

MATSUTAKE: MUSHROOM OF THE YEAR... OR MILLENNIUM?

A Finnish and Scandinavian perspective of this mushroom's history, impact on the market, and similar species; the future of the Scandinavian matsutake; and notes from the high production years 2007 and 2014.

Tuoksuvalmuska: vuoden - vai vuosituhansien sieni?

Tuoksuvalmuskan historiasta, markkina-
asemasta ja tulevaisuudesta Suomalaisesta ja
Skandinaavisesta näkökulmasta. Ajatuksia tuoksuvalmuskan
näköislajeista ja satohavaintoja runsailta satovuosilta 2007 ja
2014.

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A name

Matsutake (Japanese, translation "pine mushroom")

Tuoksuvalmuska (Finnish, translation "odor tricholoma")

Tricholoma matsutake (former scientific name *Tricholoma
nauseosum*, specific epithet translation "sickening")

While matsutake has been known as a species
for over one thousand years in Japan, it has
only been known by a scientific name in the
second millennium. The story of the name "matsutake" is
a long convoluted one containing drama, suspicion, DNA-
investigations, and international politics.

In the western literature matsutake is first mentioned
in 1784 by a Swedish researcher named Thunberg. Elias Fries
first described what we now call *Tricholoma matsutake* in
1849 from Halmbyboda, near Upsala, Sweden (Fries, 1854;
1857). At that time he gave the species the name *Agaricus
focalis* var. *goliath*; a reference to the Swedish name for this
mushroom, *goliatmusseron* ("musseron" = *Tricholoma*). From
the detailed paintings of Fries, we can see that the species in
question is quite probably *T. matsutake*, but unfortunately
the type sample Fries collected has not survived through
the years in the museum collection. (Even if it would have
survived, the DNA would probably have been decomposed,
and of no use for further study.)

In 1905 Norwegian Axel Blytt described the species as
Armillaria nauseosa. Unaware of the Norwegian description
Tricholoma matsutake, photo Jorma Palmén, Finland.



A Brief History of the “Discovery” of matsutake in Finland

1977: A massive harvest of matsutake in Finnish and Swedish Lapland.

1988: “*T. nauseosum* of Europe is synonymous with *T. matsutake* of Asia” – Ilkka Kytövuori, published in journal *Karstenia*.

1999: Kirsti and Martti Palmén featured in Finnish *Mushroom Magazine* article “Year of matsutake.”

2000: Niclas Bergius and Eric Danell, University of Uppsala, Sweden determine that according to DNA-sequencing Scandinavian matsutake is the same species as matsutake of Japan.

2003: A company in Skellefteå, Sweden, Svamp I Norr AB, begins matsutake exportation to Japan.

2004: A relatively good harvest of matsutake in Finnish Lapland, some harvesters reached a hundred kilograms of matsutake during the season.

2007: An exceptionally abundant matsutake harvest in Finnish Lapland. The Arctic Flavors Society named matsutake as “the mushroom of the year” in Finland. A Finnish company Baabeli begun a pilot project to educate a collector network and to export matsutake from northern Finland to Japan. Many of the collectors harvest several hundreds of kilograms each, but in the end only a couple thousand kilograms of Finnish matsutake were exported to Japanese market during the autumn 2007.

2014: An exceptional year for matsutake; the harvest was both abundant and continued for almost two months. The general public had finally become familiar with the species, and the harvest was collected for domestic use—no attempts were made to export matsutake to Japan from Finland in 2014.



Neolentinus lepideus, photo Jorma Palmén, Finland.

is, the Swedish (Scandinavian) matsutake is the very same species that has been harvested as a highly valued delicacy for at least 1,200 years in Japan. Thus, *T. nauseosum* is *T. matsutake*. Furthermore, a single name of this mushroom should be decided on ... and the synonym should be pruned from the lexicon.

According to the St. Louis Botanical Code the oldest scientific name prevails. Originally, Axel Blytt's *nauseosum* was used as matsutake's scientific forename and thus should have precedence. In 2000 Sven-Gunnar Ryman, together with Bergius and Danell, proposed in their publication of DNA-investigations, that matsutake's scientific name should be changed to *T. matsutake*. (Despite this name, given in 1925 by Ito and Imai, it was not the oldest one for this mushroom.) In 2002 *T. matsutake* became unconventionally chosen to be the scientific name, in preference to *nauseosum*. The motive for the change in the scientific name was unconventional and darkly humorous. Apparently, none of the researchers working through the issue at the time dared to present to their Japanese colleagues a choice of giving their national treasure a name *nauseosum* (“sickening”). As a result, the political relations between Scandinavian countries and Japan remained on a friendly basis, and world peace was not interrupted during the delicate business concerning a mushroom name.

Every now and then one may hear someone using term “Latin name” synonymous with “scientific name.” In the case of matsutake, the term scientific name is more correct, as the scientific forename of the species is not in Latin, but comes from the Japanese language. Among mushrooms and plants there are other examples where the scientific names do not come from Latin. Therefore the term “scientific name” can be recommended in general use as a more accurate expression than the term “in/from Latin.”

Timeline

More than one thousand years before Mr. Thunberg ever mentioned this prized mushroom species, the Japanese were writing poetry about it. In Japan, eating matsutake fruitbodies was only allowed for the members of the emperor's court;

of the species, Japanese Seiya Ito and Sanshi Imai described this same mushroom twenty years later—a species well known in Japan—giving it the name *Armillaria matsutake*.

In 1943 Rolf Singer moved matsutake from *Armillaria* to *Tricholoma*. At the time the Scandinavian species was considered synonymous with that of a species found in Mediterranean environment, *Tricholoma caligatum*.

Finnish mycologist Ilkka Kytövuori published in 1988, in the journal *Karstenia*, his investigation results which determined Blytt's *Tricholoma nauseosum* to be a separate species. In addition Kytövuori found the Scandinavian matsutake and Japanese matsutake were one and the same. Since the international researchers did not consider the traditional morphological (anatomical) research methods objective enough, Kytövuori's published results didn't actually get the attention they deserved.

In 2000 Swedish research groups led by Niclas Bergius and Eric Danell published DNA sequencing results that supported the findings of Kytövuori, published ten years earlier. That

severe penalty for all others. The temptation of this forbidden fruit has undoubtedly been accelerating the rise in popularity of this species, especially during the beginning of modern times when the emperor's power has been giving way to that of the growing democracy. However, the popularity of matsutake in Japan is hardly due entirely to its glamorous history, for the species has a revered place on the tables of Japanese cuisine.

The mushroom that has fascinated poets and storytellers has also been claimed to enhance male reproduction and female felicity. References to such claims have been the subject of recent newspaper articles, but experts are quick to deny any evidence in support, likening them to mythologies about the physiological effects of reindeer horn powder, dried blueberry and some other organic products. The morphology/appearance of a young matsutake fruitbody might encourage one's imagination and support the corresponding placebo. Similar beliefs involve other fungal species, including shiitake (*Lentinula edodes*).

When September turns to October in Japan, the season of matsutake begins. The market expands exponentially and if the matsutake harvest is not filling the market demand, the price can grow relatively high. The story is the same around the world with other seasonal popular delicacies. In Finland we could probably compare the phenomenon with the annual river crayfish season at the end of July, or the beginning of the early cabbage harvest (and to the popularity of lamb-cabbage rolls connected to the harvest during the autumn). Just as for many

Finns the river crayfish and cabbage dishes are popular in the beginning of the harvest season, the fresh matsutake buttons with their characteristic aroma have become an inseparable part of the autumn season in Japanese cuisine.

My own personal experience with matsutake spans almost 40 years. The first memory of matsutake I can recall is about *T. focale* and *T. matsutake* (*T. nauseosum* at the time) from the year 1977, when I found fruitbodies of these two species growing near each other. When the fruitbodies are young, the visual resemblance of the two species is remarkable. As a youngster, I did not know the names of these two species, but the observation is a permanent memory for a very obvious reason: I remember pondering how it can be possible to have two species so similar in nature, if they actually were two separate species—and how can one be sure about this? I can even recall deducing further that maybe the strong aroma in some of the fruitbodies has more to do with local soil conditions and nutrition, or to a certain stage of development. I later learned other macroscopic differences between the species.

The market: demand, quality and price

According to the Japanese experts, the characteristic aroma of a freshly picked, unopened matsutake fruitbody can be preserved not more than three days under optimal conditions during transport.

In Japan the annual demand for matsutake mushrooms is



Tricholoma focale (Right) and *T. matsutake* (Left), photo Outi Pohjola, Finland.

far greater than the total imported and domestic matsutake harvest can supply. While there are certain challenges in importing fresh mushrooms to Japan, the domestic harvest of matsutake has been diminishing year by year due to decreasing area of “shiro” (underground mycelia colony of *T. matsutake*)-bearing pine forests. Market demand remains high from September thru October, when the price can double overnight; best price is for unopened buttons. Additionally, in Japan the quality is often thought to be in correlation to the region where the fruitbodies have grown; according to many, the best quality of matsutake is collected from the areas near Hiroshima and Kyoto, while Hokkaido is not nearly so highly regarded.



Pholiota heteroclita, photo Jorma Palmén, Finland.

On the islands of Japan the host tree species and ecotypes vary from one location to another and the topsoil humus layer can be relatively thick on some islands. In such soils it is very difficult for unopened matsutake mushrooms to penetrate through the thick organic layer. Harvested matsutake mushrooms from such regions are often damaged or misshapen. This condition differs strongly from the habitat in Scandinavia. For example in Finnish Lapland, where the organic layer overlaying the mineral soil is usually only some centimeters in thickness, matsutake fruitbodies are usually still unopened and in perfect condition after penetrating through the organic top layer to the soil surface.

In the USA commercial matsutake (*T. magnivelare*) is divided to six quality classes. The most valuable Class 1 are buttons with closed caps and gills are still completely hidden. (Many of these are harvested by digging or raking to get them before they break the soil surface.) Since a fruitbody can continue maturing in a mushroom basket, it may have decreased to quality Class 2 by the time it arrives at the market. Class 2 matsutakes are mostly closed caps but where veil (covering over gills) may be partly opened. In Class 3 parts of the veil is attached to the cap, but most of the gills are revealed. Class 4 mushrooms are fully opened and may have some defects or blemishes. Class 5 the cap is fully opened and there may be damage or parts of the cap may be missing. In Class 6 the fruitbodies are of low quality and some parts of them may have been removed. The specific price of the quality Class 6 may decrease to one twentieth part of the specific price of the Class 1.

In Finland, The Society of Arctic Flavors developed its own system for classification, which follows faithfully the system used in North America, above. In 2007 a Finnish company, Baabeli, was purchasing fruitbodies in the Classes 1, 2 and 3 and paying 20, 15 and 5 Euros/kg, respectively (K. Karttunen, personal communication).

In Japan the history of domestic matsutake harvesting is ancient. Because of diminishing Japanese pine forests, as well as the increasing market demand, matsutake are imported to Japan in high volume. In the 1940's the Japanese annual domestic matsutake production was 12,000 tons per year. It is much less than this nowadays. Due to the diminishing area of forests favorable for matsutake, even during the best years the domestic harvest reaches only about 1,000 tons. In addition to this, 2,000 tons are imported from China, Korea, Morocco and the USA every year. A few tons of mushrooms are being imported from Scandinavia every year, but are “small potatoes” in comparison to the potential demand for them in Japan. It is important to note that Scandinavian matsutake are more highly valued in Japan than its close relative species from elsewhere, as Scandinavian and Japanese matsutake species are now considered to be one and the same.

Many Finns have come to learn the physical appearance of matsutake from the books of a well-known Finnish mycologist and author Mauri Korhonen. While matsutake can be confused with some other species by its looks, it can easily be separated from other species by its characteristic aroma. A person who has had a chance to experience the smell of a good fresh matsutake can never forget its unique aroma. This does not necessarily mean that everybody will like the aroma or the taste of matsutake; public opinions regarding this mushroom are strongly divided. For me personally, the most memorable

gastronomical experience with *T. matsutake* has been a dish of few mm thin matsutake slices grilled on an open backyard charcoal grill, with salt, lemon juice, and soya seasoning. An unfavorable experience took place during an educational course concerning mushroom dishes (and documented in the Finnish *Mushroom Magazine*, 1/2008). I must say our experiment with deep-frozen matsutake wasn't really a success. I would like to recommend to our readers to use only fresh matsutake in their first experiments with matsutake. The precious odor vanishes from the dried fruitbodies, and the deep-frozen fruitbodies do not contribute very nicely as a raw material. In Japan popular matsutake dishes made of fresh mushrooms include soups, matsutake tempura and grilled mushrooms. These delicacies are hardly ever found on the menus of Japanese restaurants in Europe.

Similar species

Tricholoma caligatum, the "southern matsutake," has (mostly) the same characteristic smell as matsutake. In some sources it is mentioned to be bitter in taste, although it has been imported to Japan from Africa. Its ring, the brown scales and fibers and the general appearance remotely resemble *T. matsutake*. The species is not from Finland (no sample has been reported from any of the scientific collections yet) but some findings with descriptions fitting the characteristics of this species are known. Elias Fries painted two different images of *T. matsutake*, one was a bigger variety of *T. matsutake* reminiscent of *T. caligatum*.

A rare species is *Tricholoma dulciolens* Kytövuori which has the same distinctive smell as *T. matsutake*, but freshly picked is bitter in taste (I. Kytövuori, personal communication). I have had the opportunity to personally experience the smell of a *T. dulciolens* in 2005 at the Nordic Mycological Congress with Ilkka Kytövuori, who later confirmed the identification from the spores. The smell is identical to *T. matsutake*. However, the anatomy of *T. dulciolens* differs from matsutake; it is generally smaller, the stem is thinner and the overall appearance is more fragile. In addition to *T. caligatum* and *T. dulciolens*, in Europe there are a few other species carrying the same characteristic smell as *T. matsutake*, the most common of them is *Pholiota heteroclita*, an inedible saprophyte often found on birch and sometimes on aspen.

In North America *Tricholoma magnivelare*, "western matsutake," grows with lodgepole pine (*Pinus contorta*) and Douglas-fir (*Pseudotsuga menziesii*). This firm, pale-colored *Tricholoma* species often creates sizable fruitbodies with the same characteristic odor as matsutake of the East. It tends to be paler than (or darker than, depending on your references) *T. matsutake*. Interestingly, in certain areas of North America the fruitbodies are said to lack the characteristic smell, so it's possible that "*T. magnivelare*" might actually be more than one species or subspecies.

Tricholoma focale is inedible. As the fruitbodies mature and dry, they become more distinctively red in color than *T. matsutake*. *T. focale* is a fox red look-alike species, which lacks the characteristic smell of *Tricholoma matsutake*. The pictures of this species in books differ from each other considerably, and it is reasonable that this species also consists of at least two separate species. Even though *T. matsutake* and *T. focale* resemble each other visually, there is a simple procedure

to distinguish these two species. The method is simple and one can do this with closed eyes: when trying to pick up a fruitbody with a forefinger and a thumb, the stem of *T. focale* sharpens downwards and it can easily be picked up with two fingers. With *T. matsutake* the situation is different; the fruitbody is so toughly attached to the ground, that two fingers are hardly enough to separate it from the ground in one piece. While collecting *T. matsutake*, it is a useful tip to keep a large spoon or other suitable tool in your basket. It can be used for digging the fruitbody carefully from the soil to collect it in a flawless condition.

A group of brown *Tricholoma* species grows with coniferous trees: *T. imbricatum*, *T. vaccinum*, *T. pessundatum*, *T. albobrunneum* and *T. stans*. Confusing any of these species with *T. matsutake* is not likely if one has any prior knowledge or experience in identifying mushrooms. Over the years we have learned that it is remarkable how species of entirely different appearance can be confused in identification. Therefore I must repeat here: never fully trust an identification performed over the phone or made from an image. It might sound a bit funny, but every once in a while I receive phone calls from people asking me to identify the species according to their verbal description.

An edible species, *Neolentinus lepideus*, may sometimes resemble *T. matsutake* by the coloring and structure of the cap surface, but as a saprophyte it differs from *T. matsutake* by its anatomy, biotope (habitat), and by lacking the characteristic smell of matsutake.

Cortinarius balteatus should not be confused with *T. matsutake*. However, this species appeared in the matsutake buying stands in northern Finland during August 2007. After learning the smell of a fresh matsutake, any confused picker should not make such a misidentification again.

Favorable habitat and detection of matsutake using radioactive isotopes

In Scandinavia *T. matsutake* grows abundantly in pine forests of low soil nutrient and usually containing some sand. The most common mineral in favorable soil is potassium feldspar (KAlSi_3O_8). This information can be used to identify areas favorable for growth of *T. matsutake* from airborne radiometric maps. The energy of the natural radiometric gamma spectrum includes the three most active natural radionuclides; potassium ^{40}K , Thorium ^{232}Th and Uranium ^{235}U and their daughter nuclides. *Tricholoma matsutake* will not grow in clayey soils (but which are also known to be enriched of Th). The U signal (which is actually calculated from the daughters) can generally be used to delimit uncovered granitic bedrock areas (but which are not that favorable for growth of matsutake). K signal is connected to high potassium feldspar content, which correlates with pine forests. When considering areas with both high ^{40}K signal and low Th and Low U signal, one finds areas of top soil sands enriched in potassium feldspars (sands, gravel, and tills) with a thin organic top layer (since ^{40}K signal appears measurable, the thin organic layer is not completely masking it). These environments are often favorable to growth of pine trees and also matsutake.

The airborne mapping method is not conclusive, for two reasons: a) there are two different habitats where *T. matsutake* grows (the dry pine forest biotope, a spruce forest biotope) and



Tricholoma focale (Left) and *T. matsutake* (Right), photo Outi Pohjola, Finland.



Tricholoma caligatum, photo Ettore Diana, Italy.

In 2014 one visitor actually bit off a small piece from the display mushroom when she realized that the mushroom was not for sale!

the method is only sensitive to identify the first one b) a good pine forest may at times grow on sandy soils covered with a very thick organic layer and may totally cover the radiometric signal. However, the airborne mapping method may be a good help in research when separating the two matsutake biotopes.

An earlier belief was that in Scandinavia *T. matsutake* is a rather northern species. During the last two decades, mapping of harvest data has shown this mushroom can be found in pine forests throughout Scandinavia. Even during “poor” harvest years, the harvest can be good locally and locally therefore a collector network is useful to determine where best to collect

(a similar network is used by *Boletus edulis* collectors in Finland, organized by Lorenzo Dalla Valle).

Varying roles and hosts

In vitro experiments with *T. matsutake* have revealed chemistry of a facultative saprotroph (a decomposer of organic material), when no mycorrhizal host species are available (Vaario et al., 2012). While matsutake can vary between the roles of an ectomycorrhiza and a saprotroph in vitro, it can also form symbiotic relationships with a wide variety of tree species. It has been reported to form a symbiotic interaction (in vitro) with roots of common wild cherry, *Prunus speciosa*, which is known to often have arbuscular symbionts in nature (Murata et al., 2014).

In nature numerous tree species are known to host *T. matsutake*: American red pine (*Pinus resinosa*), Austrian pine (*P. nigra*), stone pine (*P. pinea*), white pine (*P. alba*), Korean pine (*P. koraiensis*), northern Japanese hemlock (*Tsuga diversifolia*), Glehn's spruce (*Picea glehnii*), Aomori-todomatsu also known as Maries' fir (*Abies mariesii*), and Japanese white birch (*Betula platyphylla* var. *japonica*) (Murata et al., 2015). In China *T. matsutake* is known to grow with a number of different pine species. In Finland *T. matsutake* grows with European pine, *P. sylvestris*, and Norway spruce, *Picea abies* (Vaario et al., 2014). As matsutake carry the same genes in different countries, there are some known small differences in genotypes that vary according the species of the host.

Harvest time distribution

The harvest season of *T. matsutake* in Finland usually runs between July and October, with the harvest season in full swing in August. The beginning of the season varies usually some weeks from one locality to another and the harvest continues usually from 2 to 3 weeks in any one location, sometimes (but rarely) a little longer. The "super years" seem to occur every 5–12 years, depending on the definition of "super year." During the years between the "super years," generous local harvests can happen, as my family members have experienced in Jokkavaara, Rovaniemi, during the years 2000, 2001, 2004, 2007 and 2014. While writing this in the beginning of September 2015, the harvest has just peaked. My sister Outi Pohjola reported collecting 56 matsutake in a single day at Rovaniemi. This is a rather good catch, since she checks the known matsutake growing locations every two days.

Future challenges

Exporting matsutake from Finland to Japan is a challenging task: a certain portion has to be allocated for material loss, the transportation is expensive, and the qualitative control by Japanese customs authorities (especially on the radionuclide concentrations) is rather intensive. Due to these obstacles and because of the lack of competition, the price paid to the pickers is only in the range of tens of euros per kg at the most. This is a rather low price in comparison to what is being paid for the mushrooms in Japan. Since the buying organization is presently operating only during a limited time period on a limited number of localities, the collectors do not have a real chance for considerable earnings.

Would it be possible to sell *T. matsutake* directly to Japanese tourists in Finland? An urban legend tells about a man, who

collects *T. matsutake* from Nuuksio (near Helsinki, on the southern coast of Finland), and carries them to a location popular among tourists (the Sibelius Monument near downtown Helsinki) to sell his harvest directly to Japanese tourists. The Sibelius Monument is generally known to attract Japanese tourists, but there is no evidence that the story of the mushroom seller is true. However, the thought is innovative, and why couldn't one sell *T. matsutake* on a normal market?

Actually, in an annual mushroom exhibition arranged by the Finnish Mycological Society in Helsinki, some Japanese tourists have many times tried to buy the display fruitbodies from the exhibition staff. In 2014 one visitor actually bit off a small piece from the display mushroom when she realized that the mushroom was not for sale!

The travel agencies might be able to organize matsutake hiking trips for Japanese tourists to the known matsutake forests in the south and Finnish Lapland, Kainuu, Rovaniemi, Kolari, and even further north. Japanese restaurants might be interested in offering matsutake dishes on their menus seasonally, if mushrooms could be sourced locally. Keeping and enjoying a highly valued mushroom for local consumption reduces its carbon footprint ... and is better for the planet.

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Jorma Palmén is Chairman of the Board of the Finnish Mycological Society. In addition to his deep interest in mycology, Mr. Palmén's expertise covers mineralogy, structural geology, environmental geology, geochemistry and digital imaging techniques. His research has combined mineralogy, geochemistry and mycology. Palmén is a member of the Finnish Geological Society, the Society of Exploration Geophysicists and the Finnish Mineralogical Association. Mr. Palmén has coordinated a project combining spatial soil geochemistry investigations and remote sensing data to assess afforestation capabilities in Africa. Presently he is working with his innovation Ladimo, developing a novel instrument to achieve accurate real time 3D-point cloud data by combining laser technology, photogrammetry and numerical modeling.

Jorma Palmén graduated from University of Helsinki, Department of Geology and Mineralogy, with majors in Geology and Mineralogy in 1997. He completed his Licentiate of Technology degree from Helsinki University of Technology, Laboratory of Engineering Geology and Geophysics, in 1999. Mr. Palmén has worked at the University of Helsinki and

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