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Factory Production Process of Shiitake Mushrooms

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Short Research Article

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ABSTRACT

In recent years, edible mushrooms factory production has been developing rapidly, equipped with a multitude of facilities and equipment supporting the shiitake mushroom stick cultivation mode, which can fully realize the whole process of mechanized operation. This paper introduces the main processes of shiitake mushroom factory production, which include shiitake mushroom stick making process, stick sterilization process, cooling inoculation process, solid and liquid strain cultivation process and mushroom emergence process. Factory production of shiitake mushrooms improves product quality and production efficiency, reduces the economic cost of cultivation, which is essential for the future prosperous development of shiitake mushroom industry.

Keywords: Shiitake mushrooms; stick making; sterilization; inoculation; strain culture.

1. INTRODUCTION

The shiitake mushroom, because of its tender taste, delicious flavor with rich nutrition, has become an essential dish on people's dinner table and is one of the most produced edible mushrooms in the world [1]. The artificial cultivation of the shiitake mushroom originated in China with a history of cultivation for nearly a thousand years. With continuous economic and social development, the shiitake mushroom cultivation industry has gradually transformed from family-based smallholder workshop production to factory-based process production due to its high proportion of labor cost.

In recent years, edible mushroom factory production has been developing rapidly, and the facilities and equipment supporting the shiitake mushroom stick cultivation mode have been

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emerging, which can fully realize the whole process of mechanized operation [2]. On this basis, some enterprises have built Shiitake mushroom stick factory production workshops, where only the mushroom emergence is carried out in the facility greenhouse, while all other aspects are operated in the factory workshop. This paper briefly introduces the main processes of shiitake mushroom factory production, which include the production process of shiitake mushroom sticks, sterilization process of mushroom sticks, cooling inoculation process, cultivation process of mushroom seed production, as well as the emergence process.

2. STICK-MAKING AND STERILIZATION PROCESS

2.1 Stick Making Process

The recipe of mushroom sticks is 79% wood-chips, 20% wheat bran and 1% gypsum, with wood chips of hard live leafy trees and 55% water content. The wood chips are pre-wetted in advance, wheat bran and gypsum are added into the first-class mixing pot in proportion, then dry mixed and added into the pre-wetted wood chips, adding water to about 53% for the first time. About 10 days before bar making, the wood chips are pre-wetted and fermented, during which the pile is continuously turned over with a shovel. The physical and chemical properties of the wood chips are kept consistent [3]. The purpose of pre-wet fermentation is to soften the wood-chips.

It can avoid contamination caused by wood chips puncturing the bag when bagging, and at the same time can improve the water retention capacity of wood-chips. On the other hand, the water-holding capacity of wood chips has been improved. Measure the water content with a quick water content meter after adding water, and then add water to the required water content for the second time according to the measurement result. Use an automatic bagging machine to fill bags, the speed is 500~600 bags/h. After bagging, the sticks are pricked with holes and put with breathable tape to prevent the bags from rising by autoclaving.

The automatic bacillus bagging machine with an electronic device controls mixing, transferring, bagging, tying, and so on. Each machine can produce 700 sticks per hour, and 5 production lines can produce 200,000 sticks per day at full capacity. This automatic production equipment is put into production, which greatly reduces the labor cost and solves many uninteresting factors such as uneven mixing and uneven tightness of sticks in the traditional mode of production. The finished bag-making rate is more than 99% [4]. The machine is easy to operate, the bagging quality is uniform, the weight and tightness of each bag are the same, the rate of broken bacteria is very low, and the effect of good fungus, saves labor and time. The automatic bacillus bagging machines shown in Fig. 1

Fig. 1. The automatic bacillus bagging machine

2.2 Sterilization Process

Sterilize immediately after the bagging, and try to shorten the time between adding water to the culture material and sterilization to avoid acidification of the culture material. Use a double-door autoclave with autoclaving at 116~118℃. If using water retention film, lower the sterilization temperature to 112~113℃ to prevent the water retention film from denaturing at high temperatures. Adjust the sterilization time according to the placement density of the sticks, the higher the density the longer the sterilization time. Since the sticks cannot be stacked, they are placed at a lower density and have better heat transfer in the sterilizer, generally requiring only 5-6 h of sterilization at 112℃ and high pressure. Fig. 2 shows autoclaving [5].

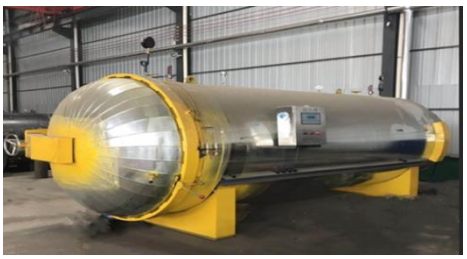

Fig. 2. The Double-door autoclave steam sterilizer

3. COOLING AND INOCULATION PROCESS

After sterilization, open the back door of the sterilizer and discharge the remaining base vapor into the pre-cooling room, after the vapor is exhausted, the sticks will be directly dumped into the cooling room for cooling. To save electricity costs, you can use filtered fresh air for natural cooling first, and then use the cooler for forced cooling, cooling to 18-20℃ for inoculation. Be sure to let the medium temperature drop to below 20℃in a purified environment. When sterilization under atmospheric pressure, special attention should be paid to the rapid cooling of the pot after release to prevent contamination from air inversion. After inoculation, the sticks can be put on transparent tape or an outer bag to prevent the strain from falling and reduce the contamination rate.

There are two advantages of the shiitake solid inoculation machine compared with the traditional manual inoculation. Firstly, it can realize dense inoculation. Increase the germination point of linden wood, the germination area is bigger when there are more germination points, so that the mycelium can penetrate the linden wood in a shorter period of time [6]. Limewood and the outside world for gas exchange mainly by absorbing water and evaporating water, alternating wet and dry moisture movement can make the internal lime wood get enough oxygen, making mycelium deep lime wood eating material, to accelerate the lime wood maturity, reduce the chance of infection by miscellaneous bacteria.

Secondly, deep inoculation can be realized. If the seed hole is deep, it can be filled with more bacteria, which is good for drought prevention and can make the seed block at the bottom of the seed hole less stimulated by the outside temperature difference. Mycelium in the seed pieces will germinate quickly under the condition of constant temperature and humidity, thus the survival rate can be improved. Deep hole, can increase the depth of the wood tangential, so that the mycelium absorbed to more adequate nutrients, the production will be greatly improved [7].

The control system of the automatic inoculation machine adopts Siemens PLC program control, with a high degree of automation. It can automatically complete a series of actions from conveying, wiping, punching, inoculating, compacting, etc. The production efficiency can reach 600^700 packs per hour. It replaces the original single and frequent inoculation action done by manual. The production efficiency is significantly improved and the labor intensity is reduced. The automatic solid strain inoculation machine is shown in Fig. 3.

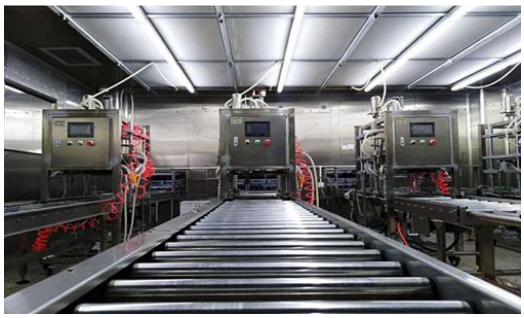

Fig. 3. The automatic bacillus bagging machine

4. STRAIN PRODUCTION MODE

4.1 Conventional Solid Strain Production Mode

Solid strain production is generally from the mother strain by step expansion, can be through the test tube mother strain - solid three fish bottle seed-original seed-cultivar production mode [8]. It can also be produced through the production method of test tube mother seed-branch seed-cultivar, in order to improve the consistency of the age of the bacteria and mycelium full bag time. The inoculation hole is reserved in the center of the bag. It usually takes 24~27 days for the full growth of the dicot vial, and 27~30 days for the full growth of the original, branch and cultivar. It takes 3 months to expand the whole seeds from the mother seeds in the test tube to the cultivars that can be used.

4.2 Liquid-to-solid Strain Production Method

Cultivating liquid strains, automatic operation, simple and clear process (compared to solid strains, greatly simplifies the spawn making process).The liquid strain medium is rich in nutrients, and the mycelium can sprout quickly after inoculation (occupy the growth advantage), with high inoculation efficiency, quick cover of establishment, and consistent age, thus reducing the contamination rate and shortening the culture

cycle of the strain; at the same time, the cost advantage of liquid strain production is obvious, which is suitable for large-scale and factory production of shiitake mushroom.

To reduce the time of strain expansion, the way of solid strain expansion step by step is changed to the production method of test tube mother strain - triangle bottle liquid bacteria and - fermenter liquid bacteria and cultivars. Depending on the variety of liquid strain culture time is different, triangle bottle liquid strain generally needs 7~10 days to reach the required bacterium ball concentration, fermentation tank strain generally need 9~11 days can be used, also can reduce the liquid strain fermentation time by increasing the amount of inoculum [9]. The solid cultivars inoculated with liquid strains can generally grow full in about 21 days, and the production cycle from the test tube master seed expansion to the cultivars that can be used is not more than 40 days, which is 50 days less than the solid strain expansion, considerably shortening the strain production cycle and laying the foundation for the enterprise to quickly put into production. Fig. 4 is the triangle bottle liquid strain.

Fig. 4. The triangle bottle liquid strain

Liquid triangle flask medium generally uses soybean meal as the main nitrogen source, glucose or sucrose as the carbon source, then adds a small amount of trace elements and nutrient enrichment components, and can use shaker culture or magnetic stirrer culture with temperature control at about 24℃. The culture medium formula of the fermentation tank is the same as that of a liquid triangular flask, but it needs to add a defoamer. Fermenters can be used in situ sterilized fermenters or Korean-type fermenters. The total investment of using in-situ sterilized fermenters is less and does not depend on the construction progress of the autoclave and purification workshop, but the operation is slightly tedious [10].

Fermenter culture liquid strain is to beat the mycelium into the fermenter and pure water for mixing, 10-15 days, the concentration and viability to reach the established requirements, implant the strain into the sticks. The fermentation tank provides uniform and constant nutrient conditions for the growth of liquid bacteria, which mainly includes increasing the dissolved oxygen concentration and fully mixing the culture medium. During the fermentation process of edible mushroom, the mycelium is entangled into spheres with each other, so the fermentation tank needs to be kept clean, tidy and free of contaminants in the liquid strain fermentation production process. The process of production is cleaning and inspection of the fermentation tank - disinfection of the fermentation tank - ingredients - feeding - sterilization - cooling - fermentation - cultivation - bottling.

During the fermentation process, the pressure inside the tank should not exceed 0.17mpa. During actual consumption, when the jacket is preheated by steam, the inlet pressure must be controlled within the working pressure range of the equipment (not more than 0.2mpa), otherwise, it will cause damage to the fermenter. When emptying and actual emptying, the remaining water must be exhausted in the sheath of the fermenter. If not, the inner barrel of the fermenter may be compressed, causing damage to the equipment [11]. In addition, excessive condensate can lead to dilution of the medium and failure to meet process requirements. The negative pressure inside the fermenter is strictly prohibited to be generated in the process of removing the empty tank and cooling after the actual removal to avoid contamination or even damage to the equipment. During the fermentation process, the pressure in the fermenter should be kept between 0.03-0.05mpa to avoid contamination. The pressure in the gas pipe must be kept higher than the pressure in the fermenter during each operation, otherwise, the liquid in the fermenter will flow back into the filter and block the filter element or make the filter fail. Fig. 5 is the bit sterilization fermenter.

5. CULTIVATION AND MUSHROOM EMERGENCE PROCESS

Use angle iron bed frame tic-tac-toe culture mode or grid bed frame mode to cultivate mushroom sticks, mushroom mycelium grows slower at low temperature, so culture temperature should not be lower than 16℃,

temperature control at 22~23 ℃ , humidity 65%~70%, CO_2 concentration below 3 000 mg/m3.For light management, the initial culture is managed in darkness as much as possible for 30-40 days (no lighting is needed except for inspection); after that, 100-300 lux light is given during the day and lights are turned off at night. Adequate ventilation is provided by pressurized ventilation fans in air-conditioned facilities with insulating materials. Care should be taken not to blow strong winds on the newly inoculated (initial culture) blocks.

Fig. 5. The bit sterilization fermenter

After 20~30 days of inoculation, the first time to stab hole oxygenation, after 40~45 days of inoculation, the second time to stab hole oxygenation, after stab hole oxygenation, pay attention to control the temperature of the sticks, the center temperature of the sticks should not exceed 28℃ to prevent burning bacteria. The 2nd time after oxygenation, give light irradiation to promote color change. The culture temperature is set at 20-23 ℃ . Due to the existence of breathable film, breathable bags cannot be stacked and placed in the culture, but only a single placement on the culture shelf, culture density is low, the uniformity is good, and do not need to pierce the hole to increase oxygen, as long as the bags are not punctured, there is generally no pollution problem in the later stage. Fig. 6 is the grid bed frame [12].

When the sticks turn color completely and are elastic, the sticks reach physiological maturity, then the bags can be cut and mushroomed. Place the broken bag upside down with the bottom facing up. The temperature is controlled by the shade net, plastic film and water curtain fan of the mushroom emergence greenhouse, and the best growing temperature is 10~25℃. The concentration of CO_2 is below 1,500 mg/m3 and the light intensity is 500 to 1,000 lux, with lighting on during the day only.

After harvesting, we have to manage the next crop of shiitake mushrooms, so we have to give a period of 20 to 30 days to nurture the mushrooms to form the original base. The temperature should be controlled at 20-23℃. Humidity is managed at 60% to 90%, and water is sprayed twice a day for 20 minutes each time.CO_2 concentration should be below 2,000 mg/m3. Light level 50-300 lux, light on only during the day. After the mushroom cultivation, the blocks are immersed in water at 15-16℃ and removed after 20-22 hours for the second crop of mushrooms. After the second crop of mushrooms, the blocks were removed from the mushroom room and discarded immediately. The more mushrooms are produced, the more susceptible they are to disease infection. Therefore, after the 2nd crop is picked indoors, all the blocks should be finished to ensure the yield by speeding up the annual turnover rate, and if the blocks continue to produce mushrooms after the 2nd crop, they can be cultivated and managed in the open air except for the high temperature period in summer, and not in the mushroom room.

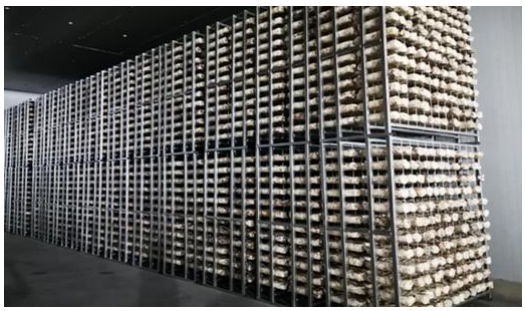

Fig. 6. The mesh bed frame

6. CONCLUSION

In shiitake mushroom block cultivation, a batch of mushroom blocks can be harvested for a long period of time. However, in factory cultivation, it is easy to use the same facility again and again, so it is necessary to finish the harvest as short as possible. Short-term harvesting is good for the prevention of pests and diseases, thus ensuring a safe harvest without pesticide residues. This ensures a safe harvest without pesticide residues. As with other edible mushrooms, the most attractive feature of factory cultivation is the stable harvest of safe edible mushrooms. At present, the cultivation technology of shiitake mushroom mainly relies on manual experience management, while factory production of shiitake mushroom improves product quality and production efficiency, and reduces the economic cost of shiitake mushroom cultivation. It is

important to sort out the whole process of Shiitake mushroom factory production for the future prosperous development of Shiitake mushroom industry.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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