

= *Exsudoporus frostii* =

*Exsudoporus frostii* ( formerly *Boletus frostii* ) , commonly known as Frost 's bolete or the apple bolete , is a bolete fungus first described scientifically in 1874 . A member of the family Boletaceae , the mushrooms produced by the fungus have tubes and pores instead of gills on the underside of their caps . *Exsudoporus frostii* is distributed in the eastern United States from Maine to Georgia and Arizona , and south to Mexico and Costa Rica . A mycorrhizal species , its fruit bodies are typically found growing near hardwood trees , especially oak .

*Exsudoporus frostii* mushrooms can be recognized by their dark red sticky caps , the red pores , the network @-@ like pattern of the stem , and the bluing reaction to tissue injury . Another characteristic of young , moist fruit bodies is the amber @-@ colored drops exuded on the pore surface . Although the mushrooms are considered edible , they are generally not recommended for consumption because of the risk of confusion with other poisonous red @-@ pored , blue @-@ bruising boletes . *E. frostii* may be distinguished from other superficially similar red @-@ capped boletes by differences in distribution , associated tree species , bluing reaction , or morphology .

= = Taxonomy = =

The species was named by the Unitarian minister John Lewis Russell of Salem , Massachusetts , based on specimens found in Brattleboro , Vermont . He named the fungus after his friend , another amateur American mycologist , Charles Christopher Frost , who published a description of the species in his 1874 survey of the boletes of New England . When the name of a species is contributed by an individual , but the name is formally published by another , the contributor 's name can be cited , separated from the publishing author as apud ; for this reason , the name and authority are written *Boletus Frostii Russell apud Frost* in some older literature . Bernard Ogilvie Dodge made reference to *B. frostii* in 1950 during an address to the Mycological Society of America , in which he spoke about the role of the amateur in discovering new species : " They would have informed us all about the man Russell , who named a fine new bolete for his friend Frost , and about the man Frost , who named a fine new bolete for his friend Russell . *Boletus Frostii* and *Boletus Russellii* are mushrooms with character , even though they were described by amateurs . " However , in attempting to establish a lectotype specimen , mycologist Roy Halling examined both Russell 's original material and his accompanying notes ; he concluded that it was Frost who made the original species determinations , further suggesting " there is no evidence to show that Russell ever collected *B. frostii* or wrote a description of it . "

William Murrill in 1909 placed the species in the genus *Suillellus* , while Sanshi Imai transferred it to *Tubiporus* in 1968 . *Tubiporus* has since been synonymized with *Boletus* . In 1945 , Rolf Singer described a bolete he found in Florida ; although he originally described it as a subspecies of *B. frostii* , he later considered the differences between the taxa significant enough to warrant publishing *Boletus floridanus* as a unique species . Following recent molecular studies that outlined a new phylogenetic framework for the Boletaceae , the bolete was transferred to the newly circumscribed genus *Exsudoporus* .

*Exsudoporus frostii* is commonly known as " Frost 's bolete " or the " apple bolete " . In Mexico , its vernacular name is *panza agria* , which translates to " sour belly " .

= = Description = =

The shape of the cap of the young fruit body ranges from a half sphere to convex , later becoming broadly convex to flat or shallowly depressed , with a diameter of 5 ? 15 cm ( 2 @. @ 0 ? 5 @. @ 9 in ) . The edge of the cap is curved inward , although as it ages it can uncurl and turn upward . In moist conditions , the cap surface is sticky as a result of its cuticle , which is made of gelatinized hyphae . If the fruit body has dried out after a rain , the cap is especially shiny , sometimes appearing finely areolate ( having a pattern of block @-@ like areas similar to cracked , dried mud ) . Young mushrooms have a whitish bloom on the cap surface .

The color is bright red initially , but fades with age . The flesh is up to 2 @. @ 5 cm ( 1 @. @ 0 in ) thick , and ranges in color from pallid to pale yellow to lemon yellow . The flesh has a variable staining reaction in response to bruising , so some specimens may turn deep blue almost immediately , while others turn blue weakly and slowly .

The tubes comprising the pore surface ( the hymenium ) are 9 ? 15 mm deep , yellow to olivaceous yellow ( mustard yellow ) , turning dingy blue when bruised . The pores are small ( 2 to 3 per mm ) , circular , and until old age a deep red color that eventually becomes paler . The pore surface is often beaded with yellowish droplets when young ( a distinguishing characteristic ) , and readily stains blue when bruised . The stem is 4 to 12 cm ( 1 @. @ 6 to 4 @. @ 7 in ) long , and 1 to 2 @. @ 5 cm ( 0 @. @ 4 to 1 @. @ 0 in ) thick at its apex . It is roughly equal in thickness throughout its length , though it may taper somewhat toward the top ; some specimens may appear ventricose ( swollen in the middle ) . The stem surface is mostly red , or yellowish near the base ; it is reticulate ? characterized by ridges arranged in the form of a net @-@ like pattern . Mycelia , visible at the base of the stem , are yellowish white to light yellow .

The spore print of *B. frostii* is olive brown . The spores are thick walled , smooth , and spindle shaped , with dimensions of 11 ? 15 by 4 ? 5  $\mu$ m . Longer spores up to 18  $\mu$ m long may also be present . The cap cuticle , or pileipellis , is made of a tangled layer of gelatinized hyphae that are 3 ? 6  $\mu$ m wide . The spore @-@ bearing cells , the basidia , are four spored and measure 26 ? 35 by 10 @. @ 5 ? 11 @. @ 5  $\mu$ m . Cystidia are non @-@ fertile cells interspersed among the basidia , and they are prevalent in the hymenial tissue of *E. frostii* . These hyaline ( translucent ) cells measure 30 ? 53 long by 7 @. @ 5 ? 14  $\mu$ m wide , and range in shape from somewhat like a spindle ( tapering at each end , but with one end typically rounded ) to subampullaceous ? shaped somewhat like a swollen bottle .

= = = Edibility and nutritional composition = = =

In 1910 , Murrill wrote of this mushroom 's edibility : " Usually viewed with suspicion because of its red hymenium , but its properties are not accurately known . " Since then , several authors have advised against consuming the species , due to its resemblance to other toxic red @-@ capped boletes . In his 100 Edible Mushrooms ( 2007 ) , Michael Kuo notes that although the mushroom is apparently edible for some , it " affects others negatively " . Despite these warnings , *Exsudoporus frostii* is edible , and David Arora mentions that it is commonly sold in rural markets in Mexico ; a 1997 study suggests that it is only consumed in rural areas in Querétaro state . Its taste and odor have been described as " pleasant " or " sweet " and somewhat like citrus , although the cuticle of the cap may taste acidic .

Chemical analysis of fresh fruit bodies collected in Mexico showed them to have the following composition : moisture 94 @. @ 53 % ; ash 3 @. @ 23 milligrams per gram of mushroom ( mg / g ) ; dietary fiber 30 @. @ 24 mg / g ; fat 3 @. @ 68 mg / g ; and protein 15 @. @ 81 mg / g . The free fatty acid content of dried fruit bodies was 45 mg / g , slightly more than the common button mushroom ( *Agaricus bisporus* ) , which had 35 mg / g . The majority of this total was oleic acid ( 19 @. @ 5 mg / g ) , followed by linoleic acid ( 16 @. @ 8 mg / g ) and palmitic acid ( 16 @. @ 9 mg / g ) .

= = = Similar species = = =

Other red @-@ capped boletes include the poisonous *B. flammans* and *B. rubroflammeus* ; the former grows most commonly under conifers , the latter in association with hardwoods in eastern North America and southern Arizona . Often confused with *B. frostii* are *E. permagnificus* and *B. siculus* , but the latter two species are known only from Europe and always grow in association with oaks . The fruit bodies of young specimens of *B. kermesinus* , newly described from Japan in 2011 , are similar in appearance to *B. frostii* . In addition to its distribution , *B. kermesinus* can be distinguished from *B. frostii* by having flesh that does not bruise blue and a stem in which the reticulum is not as deep and coarse . *B. pseudofrostii* , found in Belize , produces smaller caps that

are 1 @. @ 7 to 2 @. @ 0 cm ( 0 @. @ 7 to 0 @. @ 8 in ) in diameter . *Boletus russelli* , found in eastern North America , has a red to reddish @-@ brown cap and reticulate stem , but its pore surface is yellow , and the fruit body does not bruise blue .

*Exsudoporus floridanus* differs from *E. frostii* in having a lighter cap color and in the texture of the cap surface : it is tomentose ( covered with dense , short , soft , matted hairs ) or velutinous ( like velvet ) , compared to the relatively smooth surface of *E. frostii* . Singer notes that although the physical characteristics between the two taxa may be blurred and are hard to define , the area of origin can reliably distinguish them : *E. floridanus* is found on shaded lawns and scrubland in open oak stands in non @-@ tropical regions of Florida , typically on grassy or sandy soil , where it fruits between May and October .

= = Ecology , habitat , and distribution = =

*Exsudoporus frostii* is a mycorrhizal species , meaning that the fungus forms associations with the roots of various species of trees . These associations are mutualistic , because the fungus absorbs mineral nutrients from the soil and channels these into the plant , while the plant provides the fungus with sugars , a product of photosynthesis . The characteristic feature of the mycorrhiza is the presence of a sheath of fungal tissue that encases the terminal , nutrient @-@ absorbing rootlets of the host plant . The fungus forms an extensive underground network of hyphae that radiate outward from the surface of the root sheath , effectively increasing the surface area for nutrient absorption . The hyphae also invade between the root cortical cells to form a Hartig net . Using pure culture techniques , *Exsudoporus frostii* has been shown to form mycorrhizae with Virginia pine ( *Pinus virginiana* ) , while a field study confirms a similar association with the oak *Quercus laurina* .

The fruit bodies grow solitarily , scattered , or in groups on the ground under hardwood trees ; the fungus fruits in summer to early autumn . William Murrill noted its preference for growing in " thin oak woods , where the light is sufficient to enable grass to grow " , and Alexander H. Smith mentioned its preference for growing in " thin , sandy soil under scrub oak . " In the United States , it is distributed from Maine south to Georgia , extending west to Tennessee , Michigan , and southern Arizona . In Mexico , it is often found under Madrone . It has also been collected in Costa Rica , where it associates with the oak species *Quercus copeyensis* , *Q. costaricensis* , *Q. rapurahuensis* , and *Q. seemanii* . A 1980 publication tentatively suggested that the fungus was also present in Italy , but the author later determined that the putative *E. frostii* was actually *Boletus siculus* .

Fruit bodies can be parasitized by the mold @-@ like fungus *Sepedonium ampullosporium* . Infection results in necrosis of the mushroom tissue , and a yellow color caused by the formation of large amounts of pigmented aleurioconidia ( single @-@ celled conidia produced by extrusion from the conidiophores ) .