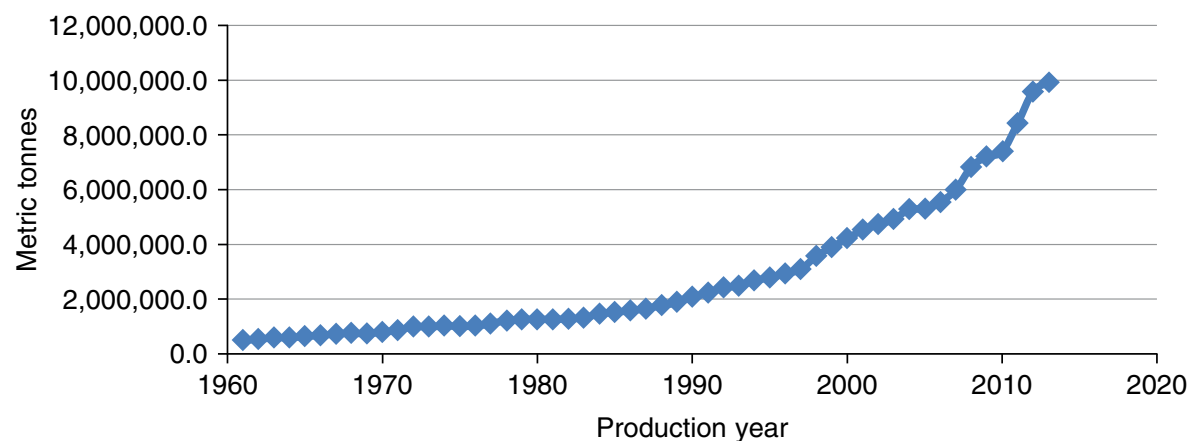


# Chapter 7

# Fungi application

Dr. Ariyah Terasawat

# Introduction



**Figure 6.1** Development of world mushroom production. Source: FAOStat.

**Table 6.1** Amounts of mushrooms and truffles\* produced by the top 10 producers in the world.

Country	Mushroom production in 2013 (tonnes)
China	7,076,842
Italy	792,000
United States	406,198
Netherlands	323,000
Poland	220,000
Spain	149,700
France	104,621
Iran (Islamic Republic of)	87,675
Canada	81,788
United Kingdom	79,500
World (total)	9,935,706

\*Truffles are only a very minor portion of the amounts of mushrooms listed in this table. Source: FAOStat.

## 6.2 The Main Cultivated Mushroom Species

When considering mushroom production on a global scale, about 75% is believed to be covered by three main species or genera:

1. *A. bisporus* (estimated at 30% of the world's mushroom production),
2. the genus *Pleurotus* (five to six cultivated species at about 27%)
3. *Lentinula edodes* (about 17%)

Button Mushroom/Champignon de Paris (*Agaricus bisporus*)



*Agaricus bisporus* is grown in a process involving six sequential steps, involving **composting, spawning, and spawn-run, casing, pinning, and cropping**. Substrate production starts with the preparation of a mixture of raw materials.

In Europe, mainly wheat straw or horse-bedded wheat straw, chicken manure, gypsum, and water are used to prepare mushroom compost. In the United States, also hay, corncobs, cottonseed hulls, or cocoa bean hulls are added to the raw materials.

### **Phase I composting**

- begins by mixing and wetting the ingredients and stacking them in a large pile for several days to soften.
- Once the pile is wetted and formed, aerobic fermentation (composting) starts. Heat, ammonia, and carbon dioxide (CO<sub>2</sub>) are released as by-products from microbial metabolism.
- As temperatures increase above 70 °C, microorganisms cease growing and a chemical reaction begins which is believed to make the cellulose and hemicellulose components in the straw more accessible for microbial degradation later in the process.
- As temperatures rise to 80 °C during phase I composting, any food pathogens that might have been present in the manure will be killed.

## **phase II spawning**

the compost is uniformly heated to 56 °C and kept at this temperature for about 8 hours.

1. The first objective of phase II is to pasteurize the composted substrate and kill insects and nematodes that can adversely affect the mushroom crop.
2. The second goal of phase II is to complete the composting process by allowing the development of a thermophilic microflora (thermophilic fungi (especially *Scytalidium thermophilum*), bacteria, and actinomycetes (“fire fang”)). The thermophilic microflora consumes all freely available carbohydrates from the compost and incorporates gaseous and soluble ammonia into its biomass.
3. At the end of phase II, volatile ammonia should be below 0.05%, as ammonia is toxic to the mushroom mycelium. This usually takes about 5 days in a tunnel system. If phase II composting is performed in a mushroom bed, it may take anywhere from 7 to 18 days, depending on how the air and compost temperatures are managed to control microbial activity.

### Phase III spawn-run

1. After cooling the phase II compost to 25 °C, spawn grains are mixed evenly through the compost.
2. After this, the mycelium is allowed to colonize the compost at 25 °C (spawn-run). Relative humidity of the air should be high to minimize drying of the substrate surface.
3. Spawn-run takes 14–17 days in a tunnel system. If spawn-run is performed in mushroom beds, it usually requires 14–21 days. At the end of spawn-run, supplements can be added.
4. Many of these supplements consist of a high-protein oil material, such as soybean meal, corn meal, or feather meal, which has been treated to delay the availability of the nutrients for the mushroom.
5. Supplements have to be treated to make them hard to degrade. If not treated, bacteria and competitor molds in the compost can use the nutrients in the supplements to outcompete the *A. bisporus* mycelium. Addition of supplements to the compost at the end of spawn-run increases the yield of mushrooms.
6. After addition of the supplements to the compost, a casing layer of about 5 cm is loaded on top of the compost (sphagnum peat and limestone). Limestone serves to neutralize the low pH of the peat (pH 3.5–4.5) to a value of about 7.5. The function of a casing layer is to trigger the mycelium to switch from vegetative growth to the development of mushrooms. The casing also functions as a moisture supply for the mushrooms and their rhizomorphs (thicker threads of mushroom mycelium).
7. Colonization of the casing soil can take 14 days at 25 °C and relative humidity of the air of 93–95%. To shorten the time needed to colonize the casing soil, small amounts of compost are mixed through the casing.

## Phase IV casing and V pinning

1. During the colonization of the casing soil, a bacterial population (especially bacteria from the genus *Pseudomonas*) develops near the fungal strands, living on the sugars, amino acids, and volatile compounds that are released by the fungus. These bacteria are important for the fructification of *A. bisporus*. In order to allow *A. bisporus* to produce mushrooms, the growing rooms need to be vented.
2. The mushroom growers gradually lower the air temperature to about 18 °C and the carbon dioxide content in the air to about 1,000–1,200 ppm. To achieve a lower carbon dioxide content in the air, they need to let in fresh air from outside the growing room. The relative humidity is lowered to about 90%.
3. On the rhizomorphs that have developed in the casing soil, small primordia start to develop.
4. From the onset of venting till the harvest of closed mushrooms takes about 10 days. Especially in the last days before harvest, the mushrooms double in weight every 24 hours.

## Phase VI cropping

1. Mushrooms are harvested over a 2- to 4-day period, and after harvest, new mushrooms start to develop and these will be ready for picking about 7–10 days later. Each crop of mushrooms is called **a flush**.
2. The first two flushes account for the majority of the total yield. In later flushes, much less mushrooms can be harvested. In most countries, the mushrooms are harvested by hand and are picked at a time before the cap becomes soft. When the cap becomes soft, it is an indication that the mushroom is starting to lose its quality and starts to open up and release spores.
3. In the Netherlands, about 60% of the crop is harvested mechanically. Mushrooms that are harvested mechanically are produced for the canning industry and frozen mushrooms.

## 6.2.2 Oyster Mushroom (*Pleurotus* Species)

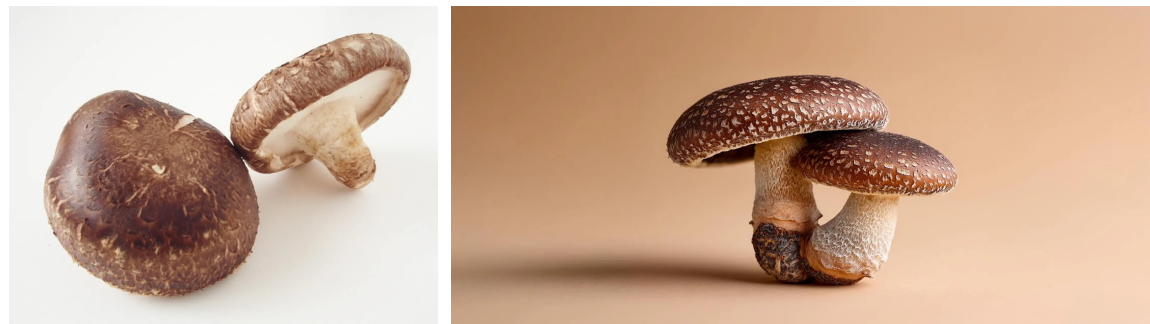
*P. sajor-caju*, *P. cystidiosus*, *P. cornucopiae*, *P. pulmonarius*, *P. tuber-regium*, *P. citrinopileatus*

They have been reported to grow on most hardwoods, wood by-products such as sawdust, paper, pulp sludge, all the cereal straws, corn and corn cobs, coffee residues such as coffee grounds, hulls, stalks, and leaves, banana fronds, waste cotton, Azolla ferns, bean straw and pods, on Brassica crop residues like rape and mustard, on cactus, agave, and yucca, on cardamom pulp, coconut husks, groundnut shells, and water hyacinth, cassava stipes, leaves, and peels, potato foliage, quinoa plants, sesame stems, sunflower peels, and many more.



## 6.2.3 Shiitake (*Lentinula edodes*)

This traditional method of cultivation has been described in China by Wang Zeng as early as ad 1313 in The Agriculture Book.



## 6.3 The Main Species of Mushroom Collected in Nature

### 6.3.1 Chanterelle (*Cantharellus cibarius*)



### 6.3.3 Truffles (Tuber species)

*T. melanosporum*, *T. magnatum*, *T. uncinatum*,  
and *T. borchii*

*T. melanosporum* range from 40 to 150 tonnes/year at market prices ranging from 300 to 450 €/kg.

*T. magnatum* the annual harvest ranges from 10 to 30 tonnes at a mean market price, over 1,000 €/kg

*T. uncinatum* the annual harvest ranges from 10 to 30 tonnes at a mean market price between 100 and 180 €/kg.

*T. aestivum* the annual harvest ranges from 50 to 100 tonnes at a market price ranging from 50 to 100 €/kg.

### 6.3.2 Morels (*Morchella* species)



### 6.3.4 Boletes (*Boletus* Species)



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# รู้จักเห็ดป่า

เห็ดเผาะ



เห็ดขมิ้น



เห็ดระโงกส้ม



เห็ดโคน



เห็ดแดง



เห็ดทรัฟเฟิลไทย



เห็ดตับเต่า



บ้านและสวน

Garden & Farm

เห็ดตับเต่า *Thaeogyroporus porementosus*

เห็ดเผาะ *Astraeus hygrometricus*

เห็ดขมิ้น *Craterellus aureus*

เห็ดทรัฟเฟิลไทย *Tuber thailandicum*

เห็ดโคน *Termitomyces fuliginosus* Heim.

<https://gardenandfarm.baanlaesuan.com/279334/farming-101/plant-tissue-culture>

**Table 6.2** Proximate composition per 100 g of fresh weight of raw fresh mushrooms compared to other foods.

	Water	Energy	Protein	Total lipid (fat)	Ash	Carbohydrate, by difference	Fiber, total dietary	Sugars, total
	g	kcal	g	g	g	g	g	g
<i>Mushrooms</i>								
White mushrooms	92.45	22	3.09	0.34	0.85	3.26	1	1.98
Oyster mushrooms	89.18	33	3.31	0.41	1.01	6.09	2.3	1.11
Shiitake	89.74	34	2.24	0.49	0.73	6.79	2.5	2.38
Enokitake	88.34	37	2.66	0.29	0.91	7.81	2.7	0.22
Maitake	90.37	31	1.94	0.19	0.53	6.97	2.7	2.07
Morels	89.61	31	3.12	0.57	1.58	5.1	2.8	0.6
<i>Other foods</i>								
Corn grain, yellow (dried)	10.37	365	9.42	4.74	1.2	74.26	7.3	0.64
Hamburger, raw	67.13	198	19.42	12.73	1.71	0	0	0
Soybeans, green, raw	67.5	147	12.95	6.8	1.7	11.05	4.2	No data
Chicken, broilers or fryers, meat only, raw	75.46	119	21.39	3.08	0.96	0	0	0
Potatoes, flesh and skin, raw	79.25	77	2.05	0.09	1.11	17.49	2.1	0.82
Carrots, raw	88.29	41	0.93	0.24	0.97	9.58	2.8	4.74
Cabbage, raw	92.18	25	1.28	0.1	0.64	5.8	2.5	3.2
Spinach, raw	91.4	23	2.86	0.39	1.72	3.63	2.2	0.42
Tomatoes, red, raw	94.52	18	0.88	0.2	0.5	3.89	1.2	2.63
Lettuce, green leaf, raw	94.98	15	1.36	0.15	0.62	2.87	1.3	0.78
Cucumber, with peel, raw	95.23	15	0.65	0.11	0.38	3.63	0.5	1.67

Data from the USDA National Nutrient Database.

## 6.4 Nutritional Value of Mushrooms

**Table 6.3** Contents of vitamins in 100 g of raw fresh mushrooms.

		White mushrooms	Oyster mushrooms	Shiitake	Enokitake	Maitake	Morels
Vitamin A (RAE)	µg	0	2	No data	0	0	0
Thiamin (vitamin B1)	mg	0.081	0.125	0.015	0.225	0	0.069
Riboflavin (vitamin B2)	mg	0.402	0.349	0.217	0.2	0.146	0.205
Niacin (vitamin B3)	mg	3.607	4.956	3.877	7.032	0.242	2.252
Pantothenic acid (vitamin B5)	mg	1.497	1.294	1.5	1.35	6.585	0.44
Pyridoxin (vitamin B6)	mg	0.104	0.11	0.293	0.1	0.056	0.136
Folate, total (vitamin B9)	µg	17	38	13	48	0.056	9
Cobalamine (vitamin B12)	µg	0.04	0	No data	0	0	No data
Vitamin C (total ascorbic acid)	mg	2.1	0	No data	0	0	No data
Vitamin D2 (ergocalciferol)	µg	0.2	0.7	0.4	0.1	28.1	5.1
Vitamin D3 (cholecalciferol)	µg	0	0	0	0	0	0
Vitamin E (alpha-tocopherol)	mg	0.01	0	No data	0.01	0.01	No data

Data from the USDA National Nutrient Database.

**Table 6.4** Contents of minerals in 100g of raw fresh mushrooms and other raw foods.

	Calcium, Ca	Iron, Fe	Magnesium, Mg	Phosphorus, P	Potassium, K	Sodium, Na	Zinc, Zn	Copper, Cu	Manganese, Mn	Selenium, Se
	mg	mg	mg	mg	mg	mg	mg	mg	mg	µg
White mushrooms	3	0.5	9	86	318	5	0.52	0.318	0.047	9.3
Oyster mushrooms	3	1.33	18	120	420	18	0.77	0.244	0.113	2.6
Shiitake	2	0.41	20	112	304	9	1.03	0.142	0.23	5.7
Enokitake	0	1.15	16	105	359	3	0.65	0.107	0.075	2.2
Maitake	1	0.3	10	74	204	1	0.75	0.252	0.059	2.2
Morels	43	12.18	19	194	411	21	2.03	0.625	0.587	2.2
Hamburger	12	1.99	19	175	289	68	4.55	0.063	0.01	14.2
Soybeans	197	3.55	65	194	620	15	0.99	0.128	0.547	1.5
Chicken	12	0.89	25	173	229	77	1.54	0.053	0.019	15.7
Potatoes	12	0.81	23	57	425	6	0.3	0.11	0.153	0.4
Carrots	33	0.3	12	35	320	69	0.24	0.045	0.143	0.1
Cabbage	40	0.47	12	26	170	18	0.18	0.019	0.16	0.3
Spinach	99	2.71	79	49	558	79	0.53	0.130	0.897	1.0
Tomatoes, red	10	0.27	11	24	237	5	0.17	0.059	0.114	0.0
Lettuce	36	0.86	13	29	194	28	0.18	0.029	0.25	0.6
Cucumber with peel	16	0.28	13	24	147	2	0.2	0.041	0.079	0.3

Data from the USDA National Nutrient Database.

## 6.5 Potential Medicinal Properties of Mushrooms

### $\beta$ -glucans

1. The fungal  $\beta$ -glucans are able to modulate the activity of the immune system and exert effects on both the innate and adaptive immune systems. All multicellular organisms possess receptors called “pattern recognition receptors” (PRRS), to detect innately nonself structures (including pathogen-associated molecular patterns, or PAMPs).
2. Thus, fungal  $\beta$ -glucans probably act as PAMPs and are recognized by appropriate cell-surface receptors, initiating immune responses.
3. There is a lot of scientific interest in the use of fungal  $\beta$ -glucans to influence the mode of action of the immune system.
4. One of the applications is the potential use of fungal  $\beta$ -glucans in cancer therapies. The fungal  $\beta$ -glucans lentinan (from *L. edodes*), schizophyllan (from *Schizophyllum commune*), and maitake D-fraction (from *G. frondosa*) are currently used as side treatments in cancer therapies.

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