Oyster Mushroom Cultivation

Part II. Oyster Mushrooms

Chapter 4

Spawn

DESCRIPTIONS OF COMMERCIALLY IMPORTANT *PLEUROTUS* SPECIES

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Introduction

Oyster mushrooms are one of the most popular edible mushrooms and belong to the genus *Pleurotus* and the family Pleurotaceae. Like oyster mushroom (*Pleurotus ostreatus*), many of *Pleurotus* mushrooms are primary decomposers of hardwood trees and are found worldwide. The type species of the genus *Pleurotus* (Fr.) Quel. is *P. ostreatus* (Jacq. et Fr.) Kummer. This mushroom has basidia with four basidiospores and a tetrapolar mating system. Its hyphae have clamp connections and most members of the genus, excepting a small minority, have a monomitic hyphal system.

To date approximately 70 species of *Pleurotus* have been recorded and new species are discovered more or less frequently although some of these are considered identical with previously recognized species. Determination of a species is difficult because of the morphological similarities and possible environmental effects. Mating compatibility studies have demonstrated the existence of eleven discrete intersterility groups in *Pleurotus* (Table 1) to distinguish one species from the others. Some reports indicate partial compatibility between them, implying the possibility for the creation of another species.

Table 1. Established biological species within *Pleurotus*, their corresponding synonyms and/or taxa at a subspecies level, and the respective intersterility groups.

Species	Synonyms-subspecies taxa	Intersterility groups
P. ostreatus	*P. columbinus, P. florida, P. salignus, P. spodoleucus*	Ⅰ
P. pulmonarius	*P. sajor-caju, P. sapidus*	Ⅱ
P. populinus		Ⅲ
P. cornucopiae	*P. citrinopileatus*	Ⅳ
P. djamor	*P. flabellatus, P. ostreatoroseus, P. salmoneostramineus, P. euosmus*	Ⅴ
P. eryngii	*P. ferulae, P. nebrodensis, P. hadamardii, P. fossulatus*	Ⅵ
P. cystidiosus	*P. abalonus*	Ⅶ
P. calyptratus		Ⅷ
P. dryinus		Ⅸ
P. purpureo-olivaceus		Ⅹ
P. tuber-regium		XI

(Source: A pluralistic approach in the study of *Pleurotus* species with emphasis on compatibility and physiology of the European morphotaxa by Georgios Zervakis and Constantinos Balis, 1996)

Wild *Pleurotus* mushrooms are distributed through out the world as shown in Table 2. *P. pulmonarius* and *P. cystidiosus* are known to be distributed in the tropical and subtropical region, while *P. eryngii* are collected in Europe, Africa and most of Asia except Korea and Japan, where the mushroom is commercially cultivated. *P. ostreatus*, the most important commercial mushroom within the genus *Pleurotus* is widespread in temperate areas. The species is quite adaptable to a range of climates and substrate materials, making itself the second most common mushroom produced worldwide following button mushroom.

Table 2. Established biological species of *Pleurotus* and their known world-distribution

	Europe	Asia	N. America	S. America	Africa	Australasia
P. ostreatus	o	o	o	o	o	o
P. pulmonarius	o	o	o	-	-	o
P. populinus	o	-	o	-	-	-
P. cornucopiae	o	o	-	-	-	-
P. djamor	-	o	o	o	o	o
P. eryngii	o	o	-	-	o	-
P. cystidiosus	o	o	o	-	o	-
P. calyptratus	o	o	-	-	-	-
P. dryinus	o	o	o	-	o	o
P. purpureo-olivaceus	-	-	-	-	-	o
P. tuber-regium	-	o	-	-	o	o

(Source : A pluralistic approach in the study of *Pleurotus* species with emphasis on compatibility and physiology of the European morphotaxa by Georgios Zervakis and Constantinos Balis, 1996)

Characteristics of Commercially Important *Pleurotus* Mushrooms

P. ostreatus is the most important species in which many commercial strains are developed and cultivated. *P. florida* must be generally regarded as a subspecies of *P. ostreatus* but it will be discussed separately because its morphology and physiology are very different. It is known that cultivators and mycologists have mistakenly described a variety of *P. pulmonarius* as *P. sajor-caju*. But this taxon will be used for easy understanding to growers. Other cultivated oyster mushrooms, including *P. eryngii*, *P. cystidiosus* (=*P. abalonus*), *P. cornucopiae* will be explained briefly. Although *P. tuber-regium* is being studied for use of sclerotia and basidiomata, it will be excluded from this discussion due to the lack of pertinent data.

Optimal growth temperatures and characteristics of the important species are presented in Table 3. These characteristics vary with the growth stages of the species and even the strains, but generally remain within the limits of the species. With the progress of breeding studies and other efforts to overcome the limits, the gaps between some species are getting smaller.

Table 3. Optimal growing conditions for different *Pleurotus* mushrooms

Species Conditions	*P. ostreatus*	*P. florida*	*P. sajor-caju*	*P. eryngii*	*P. cornucopiae*	*P. cystidiosus*
Spawn run (℃)	25	25	25	25	25-30	25-35
Primordia formation (℃)	10-15	10-25	10-25	10-15	20-25	20-25
Fruiting body production (℃)	10-17	15-25	18-25	13-18	20-30	25-30
CO_2 conc. (ppm)	< 1,000	< 800	400-800	< 2,000	< 1,000	< 1,000
Optimum season	Autumn	Spring, Summer	Spring,	Autumn	Summer	Summer
Applied cultivation methods	Log, Shelf, Box, Bottle, Bag	Shelf, Box	Shelf, Box	Bottle, Bag	Shelf, Box	Bottle, Bag

Temperature during spawn run

Even though there are some variations in growth of the mycelium according to the strains in a species, *P. ostreatus*, *P. florida*, *P. sajor-caju* and *P. eryngii* reach their optimum growth at 25℃, while *P. cornucopiae* and *P. cystidiosus* reach their optimum growth at 25-35℃, which suggests that they are a good choice for cultivation in both temperate and tropical regions (Fig. 1). But during the mycelium mass incubation prior to cultivation, the incubation room must be maintained at a temperature 3-5℃ lower than normal optimum temperatures because of their respiration heat.

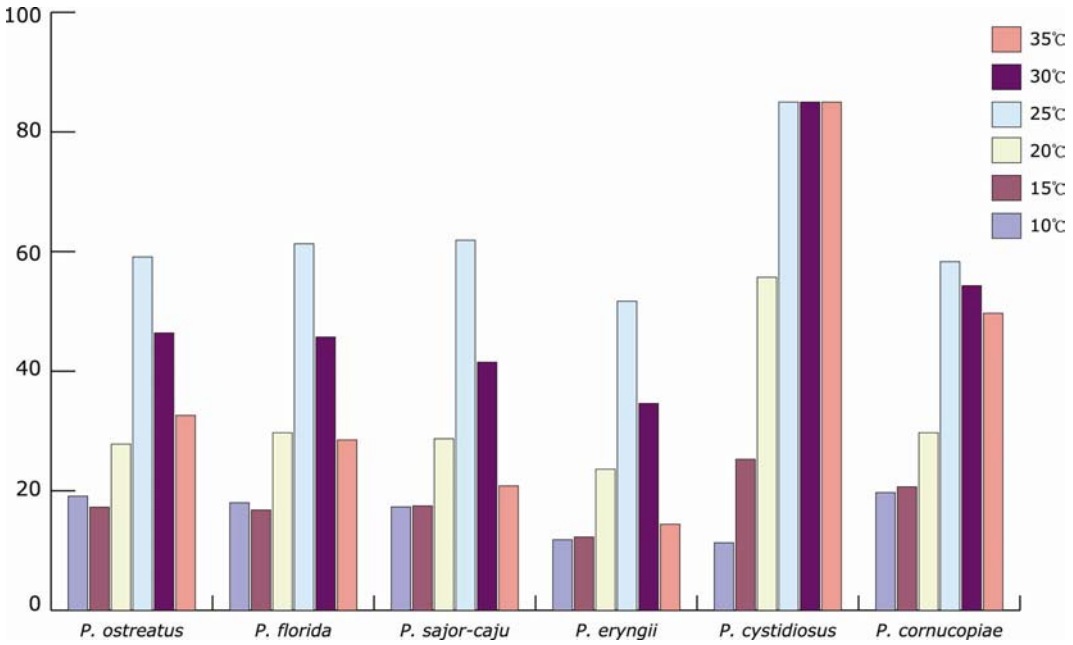

Figure 1. Effect of temperature on mycelial growth of different *Pleurotus* species

Temperature during primordia formation

In the life cycle of *Pleurotus* mushrooms there are two stages: the vegetative stage and the reproductive growth stage. Generally, some kinds of stimuli are needed for the shift from mycelial (vegetative) growth to the fruitbody formation (reproduction) phase. These stimuli include abrupt changes in temperature, humidity, gas concentration, light and nutrient reserves, and physical stimuli. Among them, a sharp temperature drop is the most effective in fruiting induction for most mushrooms. Fruiting is induced by low temperatures ranging from 10 to 15℃ in *P. ostreatus* and *P. eryngii*. However, the fruiting of *P. florida*, *P. sajor-caju*, *P. cornucopiae* and *P. cystidiosus* is less affected by temperature (Table 3).

Temperature during fruiting body development

Optimal temperature for the production of best quality oyster mushrooms stands between 10 and 18℃ while *P. eryngii* produce best from 13 to 18℃, and *P. florida* and *P. sajor-caju* produce best at 15-25℃, a wider temperature range. *P. cornucopiae* and *P. cystidiosus* can produce good mushrooms even at 30℃. Temperature during fruiting body development affects the color of caps. In order to produce dark colored mushrooms, growers might want to lower temperature within the recommended growing temperature range.

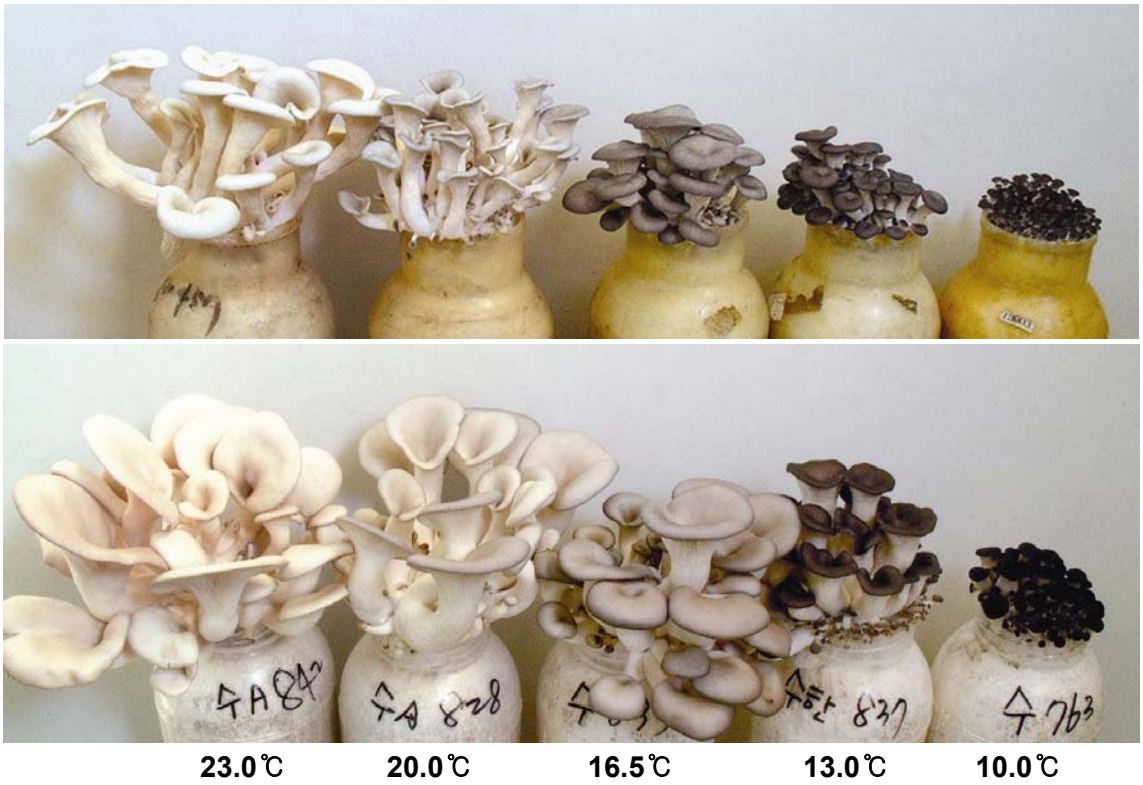

Figure 2. Effect of temperature on mushroom cap color of *P. ostreatus* strains
(Photo courtesy of Chang-Sung Jhune)

CO_2 concentration

Growers must consider the CO_2 gas concentration in the substrate containers during spawn run and the ambient CO_2 concentration during fruitbody development. During mycelial growth, CO_2 concentrations in the containers could rise up to 40%. Mycelial growth of *P. ostreatus* and *P. florida* are stimulated in the high CO_2 concentrations up to 28% and 22%, respectively. The ambient CO_2 concentration in the growing room, however, should be controlled by ventilation, especially during fruitbody formation and development. Under high CO_2 levels or with

less frequent ventilation, mushrooms produce long stipes with tiny caps, while they produce short stipes with broad caps under low CO_2 levels or frequent ventilation. In *P. ostreatus*, a CO_2 concentration higher than 1,000 ppm will produce stipes that are too long and result in mushrooms of lower quality (Fig. 3).

A. Optimum CO_2 concentration

B. A little high CO_2 concentration

C. High CO_2 concentration

D. Malformed fruit bodies under high CO_2 concentration

Figure 3. Effect of CO_2 concentration on mushroom shape of ***P. ostreatus***

Cultivation methods

Proper cultivation methods vary by variety. A diversity of cultivation methods utilizing log, shelf, box, bag and bottle have been developed and sawdust, log and agro-waste including straw and cotton waste serve as a good source for mushroom substrate. Shelf and box cultivation methods are mainly applied to cultivate *P. florida*, *P. sajor-caju* and *P. cornucopiae*, while bag and bottle cultivations are used for *P. eryngii* and *P. cystidiosus*. Selection of the right cultivation methods is based on the mushroom variety, market demands and farmers' preferences.

A. Log culture

B. Shelf culture

C. Box culture

D. Bag culture

E. Bottle culture

Figure 4. Various growing methods for oyster mushroom (Photo courtesy of Chang-Hyun You and Young-Bok Yoo)

Commercial *Pleurotus* species

Pleurotus ostreatus (Jacq.: Fr.) Kummer

P. ostreatus, a wood-destroying fungus, is widespread in the temperate zones and forms fruitbodies in relatively cool temperatures in comparison with other *Pleurotus* species. This is the most frequently cultivated species among the genus *Pleurotus*. One of the features of this species is it requires a low temperature treatment called "cold shock" to initiate primordia formation.

Growing temperatures for the production of fruiting bodies is rather low at 10-2℃. As of December 2003, 66 commercial strains are available in Korea. Different strains have different degrees of heat or cold tolerance. Some strains are less affected by unfavorable temperature conditions at the latter flush stages. It is important to select proper strains for the cultivation method of a particular grower's choice. Currently, commercial strains are mainly developed by introduction, mating and selection plus protoplast fusion and mutagenesis.

Figure 5. Protoplast fusion

figure 6. Mutagenesis

***Pleurotus florida* Eger**

Figure 7. *P. florida*

P. florida is widespread in temperate, subtropical and tropical zones. It is similar in appearance to and was considered as subspecies of *P. ostreatus*. Some modern mycologists are inclined to regard it as another species with different color and different temperature requirements. Actually, there are two groups in *P. florida* at the subspecies level. One group is sexually compatible with *P. ostreatus* and the other with *P. pulmonarius*.

At low temperatures, the color of the caps is light brown, but they turn pale with increasing temperature. It could be harvested in warmer temperatures as its fruiting temperature range is wider than other *Pleurotus* mushroom and it does not require fruiting induction (cold shock). Moreover, it shows the highest yield among the *Pleurotus* species.

***Pleurotus eryngii* (DC.: Fr.) Quel**

Figure 9. *P. eryngii*

Wild *P. eryngii* are usually collected in southern Europe, North Africa and central Asia. It has many subspecies and similar taxa such as *P. fuscus* var. *ferulae* from China. This "King Oyster" mushroom is increasing in popularity due to its unique favor.

However, when one grows this mushroom, closer attention should be paid to room humidity and ventilation during fruiting and mushroom development, and spore load from other mushrooms and other disease or weed fungi in the growing room after harvest. Since *P. eryngii* is more prone to diseases and more sensitive to growing conditions but grows slower than *P. ostreatus*, most growers opt for bottles or bags filled with sawdust. It requires cold shock for primordia formation and forms fruiting bodies at 13-18℃ The cap is cream to grey-brown colored and the stipe is whitish and 10-14cm long.

***Pleurotus sajor-caju* Fr.: Fr.**

Figure 9. *P. sajor-caju*

It is known that *P. pulmonarius* was once mistaken for *P. sajor-caju*. The mushroom grows wild in subtropical and tropical regions like India. It is known to be compatible with *P. sapidus* but they are different in appearance. With its optimal temperature range for fruitbody development relatively high, it is suitable for growing in subtropical and tropical areas.

***Pleurotus cystidiosus* O.K. Mill.**
(*P. abalonus* Han, Chen & Cheng)

Figure 10. *P. cystidiosus*

P. cystidiosus is widely distributed in subtropical and tropical regions. Although it is mainly grown in subtropical region, its productivity is relatively low. The unique characteristic that distinguishes this mushroom from other *Pleurotus* species is the presence of conidia on the mycelium. Conidia are asexual spores composed of white coremia surmounted by black heads of arthroconidia, which occur on the mycelia

under light. The black spots make them look as if contaminated but do not affect the mycelial growth and fruitbody formation. Bottle and bag cultivation methods are favored for mature mycelial growth.

***P. cornucopiae* (Paulet) Rolland**

P. citrinopileatus is considered as a subspecies of *P. cornucopiae* by reason of compatibility even though it was regarded as a separate species and occurred only the eastern part of Asia until recently. It is distributed in Asia and throughout Europe and occurs on the stumps of broad-leaf trees from summer through fall. The cap is yellowish, 4-12cm and the stipe is white. It has a wheat flour odor. Because it tastes good and has a pretty color, its cultivation is expected to increase.

Figure 11. *P. cornucopiae*

Breeding of *Pleurotus* spp.

It is difficult to accurately describe all the species and commercial strains of *Pleurotus*. Different countries have different weather and growing conditions, cultivation histories, methods of utilizing native agricultural wastes, and different consumer demands. Therefore the species descriptions above may not be definitely true and applicable to all parts of the world. But it is necessary to understand the basic species-dependant characteristics in order to grow mushrooms successfully. The development of commercial strains that are suitable to the growing environment of each region and satisfy the various consumer demands must be accomplished. To this end, genetic resources for breeding have been collected, preserved and exchanged.

The following factors must be considered in breeding:

- Morphological characteristics
- Physiological characteristics
- Cultivation methods and techniques
- Yield
- Resistance to disease
- Consumer & processor demands
- Culinary value
- Storage life

Some species are well studied and have been used to develop many commercial strains, while others are not. The creation of new strains is always required to preserve genetic diversity and meet the ever-changing consumer demands.