Automation of Solid-state Bioreactor for Oyster Mushroom Composting

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This study focused on the production of high quality compost for the growth of aero-thermophilic fungi, which has a promoting effect on the growth rate and production of oyster mushrooms. The automated solid-state bioreactor system was designed on the basis of a Three-Phase-One system, which controls the serial steps of prewetting, pasteurization and fermentation processes. High numbers of thermophilic fungi and bacteria were recovered from the mushroom composts prepared by this solid-state bioreactor. The rates of composting process were depended on physical as well as chemical factors. Among these factors, the parameters of moisture content and temperature were found to be particularly important. In our automated system, constant levels of moisture content, temperature and ventilation via mixing were provided by a centralized control apparatus including PLC, water tank and water jacket systems. These features induced higher microbiological activity of aero-thermophiles.

KEYWORDS: Automation, Mushroom composting, Solid-state bioreactor

The production of oyster mushroom (Pleurotus ostreatus) has increased rapidly for the last decade and its production was ranked second after the white mushroom (Agaricus bisporus). The production and consumption of the mushroom have become extremely popular in Asia, especially in China and Korea (Chang and Miles, 1991; Lelley and Jansen, 1993). Meanwhile its production in Europe and North America remain unchanged practically over the last 15 years (Lelley and Jansen, 1993). This was primarily due to the low yield of the mushroom cultivated at a commercial scale in these regions. In order to cope with this problem and to maximize economic efficiency, the development of high quality compost is the most urgent problem to be solved in mushroom industry.

Composting is the process of preparing necessary nutrients through high temperature fermentation by thermophilic fungi. These important organisms grow optimally at temperature of greater than 40°C (Crisan, 1973). Thermophilic fungi grow extensively during the last phase of the composting process (Straatma et al., 1989; Wiegant, 1992), at which compost quality is usually determined. This process is especially important because it provides a selective pressure on the mushrooms to grow by reducing ammonia concentration, immobilizing nutrients, and positively affecting the extension rate of mycelium (Wiegant et al., 1992).

The growth-promoting effect of a thermophilic fungus, Scytalidium thermophilum, on Agaricus bisporus has been well established. Some Sepedonium species were known as growth-promoting thermophilic fungi on oyster mushroom (Pleurotus ostreatus) while S. thermophilum showed no growth-promoting effect on oyster mushroom (Lee and Hyun, 2000). The optimum temperature for the growth of thermophilic fungi is around 45–50°C and the maximum temperature is less than 60°C for all thermophilic fungi although their spores may survive at much higher temperatures.

Composting is an aerobic process in which organic matters are partially mineralized and humidified. In order to produce good quality compost, the makers should consider the following three fundamental rules; 1) a relatively short process with low energy consumption, 2) a guarantee of the compost reliability, and 3) free from harmful pathogens. For these reasons, composting should be operated in a controlled system in order to produce end products of high quality.

Sinden and Hauser (1950, 1953) developed the first composting device attached with pre-wetting and mixing systems. On the basis of this compost, a three-phase-one system (Derks, 1973) and Phase I and Phase II of Spawn Run type compostor (Edwards, 1977) were developed. Because the pre-wetting and Phase I stacks are usually controlled in part, temperature and oxygen levels within the compost fluctuate widely from 20°C to 80°C and from 0% to 21%, respectively (Randle and Plegg, 1978). These result in an inefficient composting (Smith, 1983), as well as atmospheric pollution from the production of ammonia in anaerobic regions within the stacks. Also odorous compounds (particularly sulfur compounds) and liquid run-off from the pre-wetted materials and Phase I stacks are sources of pollution (Derikxx et al., 1990).

For these reasons, several researchers have attempted to exert greater control over composting by manipulating the entire process in an enclosed system (Derks, 1973; Bech,
1978; Smith, 1983; Laborde et al., 1987; Perrin and Gaze, 1987; Gomez, 1998). However, many attempts to prepare the compost in an uniform manner were unsuccessful because of difficulty of operation, contamination of harmful microorganism, and a low yield of mushroom.

The purpose of this study is to design an upgrade bioreactor armed with a computerized controller which can control the fermentation environments and to evaluate the bioreactor for the commercial use. Therefore, in this study, we investigated environmental conditions such as temperature, carbon dioxide flux, and activity of thermophilic fungi during composting by the developed bioreactor.

Materials and Methods

Features of bioreactor. The principle underlying the construction of the solid-state bioreactor was to design a system that keeps moisture content constant, conserves heat, and maintains good aeration.

An experimental bioreactor was designed on the basis of a three-phase-one system and modified as a dynamic system that is closed and horizontal reactor with forced mixing screw (Fig. 1). A dynamic composting system was designed to control the exact temperature, amounts of oxygen, and moisture content of the compost. The main chamber of a bioreactor was constructed for composting 6,000 kg of compost as an end product. The size of bioreactor was 2.14 m (diameter), 2.17 m (height), 2.14 m (length) and 15.01 m³ (volume). The main body was covered by a water jacket with a lined water tank for the exact control of temperature.

An automatic controller, PLC FPO-C32 (Matsushita Electric Co.) was equipped for main programmable logic controller and control panel with touch screen, MT 506L (Weinteck Labs.) was used for easy operation. IBM compatible PC with Pentium processor was used to input environmental factors and main O/S was Microsoft Windows 98. A 30HP geared motor with 1/60 motor reducer was used to mix the 6 tons of composting material. The dual ribbon mixer was contrived for easy mixing by bi-directional forcing. The ventilation system consisted of a 1HP air compressor (600 l/hour) and hepa filter on airlines. Air inlet line was mounted at the bottom cover of the bioreactor to provide a controlled flow of air through the compost. Overall ventilating air was composed of 80–90% recirculated air and 10–20% fresh air. Water circulation system with a water tank, water jacket, pump, sensors, solenoid valves, and PLC was installed for the maintenance of optimum temperature. The total volume of hot water in water jacket was calculated as 0.30092 m³, the dimension and capacity of the water tank were 0.79×0.70×0.90 m (W/L/H) and 0.498 m³, respectively. Sensors and solenoid valves were attached to water and steam lines in the inside of the bioreactor (Fig. 2).

Organisms. Sepedonium sp. S-2 as thermophilic fungi was used for this study. Spore suspensions were obtained from growth on a potato dextrose agar (PDA, Difco) at 45°C. The commercial strain, Pleurotus ostreatus (KACC 500128), was obtained from the National Institute of Agricultural Science and Technology (Suwon, Korea), and used as mushroom mycelium in all experiments.

Media and growth conditions. Sepedonium sp. was maintained on PDA at 25°C. The fungi were cultured at 45°C in a medium containing 60 g of potato extract, 15 g