at maturity. Slightly sticky to touch, it is convex in shape when young and flattens with age. The colour is generally reddish-brown fading to white in areas near the margin, and continues to darken as it matures. The stipe, or stem, is 8–25 cm (3–10 in) in height, and up to 7 cm (3 in) thick—rather large in comparison to the cap;<sup>[31]</sup> it is club-shaped, or bulges out in the middle. It is finely reticulate on the upper portion, but smooth or irregularly ridged on the lower part. The under surface of the cap is made of thin tubes, the site of spore production; they are 1 to 2 cm (1½ to ¾ in) deep, and whitish in colour when young, but mature to a greenish-yellow.<sup>[32]</sup> The angular pores, which do not stain when bruised, are small—roughly 2 to 3 pores per millimetre.<sup>[33]</sup> In youth, the pores are white and appear as if stuffed with cotton (which are



Cross-section showing white flesh, broad stem, and spore tubes on the cap's underside



actually mycelia); as they age, they change colour to yellow and later to brown. The spore print is olive brown. The flesh of the fruit body is white, thick and firm when young, but becomes somewhat spongy with age. When bruised or cut, it either does not change colour, or turns a very light brown or light red.<sup>[34]</sup> Fully mature specimens can weigh about 1 kg (2 lb 3 oz); a huge specimen collected on the Isle of Skye, Scotland, in 1995 bore a cap of 42 cm (16½ in), with a stipe 18 cm (7 in) in height and 14 cm (5½ in) wide, and weighed 3.2 kg (7 lb 1 oz).<sup>[31]</sup> A similarly sized specimen found in Poland in 2013 made international news.<sup>[35]</sup>



*Boletus edulis* is considered one of the safest wild mushrooms to pick for the table, as few poisonous species closely resemble it, and those that do may be easily distinguished by careful examination.<sup>[19]</sup> The most similar poisonous mushroom may be the devil's bolete (*Rubroboletus satanas*), which has a similar shape, but has

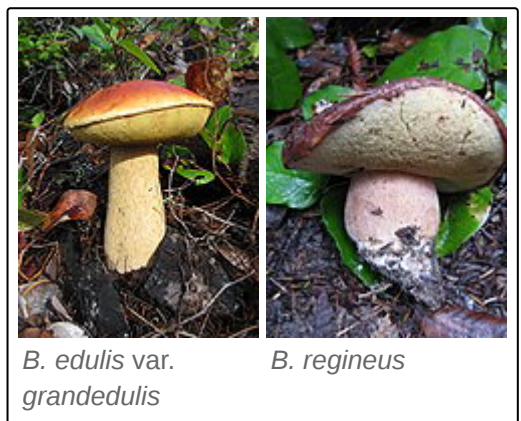
a red stem and stains blue on bruising.<sup>[19]</sup> It is often confused with the very bitter and unpalatable *Tylopilus felleus*, but can be distinguished by the reticulation on the stalk; in porcini, it is a whitish, net-like pattern on a brownish stalk, whereas it is a dark pattern on white in the latter. Porcini have whitish pores while the other has pink. If in doubt, tasting a tiny bit of flesh will yield a bitter taste.<sup>[19]</sup> It can also resemble the "bolete-like" *Gyroporus castaneus*, which is generally smaller, and has a browner stem. *Boletus huronensis*, an uncommon mushroom of northeastern North America, is another recognized look-alike known to cause severe gastrointestinal disorders.<sup>[36]</sup>

The spores are elliptical to spindle-shaped, with dimensions of 12–17 by 5–7 µm. The basidia, the spore-bearing cells, are produced in a layer lining the tubes, and arrange themselves so their ends are facing the center of the tube; this layer of cells is known technically as a hymenium. The basidia are thin-walled, mostly attached to four spores, and measure 25–30 by 8–10 µm. Another cell type present in the hymenium is the cystidia, larger sterile cells that protrude beyond the basidia into the lumen of the hymenium, and act as air traps, regulating humidity.<sup>[37]</sup> *B. edulis* has pleurocystidia (cystidia located on the face of a pore) that are thin-walled, roughly spindle-shaped to ventricose, and measure 30–45 by 7–10 µm; the "stuffed" feature of the hymenium is caused by cheilocystidia—cells found on the edges of the pores.<sup>[32]</sup> The hyphae of *B. edulis* do not have clamp connections.<sup>[33]</sup>

## Related species

Several similar brownish-coloured species are sometimes considered subspecies or forms of this mushroom. In Europe, in addition to *B. edulis* (or *cèpe de Bordeaux*), the most popular are:

- *Cèpe bronzé* ("dark cep"; *Boletus aereus*), much rarer than *B. edulis*, is more highly regarded by gourmets, and consequently more expensive. Usually smaller than *B. edulis*, it is also distinctively darker in colour.<sup>[19]</sup> It is especially suited to drying.<sup>[20]</sup>



- *Cèpe des pins* ("pine tree cep"; *Boletus pinophilus* or *Boletus pinicola*) grows among pine trees. Rarer than *B. edulis*, it is less appreciated by gourmets than the two other kinds of porcini, but remains a mushroom rated above most others.<sup>[20]</sup>
- *Cèpe d'été* ("summer cep"; *Boletus reticulatus*), also less common and found earlier.<sup>[19]</sup>

Molecular phylogenetic analyses have proven these three are all distinctive and separate species,<sup>[38]</sup> other taxa formerly believed to be unique species or subspecies, such as *B. betulicola*, *B. chippewaensis*, *B. persoonii*, *B. quercicola* and *B. venturii*, are now known to be part of a *B. edulis* species complex with a wide morphological, ecological and geographic range,<sup>[39][40]</sup> and that the genetic variability in this complex is low.<sup>[41]</sup> Similar molecular technology has been developed to rapidly and accurately identify *B. edulis* and other commercially important fungi.<sup>[42][43]</sup>

Three divergent lineages found in Yunnan province in China that are commonly marketed and sold as *B. edulis* (and are actually more closely related to *B. aereus*) were described in 2013 as *B. bainiugan*, *B. meiweiniugan* and *B. shiyong*.<sup>[44][45]</sup> The classification has since been updated and expanded. All lineages are still members of *Boletus* sect. *Boletus*, the sensu stricto "porcini clade" of the genus.<sup>[46]</sup>



*B. rex-veris*

Western North America has several species closely related to *B. edulis*. The white king bolete (*B. barrowsii*), found in parts of Colorado, New Mexico, Arizona, and California (and possibly elsewhere), is named after its discoverer Chuck Barrows.<sup>[47]</sup> It is lighter in colour than *B. edulis*, having a cream-coloured cap with pink tones;<sup>[48]</sup> often mycorrhizal with Ponderosa pine, it tends to grow in areas where there is less rainfall. Some find its flavour as good as if not better than *B. edulis*.<sup>[49]</sup> The California king bolete (*Boletus edulis* var. *grandedulis*) can reach massive proportions, and is distinguished from *B. edulis* by a mature pore surface that is brown to slightly reddish. The cap colour appears to be

affected by the amount of light received during its development, and may range from white in young specimens grown under thick canopy, to dark-brown, red-brown or yellow brown in those specimens receiving more light.<sup>[50]</sup> The queen bolete (*Boletus regineus*), formerly considered a variety of *B. aereus*, is also a choice edible. It is generally smaller than *B. edulis*, and unlike that species, is typically found in mixed forests.<sup>[51]</sup> The spring king bolete (*Boletus rex-veris*), formerly considered a variety of *B. edulis* or *B. pinophilus*, is found throughout western North America. In contrast to *B. edulis*, *B. rex-veris* tends to fruit in clusters, and, as its common name suggests, appears in the spring.<sup>[52]</sup> *B. fibrillosus* is edible but considered inferior in taste.<sup>[53]</sup>

## Habitat and distribution

The fruit bodies of *Boletus edulis* can grow singly or in small clusters of two or three specimens. The mushroom's habitat consists of areas dominated by pine (*Pinus* spp.), spruce (*Picea* spp.), hemlock (*Tsuga* spp.) and fir (*Abies* spp.) trees, although other hosts include chestnut, chinquapin, beech, *Keteleeria* spp., *Lithocarpus* spp., and oak. In California, porcini have been collected in a variety of forests, such as coastal forests, dry interior oak forests and savannas and interior high-elevation montane mixed forests,<sup>[54]</sup> to an altitude of 3,500 m (11,500 ft).<sup>[55]</sup> In northwestern Spain, they are common in

scrublands dominated by the rock rose species *Cistus ladanifer* and *Halimium lasianthum*.<sup>[56]</sup> In the Midi region of south-west France, they are especially favoured and locally called *cèpe de Bordeaux* after the town from which they are traded to the north and abroad.<sup>[57]</sup>

*Boletus edulis* has a cosmopolitan distribution, concentrated in cool-temperate to subtropical regions.<sup>[54]</sup> It is common in Europe—from northern Scandinavia, south to the extremities of Greece and Italy—and North America, where its southern range extends as far south as Mexico.<sup>[34]</sup> It is well known from the Borgotaro area of Parma, Italy, and has PGI status there. The European distribution extends north to Scandinavia and south to southern Italy and Morocco.<sup>[54]</sup> In North America, it can be found from May to October inland<sup>[58]</sup> and August to January on the West Coast.<sup>[59]</sup> In China, the mushroom can be found from the northeastern Heilongjiang to the Yunnan–Guizhou Plateau and Tibet.<sup>[34]</sup> It has been recorded growing under *Pinus* and *Tsuga* in Sagarmatha National Park in Nepal,<sup>[60]</sup> as well as in the Indian forests of Arunachal Pradesh.<sup>[61]</sup> In West Asia, the species has been reported from the northwest forests of Iran.<sup>[62]</sup>



In Lithuania

## Cultivation

Some steps have been made towards cultivating *Boletus edulis*,<sup>[63]</sup> including mycorrhization of rockrose shrubs enhanced by helper bacteria.<sup>[64]</sup>

## Non-native introductions

*Boletus edulis* grows in some areas where it is not believed to be indigenous. It is often found underneath oak and silver birch in Hagley Park in central Christchurch, New Zealand, where it is likely to have been introduced,<sup>[65]</sup> probably on the roots of container-grown beech, birch, and oak in the mid-19th century—around the time exotic trees began to be planted in the Christchurch area.<sup>[34]</sup> Similarly, it has been collected in Adelaide Hills region of Australia in association with three species of introduced trees.<sup>[66]</sup> It has been growing plentifully in association with pine forests in the southern KwaZulu-Natal Midlands in South Africa for more than 50 years and is believed to have been introduced with the import of pine trees.<sup>[67][68]</sup> It also grows in pine plantations in neighboring Zimbabwe.<sup>[69]</sup>

## Ecology

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### Fruit body production

Italian folklore holds that porcini sprout up at the time of the new moon;<sup>[19]</sup> research studies have tried to investigate more scientifically the factors that influence the production of fruit bodies. Although fruit bodies may appear any time from summer to autumn (June to November in the UK), their growth is known to be triggered by rainfall during warm periods of weather followed by frequent autumn rain with a drop in soil temperature.<sup>[54]</sup> Above average rainfall may result in the rapid appearance of large numbers of boletes, in what is known in some circles as a "bolete year".<sup>[70]</sup> A 2004 field study indicated that fruit

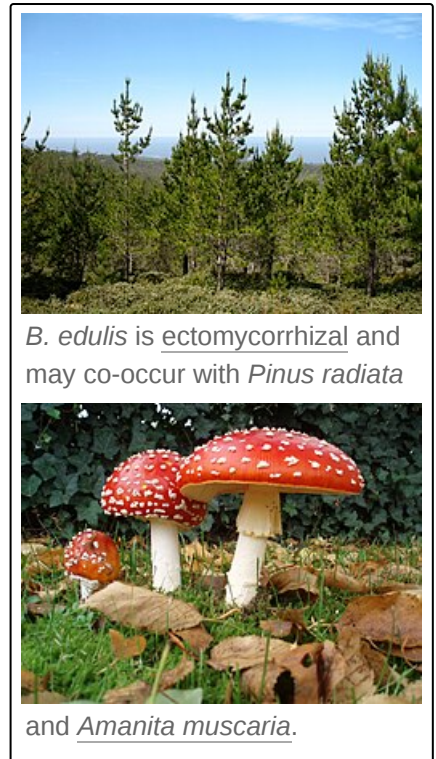


body production is enhanced by an open and sunny wood habitat,<sup>[71]</sup> corroborating an earlier observation made in a Zimbabwean study;<sup>[69]</sup> removal of the litter layer on the forest floor appeared to have a negative effect on fruit body production, but previous studies reported contradictory results.<sup>[72][73]</sup> A Lithuanian study conducted in 2001 concluded that the maximal daily growth rate of the cap (about 21 mm or 0.8 in) occurred when the relative air humidity was the greatest, and the fruit bodies ceased growing when the air humidity dropped below 40%. Factors most likely to inhibit the appearance of fruit bodies included prolonged drought, inadequate air and soil humidity, sudden decreases of night air temperatures, and the appearance of the first frost.<sup>[74]</sup> Plots facing north tend to produce more mushrooms compared to equivalent plots facing south.<sup>[75]</sup>

## Mycorrhizal associations

*Boletus edulis* is mycorrhizal—it is in a mutualistic relationship with the roots of plants (hosts), in which the fungus exchanges nitrogen and other nutrients extracted from the environment for fixed carbon from the host. Other benefits for the plant are evident: in the case of the Chinese chestnut, the formation of mycorrhizae with *B. edulis* increases the ability of plant seedlings to resist water stress, and increases leaf succulence, leaf area, and water-holding ability.<sup>[76]</sup> The fungus forms a sheath of tissue around terminal, nutrient-absorbing root tips, often inducing a high degree of branching in the tips of the host, and penetrating into the root tissue, forming, to some mycologists, the defining feature of ectomycorrhizal relationships, a hartig net.<sup>[77]</sup> The ectomycorrhizal fungi are then able to exchange nutrients with the plant, effectively expanding the root system of the host plant to the furthest reaches of the symbiont fungi.<sup>[77]</sup> Compatible hosts may belong to multiple families of vascular plants that are widely distributed throughout the Northern Hemisphere; according to one 1995 estimate, there are at least 30 host plant species distributed over more than 15 genera.<sup>[34]</sup> Examples of mycorrhizal associates include Chinese red pine,<sup>[78]</sup> Mexican weeping pine,<sup>[79]</sup> Scots pine, Norway spruce,<sup>[80]</sup> Coast Douglas-fir,<sup>[81]</sup> mountain pine,<sup>[82]</sup> and Virginia pine.<sup>[83]</sup> The fungus has also been shown to associate with gum rockrose, a pioneer early stage shrub that is adapted for growth in degraded areas, such as burned forests.<sup>[84]</sup> These and other rockrose species are ecologically important as fungal reservoirs, maintaining an inoculum of mycorrhizal fungi for trees that appear later in the forest regrowth cycle.<sup>[85]</sup>

The mushroom has been noted to often co-occur with *Amanita muscaria* or *A. rubescens*, although it is unclear whether this is due to a biological association between the species, or because of similarities in growing season, habitat, and ecological requirements.<sup>[54]</sup> An association has also been reported between *B. edulis* and *Amanita excelsa* on *Pinus radiata* ectomycorrhizae in New Zealand, suggesting that other fungi may influence the life cycle of porcini.<sup>[86]</sup> A 2007 field study revealed little correlation between the abundance of fruit bodies and presence of its mycelia below ground, even when soil samples were taken from directly beneath the mushroom; the study concluded that the triggers leading to formation of mycorrhizae and production of the fruit bodies were more complex.<sup>[87]</sup>



## Heavy-metal contamination

*Boletus edulis* is known to be able to tolerate and even thrive on soil that is contaminated with toxic heavy metals, such as soil that might be found near metal smelters. The mushroom's resistance to heavy-metal toxicity is conferred by a biochemical called a phytochelatin—an oligopeptide whose production is induced after exposure to metal.<sup>[88]</sup> Phytochelatins are chelating agents, capable of forming multiple bonds with the metal; in this state, the metal cannot normally react with other elements or ions and is stored in a detoxified form in the mushroom tissue.

## Pests and predators

The fruit bodies of *B. edulis* can be infected by the parasitic mould-like fungus *Hypomyces chrysospermus*, known as the bolete eater, which manifests itself as a white, yellow, or reddish-brown cottony layer over the surface of the mushroom.<sup>[89]</sup> Some reported cases of stomach ache following consumption of dried porcini have been attributed to the presence of this mould on the fruit bodies.<sup>[90]</sup> The mushroom is also used as a food source by several species of mushroom flies,<sup>[54]</sup> as well as other insects and their larvae.<sup>[91]</sup> An unidentified species of virus was reported to have infected specimens found in the Netherlands and in Italy; fruit bodies affected by the virus had relatively thick stems and small or no caps, leading to the name "little-cap disease".<sup>[92][93]</sup>

*Boletus edulis* is a food source for animals such as the banana slug (*Ariolimax columbianus*),<sup>[94]</sup> the long-haired grass mouse,<sup>[95]</sup> the red squirrel,<sup>[96]</sup> and, as noted in one isolated report, the fox sparrow.<sup>[97]</sup>

## Culinary uses

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A porcini mushroom and noodle soup served in a bread bowl at a Polish restaurant

*Boletus edulis*, as the species epithet edulis (Latin: *edible*) indicates, is an edible mushroom. Italian chef and restaurateur Antonio Carluccio described it as representing "the wild mushroom par excellence", and hailed it as the most rewarding of all fungi in the kitchen for its taste and versatility.<sup>[19]</sup> Considered a choice edible, particularly in France, Germany, Poland and Italy,<sup>[20]</sup> it was widely written about by the Roman writers Pliny the Elder and Martial, although ranked below the esteemed *Amanita caesarea*. When he was served *suilli*<sup>[a]</sup> instead of *boleti*,<sup>[99]</sup> the disgruntled Martial wrote:

*sunt tibi boleti; fungos ego sumo suillos* (Ep. iii. 60)  
("You eat the choice boletus, I have mushrooms that swine grub up.")<sup>[100]</sup>

The flavour of porcini has been described as nutty and slightly meaty, with a smooth, creamy texture, and a distinctive aroma reminiscent of sourdough. Young, small porcini are most appreciated, as the large ones often harbour maggots (insect larvae), and become slimy, soft and less tasty with age. The fruit bodies are collected by holding the stipe near the base and twisting gently. Cutting the stipe with a knife may risk the part left behind rotting and the mycelium being destroyed. Peeling and washing are not





A porcini mushroom sandwich in Stockholm, Sweden

recommended.<sup>[19]</sup> The fruit bodies are highly perishable, due largely to the high water content (around 90%), the high level of enzyme activity, and the presence of a flora of microorganisms.<sup>[101]</sup> Caution should be exercised when collecting specimens from potentially polluted or contaminated sites, as several studies have shown that the fruit bodies can bioaccumulate toxic heavy metals like mercury,<sup>[102]</sup> cadmium,<sup>[103]</sup> caesium and polonium.<sup>[104][105]</sup> Bioaccumulated metals or radioactive fission decay products are like chemical signatures: chemical and radiochemical analysis can be used to identify the origin of imported specimens,<sup>[106]</sup> and for long-term radioecological monitoring of polluted areas.<sup>[107]</sup>

Porcini are sold fresh in markets in summer and autumn in Europe and Russia, and dried or canned at other times of the year, and distributed worldwide to countries where they are not otherwise found.<sup>[108]</sup> They are eaten and enjoyed raw, sautéed with butter, ground into pasta, in soups, and in many other dishes. In France, they are used in recipes such as *cèpes à la Bordelaise*, *cèpe frits* and *cèpe aux tomates*.<sup>[109]</sup> Porcini risotto is a traditional Italian autumn dish.<sup>[110]</sup> Porcini are a feature of many cuisines, including Provençal,<sup>[111]</sup> and Viennese.<sup>[112]</sup> In Thailand they are used in soups and consumed blanched in salads.<sup>[113]</sup> Porcini can also be frozen, either while raw or after cooking in butter. The colour, aroma, and taste of porcini deteriorate noticeably after being frozen for four months. Blanching (or soaking and blanching) as a processing step before freezing can extend the freezer life to 12 months.<sup>[101]</sup> They are also one of the few species sold commercially as pickled mushrooms.<sup>[114]</sup>

## Dried

*Boletus edulis* is well suited to drying—its flavour intensifies, it is easily reconstituted, and its resulting texture is pleasant.<sup>[115]</sup> Reconstitution is done by soaking in hot, but not boiling, water for about twenty minutes; the water used is infused with the mushroom aroma and it too can be used in subsequent cooking. Dried porcini have more protein than most other commonly consumed vegetables, apart from soybeans. Some of their protein is indigestible, though digestibility is improved with cooking.<sup>[116]</sup>



A pile of dried porcini at the Borgotaro porcino festival in Italy

Like other boletes, porcini can be dried by being strung separately on twine and hung close to the ceiling of a kitchen. Alternatively, the mushrooms can be dried by cleaning with a brush (washing is not recommended), and then placing them in a wicker basket or bamboo steamer on top of a boiler or hot water tank.<sup>[117]</sup> Another method is drying in an oven at 25 to 30 °C (77 to 86 °F) for two to three hours, then increasing the temperature to 50 °C (122 °F) until crisp or brittle.<sup>[118]</sup> Once dry, they must be kept in an airtight container.<sup>[117]</sup> Importantly for commercial production, porcini retain their flavour after industrial preparation in a pressure cooker or after canning or bottling, and are thus useful for manufacturers of soups or stews. The addition of a few pieces of dried porcino can significantly add to flavour, and they are a major ingredient of the pasta sauce known as *carrettiera* (carter's sauce).<sup>[119]</sup>

The drying process is known to induce the formation of various volatile substances that contribute to the mushroom's aroma. Chemical analysis has shown that the odour of the dried mushroom is a complex mixture of 53 volatile compounds.<sup>[120]</sup>

## Commercial harvest

A 1998 estimate suggested that the total annual worldwide consumption of *Boletus edulis* and closely related species (*B. aereus*, *B. pinophilus*, and *B. reticulatus*) was between 20,000 and 100,000 tons.<sup>[54]</sup> Approximately 2,700 tonnes (3,000 tons) were sold in France, Italy and Germany in 1988, according to official figures. The true amount consumed far exceeds this, as the official sales figures did not account for informal sales or consumption by collectors.<sup>[55]</sup> They are widely exported and sold in dried form, reaching countries where they do not occur naturally, such as Australia and New Zealand. The autonomous community of Castile and León in Spain produces 7,700 tonnes (8,500 tons) annually.<sup>[84]</sup> In autumn, the price of porcini in the Northern Hemisphere typically ranges between \$20 and \$80 per kilogram, although in New York in 1997 the wholesale price rose to more than \$200 per kilogram due to scarcity.<sup>[55]</sup>



Porcini can vary considerably in size.

In the vicinity of Borgotaro in the Province of Parma of northern Italy, the four species *Boletus edulis*, *B. aereus*, *B. aestivalis* and *B. pinophilus* have been recognised for their superior taste and officially termed *Fungo di Borgotaro*. Here these mushrooms have been collected for centuries and exported commercially. Owing to the globalisation of the mushroom trade most of the porcini commercially available in Italy or exported by Italy no longer originate there. Porcini and other mushrooms are also imported into Italy from various locations, especially China and eastern European countries; these are then often re-exported under the "Italian porcini" label.<sup>[121][122]</sup>

In Italy the disconnect with local production has had an adverse effect on quality; for example in the 1990s some of the dried porcino mushrooms exported to Italy from China contained species of genus *Tylopilus*, which are rather similar in appearance and when dried are difficult for both mushroom labourers and mycologists alike to distinguish from *Boletus*. *Tylopilus* species typically have a very bitter taste, which is imparted to the flavour of the porcini with which they are mixed.<sup>[123]</sup>

After the fall of the Iron Curtain and the subsequent reduction of economic and political barriers, central and eastern European countries with local mushroom harvesting traditions, such as Albania, Bulgaria, Macedonia, Romania, Serbia and Slovenia, developed into exporters of porcini, concentrating primarily on the Italian market.<sup>[122]</sup> Porcini and other wild fungi from these countries are also destined for France, Germany and other western European markets, where demand for them exists but collection on a commercial scale does not.<sup>[122]</sup> Picking *B. edulis* has become an annual seasonal income earner and pastime in countries like Bulgaria, especially for many Roma communities and the unemployed.<sup>[124]</sup> A lack of control of the harvest has led to heavy exploitation of the mushroom resource.<sup>[125]</sup>

Like many other strictly mycorrhizal fungi, *B. edulis* has eluded cultivation attempts for years.<sup>[116][126][63]</sup> The results of some studies suggest that unknown components of the soil microflora might be required for *B. edulis* to establish a mycorrhizal relationship with the host plant.<sup>[127][128][129]</sup> Successful attempts at cultivating *B. edulis* have been made by Spanish scientists by mycorrhization of *Cistus* species,<sup>[63]</sup> with *Pseudomonas fluorescens* bacteria helping the mycorrhiza.<sup>[64]</sup>

## Nutrition

*Boletus edulis* mushrooms are 9% carbohydrates, 3% fat, and 7% protein (table). Fresh mushrooms consist of over 80% moisture,<sup>[133]</sup> although reported values tend to differ somewhat as moisture content can be affected by environmental temperature and relative humidity during growth and storage.<sup>[134]</sup> The carbohydrate component contains the monosaccharides glucose, mannitol and  $\alpha,\alpha$ -trehalose, the polysaccharide glycogen, and the water-insoluble structural polysaccharide chitin, which accounts for up to 80–90% of dry matter in mushroom cell walls. Chitin, hemicellulose, and pectin-like carbohydrates—all indigestible by humans—contribute to the high proportion of insoluble fibre in *B. edulis*.<sup>[135]</sup>

The total lipid, or crude fat, content makes up 3% of the dry matter of the mushroom. The proportion of fatty acids (expressed as a % of total fatty acids) are: linoleic acid 42%, oleic acid 36%, palmitic acid 10%, and stearic acid 3%.<sup>[136]</sup>

A comparative study of the amino acid composition of eleven Portuguese wild edible mushroom species showed *Boletus edulis* to have the highest total amino acid content.<sup>[137][138]</sup>

*B. edulis* mushrooms are rich in the dietary minerals, sodium, iron, calcium, and magnesium, with amounts varying according to the mushroom component and to soil composition in the geographic region of China where they were sampled.<sup>[135][139]</sup> They also have high content of B vitamins and tocopherols.<sup>[140]</sup> *B. edulis* contains appreciable amounts of selenium, a trace mineral,<sup>[141]</sup> although the bioavailability of mushroom-derived selenium is low.<sup>[142]</sup>

## Phytochemicals and research

*Boletus edulis* fruit bodies contain diverse phytochemicals, including 500 mg of ergosterol per 100 g of dried mushroom,<sup>[143]</sup> and ergothioneine.<sup>[144]</sup> The fruit bodies contain numerous polyphenols, especially a high content of rosmarinic acid,<sup>[145]</sup> and organic acids (such as oxalic, citric, malic, succinic and fumaric

### *Boletus edulis*, fresh<sup>[130]</sup>

Nutritional value per 100 g (3.5 oz)		
<u>Energy</u>	342.4 kJ (81.8 kcal)	
<u>Carbohydrates</u>	9.23 g	
<u>Fat</u>	1.70 g	
<u>Protein</u>	7.39 g	
Vitamins and minerals		
<u>Vitamins</u>	<u>Quantity</u>	<u>%DV<sup>†</sup></u>
<u>Thiamine (B<sub>1</sub>)</u>	0.105 mg	9%
<u>Riboflavin (B<sub>2</sub>)</u>	0.092 mg	7%
<u>Niacin (B<sub>3</sub>)</u>	6.07 mg	38%
<u>Pantothenic acid (B<sub>5</sub>)</u>	2.64 mg	53%
<u>Vitamin B<sub>6</sub></u>	0.051 mg	3%
<u>Folate (B<sub>9</sub>)</u>	290 µg	73%
<u>Vitamin C</u>	4.21 mg	5%
<u>Minerals</u>	<u>Quantity</u>	<u>%DV<sup>†</sup></u>
<u>Calcium</u>	1.195 mg	0%
<u>Copper</u>	0.786 mg	87%
<u>Iron</u>	0.739 mg	4%
<u>Phosphorus</u>	22.26 mg	2%
<u>Potassium</u>	203.3 mg	7%
<u>Zinc</u>	4.172 mg	38%

<sup>†</sup>Percentages estimated using  
US recommendations for adults,<sup>[131]</sup> except for  
potassium, which is estimated based on expert  
recommendation from the National Academies<sup>[132]</sup>



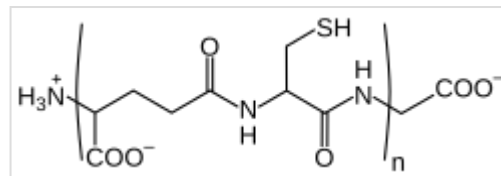
acids),<sup>[146]</sup> and alkaloids.<sup>[147]</sup>

## Aroma

Aroma compounds giving *B. edulis* mushrooms their characteristic fragrance include some 100 components, such as esters and fatty acids.<sup>[148]</sup> In a study of aroma compounds,

1-octen-3-one was the most prevalent chemical detected in

raw mushrooms, with pyrazines having increased aroma effect and elevated content after drying.<sup>[149]</sup>



Phytochelatins give *B. edulis* resistance to toxic heavy metals like cadmium.

## In human culture

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In 2023, with the signing of bill H.B. 92, *Boletus edulis* became the state mushroom of Utah.<sup>[150]</sup>

## See also

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- List of *Boletus* species
- List of North American boletes

## References

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### Footnotes

- a. The term *suilli* was also thought to encompass the related *Leccinum scabrum*.<sup>[98]</sup>

### Citations

1. Dahlberg, A. (2022) [errata version of 2019 assessment]. "*Boletus edulis*" (<https://www.iucnr.org/species/122090234/222968388>). *IUCN Red List of Threatened Species*. **2019** e.T122090234A222968388. doi:10.2305/IUCN.UK.2019-3.RLTS.T122090234A222968388.en (<https://doi.org/10.2305%2FIUCN.UK.2019-3.RLTS.T122090234A222968388.en>). Retrieved 2 July 2024.
2. "*Boletus edulis* Bull. 1782" (<http://www.mycobank.org/MycoTaxo.aspx?Link=T&Rec=356530>). *MycoBank*. International Mycological Association. Retrieved 2010-10-21.
3. Bulliard JBF. (1782). *Herbier de la France. Vol 2* (<https://archive.org/stream/herbierdelafranc4996bull#page/22/mode/2up>) (in French). Paris, France: P.F. Didot. pp. 49–96, plate 60. Retrieved 2009-11-24.
4. Esser K, Lemke PA (1994). *The Mycota: A Comprehensive Treatise on Fungi as Experimental Systems for Basic and Applied Research* ([https://archive.org/details/mossflora\\_britain00libg](https://archive.org/details/mossflora_britain00libg)). Heidelberg, Germany: Springer. p. 81 (<https://archive.org/details/mossflorabritain00libg/page/n93>). ISBN 3-540-66493-9.
5. Sowerby J. (1809). *Coloured Figures of English Fungi*. Vol. 4. London: J. Davis. p. 199. This entire work is available in Commons here, but the reference is to plate 419 with textual description on page 697. Sowerby described the same modern species as *B. edulis* on plate 111 (description on page 57).

6. Gray SF. (1821). *A Natural Arrangement of British Plants* (<https://books.google.com/books?id=g-EYAAAAYAAJ&q=A%20natural%20arrangement%20of%20British%20plants%20Gray%201821&pg=PA647>). London: Baldwin, Cradock, and Joy, Paternoster-Row. p. 647. Retrieved 2009-11-24.
7. Šutara J. (1985). "Leccinum and the question of superfluous names (Fungi: Boletaceae)". *Taxon*. **34** (4): 678–86. Bibcode:1985Taxon..34..678S (<https://ui.adsabs.harvard.edu/abs/1985Taxon..34..678S>). doi:10.2307/1222214 (<https://doi.org/10.2307%2F1222214>). JSTOR 1222214 (<https://www.jstor.org/stable/1222214>).
8. Singer R. (1986). *The Agaricales in Modern Taxonomy* (4th rev. ed.). Koenigstein, Germany: Koeltz Scientific Books. p. 779. ISBN 3-87429-254-1.
9. Smith AH, Thiers HD (1971). *The Boletes of Michigan* (<http://quod.lib.umich.edu/cgi/t/text/pageviewer-idx?c=fung1tc;cc=fung1tc;idno=agk0838.0001.001;frm=frameset;view=image;seq=229;page=root;size=s>). Ann Arbor, Michigan: University of Michigan Press. p. 221. Retrieved 2010-12-02.
10. Binder M, Besl H, Bresinsky A (1997). "Agaricales oder Boletales? Molekularbiologische Befunde zur Zuordnung einiger umstrittener Taxa". *Zeitschrift für Mykologie*. **63**: 189–196.
11. Simpson DP. (1979) [1854]. *Cassell's Latin Dictionary* (5 ed.). London: Cassell Ltd. p. 78. ISBN 0-304-52257-0.
12. Liddell HG, Scott R. (1980). *A Greek–English Lexicon* (Abridged ed.). United Kingdom: Oxford University Press. ISBN 0-19-910207-4.
13. Peter Howell, *A Commentary on Book One of the Epigrams of Martial*, The Athlone Press, 1980 p.152-3. Howell doubts the identification, and mentions the view advanced by Augusta A. Imholtz Jr., 'Fungi and piace- names, the origin of boletus,' in *AJP* Vol.98, 1977 pp.71f., that the Latin word may derive from the Spanish town Boletum, modern-day Boltaña, south of the Pyrenees, which is still famous for its mushrooms.
14. Ramsbottom J. (1989) [1953]. *Mushrooms & Toadstools*. London, England: Collins. p. 6. ISBN 1-870630-09-2.
15. Jamieson A, Ainsworth R, Morell T (1828). *Latin Dictionary: Morell's Abridgment* ([https://archive.org/details/bub\\_gb\\_U3oTAAAYAAJ](https://archive.org/details/bub_gb_U3oTAAAYAAJ)). London: Moon, Boys & Graves. pp. 121 ([https://archive.org/details/bub\\_gb\\_U3oTAAAYAAJ/page/n550](https://archive.org/details/bub_gb_U3oTAAAYAAJ/page/n550)), 596. Retrieved 2009-11-02.
16. "porcino in Vocabolario – Treccani" (<https://www.treccani.it/vocabolario/porcino>). *www.treccani.it*.
17. Pliny, *Natural History*, Bk. 16, 11, 31: "Such is the multiplicity of products in addition to the acorn that are borne by hard-oaks; but they also produce edible fungi (*boletos*) and hog mushrooms (*suillos*)." Pliny, *Natural History*, 10 vols., tr. H. Rackham, Harvard University Press/Heinemann, (1945) 1968, vol. 4, pp. 408–409.
18. Neapolitan *sillo*, and Calabrian *sillu/siddu*. See Glauco Sanga, Gherardo Ortalli, *Nature knowledge: ethnoscience, cognition, and utility*, Berghahn Books, 2003 p. 78.
19. Carluccio, pp. 36–38.
20. Zeitlmayr L. (1976). *Wild Mushrooms: An Illustrated Handbook*. Hertfordshire, UK: Garden City Press. p. 96. ISBN 0-584-10324-7.
21. Grimm J., Grimm W. (1838–1961). *Deutsches Wörterbuch*. Leipzig: Hirzel. (online (<http://www.woerterbuchnetz.de/woerterbuecher/dwb/wbgui?lemid=GS42864>) Archived (<https://web.archive.org/web/20110719114321/http://www.woerterbuchnetz.de/woerterbuecher/dwb/wbgui?lemid=GS42864>) 2011-07-19 at the Wayback Machine)
22. Jarvis MC, Miller AM, Sheahan J, Ploetz K, Ploetz J, Watson RR, Ruiz MP, Villapan CA, Alvarado JG, Ramirez AL, Orr B (2004). "Edible wild mushrooms of the Cofre de Perote region, Veracruz, Mexico: An ethnomycological study of common names and uses". *Economic Botany*. **58** (Suppl. S): S111 – S115. doi:10.1663/0013-0001(2004)58[S111:EWMOTC]2.0.CO;2 (<https://doi.org/10.1663%2F0013-0001%282004%2958%5BS111%3AEWMOTC%5D2.0.CO%3B2>). S2CID 27729532 (<https://api.semanticscholar.org/CorpusID:27729532>).

23. Schalkwijk-Barendsen H. M. E. (1991). *Mushrooms of Western Canada* (<https://archive.org/details/mushroomsofweste0000scha/page/195>). Edmonton: Lone Pine Publishing. p. 195 (<https://archive.org/details/mushroomsofweste0000scha/page/195>). ISBN 0-919433-47-2.
24. Grigson J. (1975). *The Mushroom Feast* (<https://archive.org/details/mushroomfeast00grig/page/8>). London: Penguin. p. 8 (<https://archive.org/details/mushroomfeast00grig/page/8>). ISBN 0-14-046273-2.
25. J. Simpson; E. Weiner, eds. (1989). "cepe". *Oxford English Dictionary* (2nd ed.). Oxford: Clarendon Press. ISBN 0-19-861186-2.
26. Naccari N. L. (1827). *Flora veneta*. Vol. 4–6. L. Bonvecchiato. p. 10.
27. Zeitlemayr L. (1977). *I funghi*. Edizioni Studio Tesi. p. 180.
28. Andrews, Colman (1999) [1988]. *Catalan cuisine: vivid flavors from Spain's Mediterranean coast* (2nd ed.). Boston, MA: Harvard Common Press. p. 88. ISBN 1-55832-329-5.
29. Spoerke DG, Rumack BH (1994). *Handbook of Mushroom Poisoning: Diagnosis and Treatment*. Boca Raton, Florida: CRC Press. p. 11. ISBN 0-8493-0194-7.
30. Stensaas M, Sonstegard J (2004). *Canoe Country Flora: Plants and Trees of the North Woods and Boundary Waters*. Minneapolis, Minnesota: University of Minnesota Press. p. 189. ISBN 1-57025-121-5.
31. Kozikowski GR. (1996). "Foray Report from Skye". *Mycologist*. **10** (4): 183–84. doi:10.1016/S0269-915X(96)80022-X (<https://doi.org/10.1016%2FS0269-915X%2896%2980022-X>).
32. Grund DW, Harrison AK (1976). *Nova Scotian Boletes*. Lehre, Germany: J. Cramer. pp. 73–75. ISBN 3-7682-1062-6.
33. Tylukti EE. (1987). *Mushrooms of Idaho and the Pacific Northwest. Vol. 2. Non-gilled Hymenomyces*. Moscow, Idaho: The University of Idaho Press. pp. 9–10. ISBN 0-89301-097-9.
34. Wang Y, Sinclair L, Hall IR, Cole AL (1995). "*Boletus edulis* sensu lato: a new record for New Zealand" ([http://pdfserve.informaworld.com/915037\\_920077166.pdf](http://pdfserve.informaworld.com/915037_920077166.pdf)) (PDF). *New Zealand Journal of Crop and Horticultural Science*. **23** (2): 227–31. Bibcode:1995NZJCH..23..227W (<https://ui.adsabs.harvard.edu/abs/1995NZJCH..23..227W>). doi:10.1080/01140671.1995.9513892 (<https://doi.org/10.1080%2F01140671.1995.9513892>). Retrieved 2009-12-06.
35. "Giant mushroom found in Poland" (<https://www.bbc.co.uk/news/av/world-europe-24292021>). *BBC News*.
36. Bill Bakaitis (2019). "*Boletus huronensis*: Comments on its toxicity with diagnostic images of its field characteristics and staining reactions" ([https://namyco.org/boletus\\_huronensis.php](https://namyco.org/boletus_huronensis.php)). North American Mycological Association.
37. Alexopoulos CJ, Mims CW, Blackwell M (1996). *Introductory Mycology*. New York: John Wiley and Sons. p. 495. ISBN 0-471-52229-5.
38. Vizzini A, Mello A, Ghignone S, Sechi C, Ruii P, Bonfante P (2008). "*Boletus edulis* complex: from phylogenetic relationships to specific primers". *Pagine di Micologia* (30): 49–52. ISSN 1122-8911 (<https://search.worldcat.org/issn/1122-8911>).
39. Beugelsdijk DCM; van der Linde S; Zuccarello GC; den Bakker; Draisma SGA; Noordeloos ME. (2008). "A phylogenetic study of *Boletus* section *Boletus* in Europe" (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2865352>). *Persoonia*. **20** (1): 1–7. doi:10.3767/003158508X283692 (<https://doi.org/10.3767%2F003158508X283692>). PMC 2865352 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2865352>). PMID 20467482 (<https://pubmed.ncbi.nlm.nih.gov/20467482>).



40. Dentinger BT, Ammirati JF, Both EE, Desjardin DE, Halling RE, Henkel TW, Moreau PA, Nagasawa E, Soyong K, Taylor AF, Watling R, Moncalvo JM, McLaughlin DJ (2010). "Molecular phylogenetics of porcini mushrooms (*Boletus* section *Boletus*)" (<https://web.archive.org/web/20130523094609/http://static.msi.umn.edu/rreports/2010/211.pdf>) (PDF). *Molecular Phylogenetics and Evolution*. **57** (3): 1276–1292. Bibcode:2010MolPE..57.1276D (<https://ui.adsabs.harvard.edu/abs/2010MolPE..57.1276D>). doi:10.1016/j.ympev.2010.10.004 (<https://doi.org/10.1016%2Fj.ympev.2010.10.004>). PMID 20970511 (<https://pubmed.ncbi.nlm.nih.gov/20970511>). Archived from the original (<http://static.msi.umn.edu/rreports/2010/211.pdf>) (PDF) on 2013-05-23.
41. Beugelsdijk DC, van der Linde S, Zuccarello GC, den Bakker HC, Draisma SG, Noordeloos ME (2008). "A phylogenetic study of *Boletus* section *Boletus* in Europe" (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2865352>). *Persoonia*. **20**: 1–7. doi:10.3767/003158508X283692 (<https://doi.org/10.3767%2F003158508X283692>). PMC 2865352 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2865352>). PMID 20467482 (<https://pubmed.ncbi.nlm.nih.gov/20467482>).
42. Mello A, Ghignone S, Vizzini A, Sechi C, Ruiu P, Bonfante P (2006). "ITS primers for the identification of marketable boletes". *Journal of Biotechnology*. **121** (3): 318–29. doi:10.1016/j.jbiotec.2005.08.022 (<https://doi.org/10.1016%2Fj.jbiotec.2005.08.022>). PMID 16213623 (<https://pubmed.ncbi.nlm.nih.gov/16213623>).
43. Lian B, Zang JP, Hou WG, Yuan S, Smith DL (2008). "PCR-based sensitive detection of the edible fungus *Boletus edulis* from rDNA ITS sequences" (<http://www.bioline.org.br/pdf?ej08040>). *Electronic Journal of Biotechnology*. **11** (3): 1–8. doi:10.2225/vol11-issue3-fulltext-4 (<https://doi.org/10.2225%2Fvol11-issue3-fulltext-4>) (inactive 11 July 2025). hdl:1807/48975 (<https://hdl.handle.net/1807%2F48975>). ISSN 0717-3458 (<https://search.worldcat.org/issn/0717-3458>).
44. Dentinger B (12 October 2013). "Nomenclatural novelties" (<http://www.indexfungorum.org/Publications/Index%20Fungorum%20no.29.pdf>) (PDF). *Index Fungorum* (29): 1. ISSN 2049-2375 (<https://search.worldcat.org/issn/2049-2375>).
45. Dentinger B, Suz LM (2014). "What's for dinner? Undescribed species of porcini in a commercial packet" (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4179395>). *PeerJ*. **2** (2:e570) e570. doi:10.7717/peerj.570 (<https://doi.org/10.7717%2Fpeerj.570>). PMC 4179395 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4179395>). PMID 25279259 (<https://pubmed.ncbi.nlm.nih.gov/25279259>).
46. Cui, Yang-Yang; Feng, Bang; Wu, Gang; Xu, Jianping; Yang, Zhu L. (November 2016). "Porcini mushrooms (*Boletus* sect. *Boletus*) from China" ([http://groups.kib.cas.cn/klpb/yzl/tnh\\_fblw/201509/P020150928547013572278.pdf](http://groups.kib.cas.cn/klpb/yzl/tnh_fblw/201509/P020150928547013572278.pdf)) (PDF). *Fungal Diversity*. **81** (1): 189–212. doi:10.1007/s13225-015-0336-7 (<https://doi.org/10.1007%2Fs13225-015-0336-7>). S2CID 12866685 (<https://api.semanticscholar.org/CorpusID:12866685>).
47. Volk T. (August 2004). "*Boletus barrowsii*, Chuck Barrows' bolete" ([https://web.archive.org/web/20081003220326/http://botit.botany.wisc.edu/toms\\_fungi/aug2004.html](https://web.archive.org/web/20081003220326/http://botit.botany.wisc.edu/toms_fungi/aug2004.html)). *Tom Volk's Fungus of the Month*. Department of Biology, University of Wisconsin-La Crosse. Archived from the original ([http://botit.botany.wisc.edu/Toms\\_fungi/aug2004.html](http://botit.botany.wisc.edu/Toms_fungi/aug2004.html)) on 2008-10-03. Retrieved 2008-09-23.
48. Miller HR, Miller OK (2006). *North American Mushrooms: a Field Guide to Edible and Inedible Fungi*. Guilford, Conn: Falcon Guide. p. 392. ISBN 0-7627-3109-5.
49. Evenson VS. (1997). *Mushrooms of Colorado and the Southern Rocky Mountains* (<https://books.google.com/books?id=EAeDeyqZLq0C&q=boletus%20edulis&pg=PA157>). Boulder, Colorado: Westcliffe Publishers. p. 157. ISBN 978-1-56579-192-3. Retrieved 2009-10-20.

50. Arora D. (2008). "California porcini: three new taxa, observations on their harvest, and the tragedy of no commons" ([https://web.archive.org/web/20120312213054/http://www.davidarora.com/uploads/arora\\_california\\_porcini.pdf](https://web.archive.org/web/20120312213054/http://www.davidarora.com/uploads/arora_california_porcini.pdf)) (PDF). *Economic Botany*. **62** (3): 356–75. doi:10.1007/s12231-008-9050-7 (<https://doi.org/10.1007%2Fs12231-008-9050-7>). S2CID 23176365 (<https://api.semanticscholar.org/CorpusID:23176365>). Archived from the original ([http://www.davidarora.com/uploads/arora\\_california\\_porcini.pdf](http://www.davidarora.com/uploads/arora_california_porcini.pdf)) (PDF) on 2012-03-12. Retrieved 2009-11-04.
51. Wood M, Stevens F. "California Fungi: *Boletus regineus*" ([http://www.mykoweb.com/CAF/species/Boletus\\_regineus.html](http://www.mykoweb.com/CAF/species/Boletus_regineus.html)). MykoWeb. Retrieved 2009-11-02.
52. Wood M, Stevens F. "California Fungi: *Boletus rex-veris*" ([http://www.mykoweb.com/CAF/species/Boletus\\_rex-veris.html](http://www.mykoweb.com/CAF/species/Boletus_rex-veris.html)). MykoWeb. Retrieved 2009-11-03.
53. Trudell, Steve; Ammirati, Joe (2009). *Mushrooms of the Pacific Northwest* (<https://books.google.com/books?id=WevHvt6Tr8kC>). Timber Press Field Guides. Portland, OR: Timber Press. p. 217. ISBN 978-0-88192-935-5.
54. Hall IR, Lyon AJ, Wang Y, Sinclair L (1998). "Ectomycorrhizal fungi with edible fruiting bodies 2. *Boletus edulis*". *Economic Botany*. **52** (1): 44–56. Bibcode:1998EcBot..52...44H (<https://ui.adsabs.harvard.edu/abs/1998EcBot..52...44H>). doi:10.1007/BF02861294 (<https://doi.org/10.1007%2FBF02861294>). S2CID 20934023 (<https://api.semanticscholar.org/CorpusID:20934023>).
55. Hall IR, Stephenson SR, Buchanan PK, Yun W, Cole A (2003). *Edible and Poisonous Mushrooms of the World* (<https://archive.org/details/ediblepoisonousm00hall>). Portland, Oregon: Timber Press. pp. 224 (<https://archive.org/details/ediblepoisonousm00hall/page/n224>)–25. ISBN 0-88192-586-1.
56. Oria-de-Rueda J, Martin-Pinto P, Olaizola J (2008). "Bolete productivity of cistaceous scrublands in northwestern Spain". *Economic Botany*. **62** (3): 323–30. doi:10.1007/s12231-008-9031-x (<https://doi.org/10.1007%2Fs12231-008-9031-x>). S2CID 20095996 (<https://api.semanticscholar.org/CorpusID:20095996>).
57. Taylor, Colin Duncan (2021). *Menu from the Midi: A Gastronomic Journey through the South of France*. Matador. ISBN 978-1-80046-496-4.
58. "Seasonal Chart for Edible Mushrooms" (<https://web.archive.org/web/20240331075937/http://www.centraloregonmushroomclub.com/Mushroom-Seasons.htm?m=102&s=866>). *Central Oregon Mushroom Club*. Archived from the original (<https://www.centraloregonmushroomclub.com/Mushroom-Seasons.htm?m=102&s=866>) on 2024-03-31. Retrieved 2024-03-31.
59. Audubon (2023). *Mushrooms of North America*. Knopf. p. 327. ISBN 978-0-593-31998-7.
60. Giri A, Rana P (2007). "Some Higher Fungi from Sagarmatha National Park (SNP) and its adjoining areas, Nepal" (<https://doi.org/10.3126%2Fsw.v5i5.2659>). *Scientific World*. **5** (5): 67–74. doi:10.3126/sw.v5i5.2659 (<https://doi.org/10.3126%2Fsw.v5i5.2659>).
61. Adhikary RK, Baruah P, Kalita P, Bordoloi D (1999). "Edible mushrooms growing in forests of Arunachal Pradesh". *Advances in Horticulture and Forestry*. **6**: 119–23.
62. Asef MR. (2008). "Macrofungi of Arasbaran 2. Boletes (families Boletaceae and Suillaceae)" ([http://www.sid.ir/fa/VEWSSID/J\\_pdf/50313873207.pdf](http://www.sid.ir/fa/VEWSSID/J_pdf/50313873207.pdf)) (PDF). *Rostaniha* (in Arabic). **9** (2): 210–29.
63. Wang, Yun; Chen, Ying Long (2014), Solaiman, Zakaria M.; Abbott, Lynette K.; Varma, Ajit (eds.), "Recent Advances in Cultivation of Edible Mycorrhizal Mushrooms" (<https://www.researchgate.net/publication/270546094>), *Mycorrhizal Fungi: Use in Sustainable Agriculture and Land Restoration*, vol. 41, Berlin, Heidelberg: Springer Berlin Heidelberg, p. 384, doi:10.1007/978-3-662-45370-4\_23 ([https://doi.org/10.1007%2F978-3-662-45370-4\\_23](https://doi.org/10.1007%2F978-3-662-45370-4_23)), ISBN 978-3-662-45369-8, retrieved 2022-10-03

64. Mediavilla, Olaya; Olaizola, Jaime; Santos-del-Blanco, Luis; Oria-de-Rueda, Juan Andrés; Martín-Pinto, Pablo (2015-07-26). "Mycorrhization between *Cistus ladanifer* L. and *Boletus edulis* Bull is enhanced by the mycorrhiza helper bacteria *Pseudomonas fluorescens* Migula" ([http://sostenible.palencia.uva.es/system/files/publicaciones/mediavilla\\_et\\_al\\_2015\\_mycorrhization\\_between\\_cistus\\_ladanifer\\_l\\_and\\_boletus\\_edulis.pdf](http://sostenible.palencia.uva.es/system/files/publicaciones/mediavilla_et_al_2015_mycorrhization_between_cistus_ladanifer_l_and_boletus_edulis.pdf)) (PDF). *Mycorrhiza*. **26** (2): 161–168. doi:10.1007/s00572-015-0657-0 (<https://doi.org/10.1007%2Fs00572-015-0657-0>). ISSN 0940-6360 (<https://search.worldcat.org/issn/0940-6360>). PMID 26208816 (<http://pubmed.ncbi.nlm.nih.gov/26208816>). S2CID 8967720 (<https://api.semanticscholar.org/CorpusID:8967720>).
65. Orlovich D, Stringer A, Yun W, Hall I, Prime G, Danell E, Weden C, Bulman S (2004). "*Boletus edulis* Bull. Ex Fries in New Zealand". *Australasian Mycological Society Newsletter*. **1** (1): 6.
66. Catcheside PS, Catcheside DE (2011). "*Boletus edulis* (Boletaceae), a new record for Australia" ([https://web.archive.org/web/20140517151731/http://www.environment.sa.gov.au/Knowledge\\_Bank/Science\\_research/State\\_Herbarium/Resources/Publications/Journal\\_of\\_the\\_Adelaide\\_Botanic\\_Gardens/Journal\\_search/25/1](https://web.archive.org/web/20140517151731/http://www.environment.sa.gov.au/Knowledge_Bank/Science_research/State_Herbarium/Resources/Publications/Journal_of_the_Adelaide_Botanic_Gardens/Journal_search/25/1)). *Journal of the Adelaide Botanic Garden*. **25**: 5–10. Archived from the original ([http://www.environment.sa.gov.au/Knowledge\\_Bank/Science\\_research/State\\_Herbarium/Resources/Publications/Journal\\_of\\_the\\_Adelaide\\_Botanic\\_Gardens/Journal\\_search/25/1](http://www.environment.sa.gov.au/Knowledge_Bank/Science_research/State_Herbarium/Resources/Publications/Journal_of_the_Adelaide_Botanic_Gardens/Journal_search/25/1)) (PDF) on 2014-05-17.
67. Eicker A. (1990). "Commercial mushroom production in South Africa". *Bulletin* (418). Pretoria: Department of Agricultural Development.
68. Marais LJ, Kotzé JM (1977). "Notes on ectotrophic mycorrhizae of *Pinus patula* in South Africa". *South African Forestry Journal*. **100** (1): 61–71. Bibcode:1977SAfFJ.100...61M (<http://ui.adsabs.harvard.edu/abs/1977SAfFJ.100...61M>). doi:10.1080/00382167.1977.9629436 (<https://doi.org/10.1080%2F00382167.1977.9629436>).
69. Masuka AJ. (1996). "Dynamics of mushroom (*Boletus edulis*) production in pine plantations in Zimbabwe" (<http://opendocs.ids.ac.uk/opendocs/handle/123456789/8944>). *Journal of Applied Science in Southern Africa*. **2** (2): 69–76. doi:10.4314/jassa.v2i2.16877 (<https://doi.org/10.4314%2Fjassa.v2i2.16877>).
70. Nilson S, Persson O (1977). *Fungi of Northern Europe 1: Larger Fungi (Excluding Gill-Fungi)*. Harmondsworth, England: Penguin. p. 100. ISBN 0-14-063005-8.
71. Salerni E, Perini C (2004). "Experimental study for increasing productivity of *Boletus edulis* s.l. in Italy". *Forest Ecology and Management*. **201** (2–3): 161–70. Bibcode:2004ForEM.201..161S (<https://ui.adsabs.harvard.edu/abs/2004ForEM.201..161S>). doi:10.1016/j.foreco.2004.06.027 (<https://doi.org/10.1016%2Fj.foreco.2004.06.027>).
72. Baar J, Ter Braak CJ (1996). "Ectomycorrhizal sporocarp occurrence as affected by manipulation of litter and humus layers in Scots pine stands of different age". *Applied Soil Ecology*. **4** (1): 61–73. Bibcode:1996AppSE...4...61B (<https://ui.adsabs.harvard.edu/abs/1996AppSE...4...61B>). doi:10.1016/0929-1393(96)00097-2 (<https://doi.org/10.1016%2F0929-1393%2896%2900097-2>).
73. Baar J, de Vries FW (1995). "Effects of manipulation of litter and humus layer on ectomycorrhizal colonization potential in Scots pine stands of different age". *Mycorrhiza*. **5** (4): 267–72. Bibcode:1995Mycor...5..267B (<https://ui.adsabs.harvard.edu/abs/1995Mycor...5..267B>). doi:10.1007/BF00204960 (<https://doi.org/10.1007%2FBF00204960>). S2CID 32618842 (<https://api.semanticscholar.org/CorpusID:32618842>).
74. Kasparavicius, J. (2001). "Influence of climatic conditions on the growth of fruit bodies of *Boletus edulis*". *Botanica Lithuanica*. **7** (1): 73–78. ISSN 1392-1665 (<https://search.worldcat.org/issn/1392-1665>).



75. Martín-Pinto P, Vaquerizo H, Peñalver F, Olaizola J, Oria-de-Rueda J (2006). "Early effects of a wildfire on the diversity and production of fungal communities in Mediterranean vegetation types dominated by *Cistus ladanifer* and *Pinus pinaster* in Spain". *Forest Ecology and Management*. **225** (1–3): 296–305. Bibcode:2006ForEM.225..296M (<https://ui.adsabs.harvard.edu/abs/2006ForEM.225..296M>). doi:10.1016/j.foreco.2006.01.006 (<https://doi.org/10.1016%2Fj.foreco.2006.01.006>).
76. Quan L, Lei ZP (2000). "A study on effect of ectomycorrhizae on promoting *Castanea mollissima* resistance to drought and its mechanism". *Forest Research* (in Chinese). **13** (3): 249–56. ISSN 1001-1498 (<https://search.worldcat.org/issn/1001-1498>).
77. Smith, Sally; Read, David. Mycorrhizal Symbiosis. Academic press, 1996
78. Fu SC, Tan Q, Chen MJ, Shang XD, Cai LY, Zhang MY (2009). "Mycorrhizal synthesis involving *Boletus edulis* and *Pinus massoniana*". *Acta Edulis Fungi*. **16** (1): 31–41. ISSN 1005-9873 (<https://search.worldcat.org/issn/1005-9873>).
79. Gross E, Thomazini-Casagrande LI, Caetano FH (1998). "A scanning electron microscopy study of ectomycorrhizae on *Pinus patula* Schiede and Deppe". *Naturalia (Rio Claro)*. **23** (1): 93–101. ISSN 0101-1944 (<https://search.worldcat.org/issn/0101-1944>).
80. Ceruti A, Tozzi M, Reitano G (1987–88). "Micorrize di sintesi tra *Boletus edulis*, *Pinus sylvestris* e *Picea excelsa*" [Mycorrhizal synthesis between *Boletus edulis*, *Pinus sylvestris* and *Picea excelsa*]. *Allionia (Turin)* (in Italian). **28**: 117–24. ISSN 0065-6429 (<https://search.worldcat.org/issn/0065-6429>).
81. Gobl F. (1977). "Mycorrhiza in Austrian Douglas fir stands". *Centralblatt für das Gesamte Forstwesen* (in German). **94** (4): 185–94. ISSN 0379-5292 (<https://search.worldcat.org/issn/0379-5292>).
82. Froidevaux L, Amiet R (1975). "Ecto mycorrhizae endo mycorrhizae of *Pinus mugo* plus *Boletus edulis* ssp *edulis* and *Pinus cembra* plus *Suillus variegatus* formed in pure culture". *European Journal of Forest Pathology*. **5** (1): 57–61. doi:10.1111/j.1439-0329.1975.tb00935.x (<https://doi.org/10.1111%2Fj.1439-0329.1975.tb00935.x>). ISSN 0300-1237 (<https://search.worldcat.org/issn/0300-1237>).
83. Vozzo JA, Hacksdaylo E (1961). "Mycorrhizal fungi on *Pinus virginiana*". *Mycologia*. **53** (5): 538–39. doi:10.2307/3756310 (<https://doi.org/10.2307%2F3756310>). JSTOR 3756310 (<http://www.jstor.org/stable/3756310>).
84. Agueda B, Parlade J, Fernandez-Toiran LM, Cisneros O, de Miguel AM, Modrego MP, Martinez-Pena F, Pera J (2008). "Mycorrhizal synthesis between *Boletus edulis* species complex and rockroses (*Cistus* sp.)". *Mycorrhiza*. **18** (8): 443–49. Bibcode:2008Mycor..18..443A (<https://ui.adsabs.harvard.edu/abs/2008Mycor..18..443A>). doi:10.1007/s00572-008-0192-3 (<https://doi.org/10.1007%2Fs00572-008-0192-3>). PMID 18695982 (<https://pubmed.ncbi.nlm.nih.gov/18695982>). S2CID 11233267 (<https://api.semanticscholar.org/CorpusID:11233267>).
85. Águeda B, Parlade J, de Miguel AM, Martínez-Peña F (2006). "Characterization and identification of field ectomycorrhizae of *Boletus edulis* and *Cistus ladanifer*". *Mycologia*. **98** (1): 23–30. doi:10.3852/mycologia.98.1.23 (<https://doi.org/10.3852%2Fmycologia.98.1.23>). hdl:10171/18758 (<https://hdl.handle.net/10171%2F18758>). PMID 16800301 (<https://pubmed.ncbi.nlm.nih.gov/16800301>).
86. Hall IR, Wang Y, Amicucci A (2003). "Cultivation of edible ectomycorrhizal mushrooms". *Trends in Biotechnology*. **21** (10): 433–38. doi:10.1016/S0167-7799(03)00204-X (<https://doi.org/10.1016%2FS0167-7799%2803%2900204-X>). PMID 14512229 (<https://pubmed.ncbi.nlm.nih.gov/14512229>).

87. Peintner U, Iotti M, Klotz P, Bonuso E, Zambonelli A (2007). "Soil fungal communities in a *Castanea sativa* (chestnut) forest producing large quantities of *Boletus edulis sensu lato* (porcini): where is the mycelium of porcini?". *Environmental Microbiology*. **9** (4): 880–89. Bibcode:2007EnvMi...9..880P (<https://ui.adsabs.harvard.edu/abs/2007EnvMi...9..880P>). doi:10.1111/j.1462-2920.2006.01208.x (<https://doi.org/10.1111%2Fj.1462-2920.2006.01208.x>). PMID 17359260 (<https://pubmed.ncbi.nlm.nih.gov/17359260>).
88. Collin-Hansen C, Pedersen SA, Andersen RA, Steinnes E (2007). "First report of phytochelatin in a mushroom: induction of phytochelatin by metal exposure in *Boletus edulis*". *Mycologia*. **99** (2): 161–74. doi:10.3852/mycologia.99.2.161 (<https://doi.org/10.3852%2Fmycologia.99.2.161>). PMID 17682769 (<https://pubmed.ncbi.nlm.nih.gov/17682769>).
89. Kuo M. "*Hypomyces chrysospermus*" ([http://www.mushroomexpert.com/hypomyces\\_chrysospermus.html](http://www.mushroomexpert.com/hypomyces_chrysospermus.html)). *MushroomExpert.Com*. Retrieved 2009-11-02.
90. Lunghini D, Onofri S, Zucconi L (1984). "Some cases of intoxication probably caused by *Sepedonium* spp. infecting fruiting-bodies of some species of *Boletus*". *Micologia Italiana* (in Italian). **13** (1): 1/37–1/38. ISSN 0390-0460 (<https://search.worldcat.org/issn/0390-0460>).
91. Bruns TD. (1984). "Insect mycophagy in the Boletales: fungivore diversity and the mushroom habitat". In Wheeler Q, Blackwell M (eds.). *Fungus-Insect Relationships: Perspectives in Ecology and Evolution*. New York, NY: Columbia University Press. pp. 91–129. ISBN 978-0-231-05695-3.
92. Huttinga H, Wichers HJ, Dieleman van Zaayen A (1975). "Filamentous and polyhedral virus-like particle in *Boletus edulis*". *Netherlands Journal of Plant Pathology*. **81** (3): 102–106. Bibcode:1975EJPP...81..102H (<https://ui.adsabs.harvard.edu/abs/1975EJPP...81..102H>). doi:10.1007/BF01999860 (<https://doi.org/10.1007%2FBF01999860>). S2CID 35794592 (<http://api.semanticscholar.org/CorpusID:35794592>).
93. Pisi A, Bellardi ME, Bernicchia A (1988). "Virus-like particles in *Boletus edulis* Bull. ex Fr. in Italy" (<http://www.mycologia.org/cgi/reprint/94/5/757.pdf>) (PDF). *Phytopathologia Mediterranea*. **27** (2): 115–18. ISSN 0031-9465 (<https://search.worldcat.org/issn/0031-9465>). Retrieved 2009-11-03.
94. Keller HW, Snell KL (2002). "Feeding activities of slugs on Myxomycetes and macrofungi". *Mycologia*. **94** (5): 757–60. doi:10.2307/3761690 (<https://doi.org/10.2307%2F3761690>). JSTOR 3761690 (<https://www.jstor.org/stable/3761690>). PMID 21156549 (<https://pubmed.ncbi.nlm.nih.gov/21156549>).
95. Bozinovic F, Muñoz-Pedreros A (1995). "Nutritional ecology and digestive responses of an omnivorous-insectivorous rodent (*Abrothrix longipilis*) feeding on fungus". *Physiological Zoology*. **68** (3): 474–89. doi:10.1086/physzool.68.3.30163780 (<https://doi.org/10.1086%2Fphyszool.68.3.30163780>). S2CID 87835970 (<https://api.semanticscholar.org/CorpusID:87835970>).
96. Grönwall O, Pehrson Å (1984). "Nutrient content in fungi as a primary food of the Red Squirrel *Sciurus vulgaris* L". *Oecologia*. **64** (2): 230–31. Bibcode:1984Oecol..64..230G (<https://ui.adsabs.harvard.edu/abs/1984Oecol..64..230G>). doi:10.1007/BF00376875 (<https://doi.org/10.1007%2FBF00376875>). PMID 28312343 (<https://pubmed.ncbi.nlm.nih.gov/28312343>). S2CID 28125328 (<https://api.semanticscholar.org/CorpusID:28125328>).
97. Schiller AM, Larson KW (2006). "Fox Sparrow foraging on a king bolete mushroom". *Northwestern Naturalist*. **87** (3): 252. doi:10.1898/1051-1733(2006)87[252:FSFOAK]2.0.CO;2 (<https://doi.org/10.1898%2F1051-1733%282006%2987%5B252%3AFSFOAK%5D2.0.CO%3B2>). ISSN 1051-1733 (<https://search.worldcat.org/issn/1051-1733>). S2CID 86235892 (<https://api.semanticscholar.org/CorpusID:86235892>).
98. Rolfe RT, Rolfe EW (1974). *The Romance of the Fungus World*. New York: Dover. p. 287. ISBN 0-486-23105-4.
99. Brothwell DR, Brothwell P (1998) [1969]. *Food in Antiquity: a Survey of the Diet of Early Peoples*. Baltimore, MD: The Johns Hopkins University Press. p. 92. ISBN 0-8018-5740-6.

100. Morford M. (1977). "Juvenal's Fifth Satire". *The American Journal of Philology*. **98** (3): 219–45. doi:10.2307/293772 (<https://doi.org/10.2307%2F293772>). JSTOR 293772 (<https://www.jstor.org/stable/293772>).
101. Jaworska G, Bernaś E (2008). "The effect of preliminary processing and period of storage on the quality of frozen *Boletus edulis* (Bull: Fr.) mushrooms". *Food Chemistry*. **113** (4): 936–43. doi:10.1016/j.foodchem.2008.08.023 (<https://doi.org/10.1016%2Fj.foodchem.2008.08.023>).
102. Melgar MJ, Alonson J, Garcia MA (2009). "Mercury in edible mushrooms and underlying soil: Bioconcentration factors and toxicological risk". *Science of the Total Environment*. **407** (1): 5328–34. Bibcode:2009ScTEn.407.5328M (<https://ui.adsabs.harvard.edu/abs/2009ScTEn.407.5328M>). doi:10.1016/j.scitotenv.2009.07.001 (<https://doi.org/10.1016%2Fj.scitotenv.2009.07.001>). PMID 19631362 (<https://pubmed.ncbi.nlm.nih.gov/19631362>).
103. Collin-Hansen C, Yttri KE, Andersen RA, Berthelsen BO, Steinnes E (2002). "Mushrooms from two metal-contaminated areas in Norway: occurrence of metals and metallothionein-like proteins". *Geochemistry: Exploration, Environment, Analysis*. **2** (2): 121–30. Bibcode:2002GEEA....2..121C (<https://ui.adsabs.harvard.edu/abs/2002GEEA....2..121C>). doi:10.1144/1467-787302-015 (<https://doi.org/10.1144%2F1467-787302-015>). S2CID 129662148 (<https://api.semanticscholar.org/CorpusID:129662148>).
104. Collin-Hansen C, Andersen RA, Steinnes E (2005). "Molecular defense systems are expressed in the king bolete (*Boletus edulis*) growing near metal smelters". *Mycologia*. **97** (5): 973–83. doi:10.3852/mycologia.97.5.973 (<https://doi.org/10.3852%2Fmycologia.97.5.973>). PMID 16596949 (<https://pubmed.ncbi.nlm.nih.gov/16596949>).
105. Collin-Hansen C, Andersen RA, Steinnes E (2005). "Damage to DNA and lipids in *Boletus edulis* exposed to heavy metals". *Mycological Research*. **109** (12): 1386–96. doi:10.1017/S0953756205004016 (<https://doi.org/10.1017%2FS0953756205004016>). PMID 16353638 (<https://pubmed.ncbi.nlm.nih.gov/16353638>).
106. Marzano FN, Bracchi PG, Pizzetti P (2001). "Radioactive and conventional pollutants accumulated by edible mushrooms (*Boletus* sp.) are useful indicators of species origin". *Environmental Research*. **85** (3): 260–64. Bibcode:2001ER.....85..260M (<https://ui.adsabs.harvard.edu/abs/2001ER.....85..260M>). doi:10.1006/enrs.2001.4233 (<https://doi.org/10.1006%2Fenrs.2001.4233>). PMID 11237515 (<https://pubmed.ncbi.nlm.nih.gov/11237515>).
107. Grodzinskaya AA, Berreck M, Haselwandter K, Wasser SP (2003). "Radiocesium contamination of wild-growing medicinal mushrooms in Ukraine". *International Journal of Medicinal Mushrooms*. **5** (1): 61–86. doi:10.1615/InterJMedicMush.v5.i1.90 (<https://doi.org/10.1615%2FInterJMedicMush.v5.i1.90>). ISSN 1521-9437 (<https://search.worldcat.org/issn/1521-9437>).
108. Lamaison JL, Polese JM (2005). *The Great Encyclopedia of Mushrooms*. Koln, Germany: Könnemann. p. 28. ISBN 3-8331-1239-5.
109. Ramsbottom J. (1947). "Some edible fungi" (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2055419>). *The British Medical Journal*. **2** (4250): 304–305. doi:10.1136/bmj.2.4520.304 (<https://doi.org/10.1136%2Fbmj.2.4520.304>). PMC 2055419 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2055419>). PMID 20257565 (<https://pubmed.ncbi.nlm.nih.gov/20257565>).
110. Carluccio, p. 166.
111. Olney R. (1995). *A Provençal Table*. London: Pavilion. pp. 31–32. ISBN 1-85793-632-9.
112. Philpot R. (1965). *Viennese Cookery*. London: Hodder & Stoughton. pp. 139–40.
113. Solomon C. (1996). *Charmaine Solomon's Encyclopedia of Asian Food*. Melbourne: William Heinemann Australia. p. 238. ISBN 0-85561-688-1.
114. Carluccio, p. 99.
115. Carluccio, p. 96.

116. Arora D. (1986) [1979]. *Mushrooms Demystified: A Comprehensive Guide to the Fleshy Fungi* (<https://archive.org/details/arora-david-mushrooms-demystified-a-comprehensive-guide-to-the-fleshy-fungi-ten-speed-press-1986/page/530/mode/2up>) (2nd ed.). Berkeley, CA: Ten Speed Press. pp. 530–31. ISBN 978-0-89815-170-1.
117. Carluccio, p. 97.
118. Gates L, DeLong D (1992). *How to Dry Foods* ([https://books.google.com/books?id=aSBfsPQP\\_MQC&q=cooking%20Boletus%20edulis&pg=PA61](https://books.google.com/books?id=aSBfsPQP_MQC&q=cooking%20Boletus%20edulis&pg=PA61)). Los Angeles, California: HP Books. p. 61. ISBN 1-55788-050-6. Retrieved 2009-10-06.
119. Seed D. (1987). *The Top One Hundred Pasta Sauces* (<https://books.google.com/books?id=5JfdNVZlwAOC&q=cooking%20Boletus%20edulis&pg=PA25>). Berkeley, California: Ten Speed Press. p. 25. ISBN 0-89815-232-1. Retrieved 2010-11-06.
120. Misharina TA, Muhutdinova SM, Zharikova GG, Terenina MB, Krikunova NI (2009). "The composition of volatile components of cepe (*Boletus edulis*) and oyster mushrooms (*Pleurotus ostreatus*)". *Applied Biochemistry and Microbiology*. **45** (2): 187–93. doi:10.1134/S0003683809020124 (<https://doi.org/10.1134%2FS0003683809020124>). PMID 19382709 (<https://pubmed.ncbi.nlm.nih.gov/19382709>). S2CID 21525680 (<https://api.semanticscholar.org/CorpusID:21525680>).
121. Sitta N, Floriani M (2008). "Nationalization and globalization trends in the wild mushroom commerce of Italy with emphasis on porcini (*Boletus edulis* and allied species)". *Economic Botany*. **62** (3): 307–22. Bibcode:2008EcBot..62..307S (<https://ui.adsabs.harvard.edu/abs/2008EcBot..62..307S>). doi:10.1007/s12231-008-9037-4 (<https://doi.org/10.1007%2FS12231-008-9037-4>). S2CID 44274570 (<https://api.semanticscholar.org/CorpusID:44274570>).
122. Boa E. (2004). *Wild Edible Fungi: A Global Overview of Their Use and Importance to People (Non-Wood Forest Products)* (<https://books.google.com/books?id=Zd2NlcnZgvcC&q=boletus%20edulis&pg=PA97>). Rome, Italy: Food & Agriculture Organization of the UN. pp. 96–97. ISBN 92-5-105157-7. Retrieved 2009-10-30.
123. Sitta N. (2000). "Presence of *Tylopilus* into dried "Porcini" mushrooms from China". *Micologia Italiana* (in Italian). **29** (1): 96–99. ISSN 0390-0460 (<https://search.worldcat.org/issn/0390-0460>).
124. Focus Information Agency, Bulgaria. "По 1 тон гъби на ден се предават в изкупвателните пунктове в Белоградчик" (<https://web.archive.org/web/20110721185827/http://www.belogradchik.info/1/content/view/390/2/lang%2Cbg/>) [One ton of mushrooms a day are being submitted to purchasing stations in Belogradchik]. *Belogradchik.info* (in Bulgarian). Archived from the original (<http://www.belogradchik.info/1/content/view/390/2/lang,bg/>) on 2011-07-21. Retrieved 2009-11-02.
125. Drumeva M, Gyosheva M. "The Macromycetes Fungi of Bulgaria" (<http://www.worldwildlife.org/bsp/publications/europe/bulgaria/bulgaria1.html>). *World Wildlife Fund*. Retrieved 2009-11-27.
126. Chang ST, Miles PG (2004). *Mushrooms: Cultivation, Nutritional Value, Medicinal Effect, and Environmental Impact* (<https://archive.org/details/mushroomscultiva00mile>) (2nd ed.). Boca Raton, Florida: CRC Press. p. 131 (<https://archive.org/details/mushroomscultiva00mile/page/n155>). ISBN 0-8493-1043-1.
127. Veselkov IM. (1975). "Artificial propagation of *Boletus edulis* in forests". *Распутельные Ресурсы России*. **11**: 574–78.
128. Ceruti A, Tozzi M, Reitano G (1988). "Micorize di sintesi tra *Boletus edulis*, *Pinus sylvestris* e *Picea excelsa*". *Allionia (Turin)* (in Italian). **28**: 117–24.
129. Fitter AH, Garbaye J (1994). "Interaction between mycorrhizal fungi and other organisms". In Robson AD, Abbott LK, Malajczuk N (eds.). *Management of Mycorrhizas in Agriculture, Horticulture and Forestry*. Dordrecht, Netherlands: Kluwer Academic Publishers. ISBN 978-0-7923-2700-4.



130. Nutritional values are based on chemical analysis of Turkish specimens, conducted by Çağlarlırmak and colleagues at the Agricultural Faculty, Food Engineering Department, Gaziosmanpaşa University. Source: Çağlarlırmak N, Ünal K, Ötles S (2001). "Nutritional value of edible wild mushrooms collected from the Black Sea region of Turkey" (<http://www.r edalyc.org/pdf/685/68514101.pdf>) (PDF). *Micologia Aplicada Internacional*. **14** (1): 1–5.
131. United States Food and Drug Administration (2024). "Daily Value on the Nutrition and Supplement Facts Labels" (<https://www.fda.gov/food/nutrition-facts-label/daily-value-nutrition-and-supplement-facts-labels>). FDA. Archived (<https://web.archive.org/web/20240327175201/https://www.fda.gov/food/nutrition-facts-label/daily-value-nutrition-and-supplement-facts-labels>) from the original on 2024-03-27. Retrieved 2024-03-28.
132. "TABLE 4-7 Comparison of Potassium Adequate Intakes Established in This Report to Potassium Adequate Intakes Established in the 2005 DRI Report" ([https://www.ncbi.nlm.nih.gov/books/NBK545428/table/tab\\_4\\_7/](https://www.ncbi.nlm.nih.gov/books/NBK545428/table/tab_4_7/)). p. 120. In: Stallings, Virginia A.; Harrison, Meghan; Oria, Maria, eds. (2019). "Potassium: Dietary Reference Intakes for Adequacy". *Dietary Reference Intakes for Sodium and Potassium*. pp. 101–124. doi:10.17226/25353 (<https://doi.org/10.17226/25353>). ISBN 978-0-309-48834-1. PMID 30844154 (<https://pubmed.ncbi.nlm.nih.gov/30844154>). NCBI NBK545428 (<https://www.ncbi.nlm.nih.gov/books/NBK545428>).
133. Ouzouni PK, Riganakos KA (2006). "Nutritional value and metal content profile of Greek wild edible fungi". *Acta Alimentaria*. **36** (1): 99–110. doi:10.1556/AAlim.36.2007.1.11 (<https://doi.org/10.1556/2FAAlim.36.2007.1.11>).
134. Crisan EV, Sands A (1978). "Nutritional value". In Chang ST, Hayes WA (eds.). *The Biology and Cultivation of Edible Mushrooms*. New York: Academic Press. pp. 727–93. ISBN 978-0-12-168050-3.
135. Kalač P. (2009). "Chemical composition and nutritional value of European species of wild growing mushrooms: a review". *Food Chemistry*. **113** (1): 9–16. doi:10.1016/j.foodchem.2008.07.077 (<https://doi.org/10.1016/2Fj.foodchem.2008.07.077>).
136. Pedneault K, Angers P, Gosselin A, Tweddell RJ (2006). "Fatty acid composition of lipids from mushrooms belonging to the family Boletaceae". *Mycological Research*. **110** (Pt 10): 1179–83. doi:10.1016/j.mycres.2006.05.006 (<https://doi.org/10.1016/2Fj.mycres.2006.05.006>). PMID 16959482 (<https://pubmed.ncbi.nlm.nih.gov/16959482>).
137. Ribeiro B, Andrade PB, Silva BM, Baptista P, Seabra RM, Valento P (2008). "Comparative study on free amino acid composition of wild edible mushroom species". *Journal of Agricultural and Food Chemistry*. **56** (22): 10973–79. Bibcode:2008JAFC...5610973R (<https://ui.adsabs.harvard.edu/abs/2008JAFC...5610973R>). doi:10.1021/jf802076p (<https://doi.org/10.1021/2Fjf802076p>). PMID 18942845 (<https://pubmed.ncbi.nlm.nih.gov/18942845>).
138. Tsai SY, Tsai HL, Mau JL (2008). "Non-volatile taste components of *Agaricus blazei*, *Agrocybe cylindracea* and *Boletus edulis*". *Food Chemistry*. **107** (3): 977–83. doi:10.1016/j.foodchem.2007.07.080 (<https://doi.org/10.1016/2Fj.foodchem.2007.07.080>).
139. Su, Jiuyan; Zhang, Ji; Li, Jieqing; Li, Tao; Liu, Honggao; Wang, Yuanzhong (6 April 2018). "Determination of mineral contents of wild *Boletus edulis* mushroom and its edible safety assessment". *Journal of Environmental Science and Health, Part B*. **53** (7): 454–463. Bibcode:2018JESHB..53..454S (<https://ui.adsabs.harvard.edu/abs/2018JESHB..53..454S>). doi:10.1080/03601234.2018.1455361 (<https://doi.org/10.1080/03601234.2018.1455361>). ISSN 0360-1234 (<https://search.worldcat.org/issn/0360-1234>). PMID 29624491 (<https://pubmed.ncbi.nlm.nih.gov/29624491>). S2CID 4665228 (<https://api.semanticscholar.org/CorpusID:4665228>).



140. Jaworska, Grażyna; Pogoń, Krystyna; Skrzypczak, Aleksandra; Bernaś, Emilia (12 July 2015). "Composition and antioxidant properties of wild mushrooms *Boletus edulis* and *Xerocomus badius* prepared for consumption" (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4648917>). *Journal of Food Science and Technology*. **52** (12): 7944–7953. doi:10.1007/s13197-015-1933-x (<https://doi.org/10.1007%2Fs13197-015-1933-x>). ISSN 0022-1155 (<https://search.worldcat.org/issn/0022-1155>). PMC 4648917 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4648917>). PMID 26604366 (<https://pubmed.ncbi.nlm.nih.gov/26604366>).
141. Falandysz J. (2008). "Selenium in edible mushrooms" (<https://zenodo.org/record/918325>). *Journal of Environmental Science and Health, Part C*. **26** (3): 256–99. Bibcode:2008JESHC..26..256F (<https://ui.adsabs.harvard.edu/abs/2008JESHC..26..256F>). doi:10.1080/10590500802350086 (<https://doi.org/10.1080%2F10590500802350086>). PMID 18781538 (<https://pubmed.ncbi.nlm.nih.gov/18781538>). S2CID 205722725 (<https://api.semanticscholar.org/CorpusID:205722725>).
142. Mutanen M. (1986). "Bioavailability of selenium in mushrooms". *International Journal for Vitamin and Nutrition Research*. **56** (3): 297–301. PMID 3781756 (<https://pubmed.ncbi.nlm.nih.gov/3781756>).
143. Mattila P, Lampi AM, Ronkainen R, Toivo J, Piironen V (2002). "Sterol and vitamin D<sub>2</sub> contents in some wild and cultivated mushrooms". *Food Chemistry*. **76** (3): 293–98. doi:10.1016/S0308-8146(01)00275-8 (<https://doi.org/10.1016%2FS0308-8146%2801%2900275-8>).
144. Ey J, Schömig E, Taubert D (2007). "Dietary sources and antioxidant effects of ergothioneine". *Journal of Agricultural and Food Chemistry*. **55** (16): 6466–74. Bibcode:2007JAFC...55.6466E (<https://ui.adsabs.harvard.edu/abs/2007JAFC...55.6466E>). doi:10.1021/jf071328f (<https://doi.org/10.1021%2Fjf071328f>). PMID 17616140 (<https://pubmed.ncbi.nlm.nih.gov/17616140>).
145. Vamanu, Emanuel; Nita, Sultana (2013). "Antioxidant capacity and the correlation with major phenolic compounds, anthocyanin, and tocopherol content in various extracts from the wild edible *Boletus edulis* mushroom" (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3591155>). *BioMed Research International*. **2013**: 1–11. doi:10.1155/2013/313905 (<https://doi.org/10.1155%2F2013%2F313905>). ISSN 2314-6133 (<https://search.worldcat.org/issn/2314-6133>). PMC 3591155 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3591155>). PMID 23509707 (<https://pubmed.ncbi.nlm.nih.gov/23509707>).
146. Shu-Yao T, Hui-Li T, Jeng-Leun Mau LW (2007). "Antioxidant properties of *Agaricus blazei*, *Agrocybe cylindracea*, and *Boletus edulis*". *Food Science and Technology*. **40** (8): 1392–1402. doi:10.1016/j.lwt.2006.10.001 (<https://doi.org/10.1016%2Fj.lwt.2006.10.001>).
147. Ribeiro B; Lopesa R; Andradea PB; Seabraa RM; Gonçalvesa, Baptista P; Quelhasa I; Valentão P. (2008). "Comparative study of phytochemicals and antioxidant potential of wild edible mushroom caps and stipes" (<https://bibliotecadigital.ipb.pt/bitstream/10198/4404/1/18.pdf>) (PDF). *Food Chemistry*. **110** (1): 47–56. doi:10.1016/j.foodchem.2008.01.054 (<https://doi.org/10.1016%2Fj.foodchem.2008.01.054>). hdl:10198/4404 (<https://hdl.handle.net/10198%2F4404>). PMID 26050164 (<https://pubmed.ncbi.nlm.nih.gov/26050164>).
148. Csóka, Mariann; Geosel, Andras; Amtmann, Maria; Korany, Kornel (2017). "Volatile Composition of Some Cultivated and Wild Culinary-Medicinal Mushrooms from Hungary". *International Journal of Medicinal Mushrooms*. **19** (5): 433–443. doi:10.1615/intjmedmushrooms.v19.i5.50 (<https://doi.org/10.1615%2Fintjmedmushrooms.v19.i5.50>). ISSN 1521-9437 (<https://search.worldcat.org/issn/1521-9437>). PMID 28845772 (<https://pubmed.ncbi.nlm.nih.gov/28845772>).

149. Zhang, Huiying; Pu, Dandan; Sun, Baoguo; Ren, Fazheng; Zhang, Yuyu; Chen, Haitao (2018). "Characterization and comparison of key aroma compounds in raw and dry porcini mushroom ( *Boletus edulis* ) by aroma extract dilution analysis, quantitation and aroma recombination experiments". *Food Chemistry*. **258**: 260–268. doi:10.1016/j.foodchem.2018.03.056 (<https://doi.org/10.1016%2Fj.foodchem.2018.03.056>). ISSN 0308-8146 (<https://search.worldcat.org/issn/0308-8146>). PMID 29655732 (<https://pubmed.ncbi.nlm.nih.gov/29655732>). S2CID 4890378 (<https://api.semanticscholar.org/CorpusID:4890378>).
150. "H.B. 92 State Mushroom Designation" (<https://le.utah.gov/~2023/bills/static/HB0092.html>). *Utah.gov*. Utah State Legislature. Retrieved 2 April 2025.

## Cited texts

- Carluccio, A. (2003). *The Complete Mushroom Book*. London: Quadrille. ISBN 978-1-84400-040-1.
-  Media related to Boletus edulis at Wikimedia Commons
-  Data related to Boletus edulis at Wikispecies

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