Advances in Spawn Production Technique for Edible Mushrooms: From Traditional Grain Spawn to Liquid Culture Systems

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ABSTRACT-

Mushroom cultivation has emerged as one of the fastest-growing sectors in agricultural biotechnology due to its nutritional, medicinal, and economic importance. Among all the factors involved in successful mushroom cultivation, spawn quality plays the most critical role because it directly affects mycelial growth, substrate colonization, biological efficiency, fruiting behavior, yield, and disease resistance. Spawn acts as the vegetative planting material of mushrooms and serves as the carrier of actively growing fungal mycelium. Over the years, mushroom spawn production techniques have undergone remarkable transformation from primitive natural inoculation methods to scientifically controlled grain spawn systems and advanced liquid culture technologies. Traditional grain spawn methods have been used for decades because cereal grains provide excellent nutritional support for fungal growth. Wheat grains, rye grains, millet, sorghum, and maize are commonly used for spawn preparation due to their carbohydrate and protein content. Although grain spawn remains highly effective and widely practiced, several limitations such as contamination risk, uneven colonization, labor- intensive preparation, and limited scalability have encouraged researchers to develop improved spawn production systems. Recent advances in fungal biotechnology and fermentation technology have introduced liquid culture systems as a highly efficient alternative for large-scale mushroom production. Liquid spawn technology involves the cultivation of fungal mycelium in nutrient-rich broth media under sterile and controlled environmental conditions. Compared to conventional grain spawn, liquid culture systems provide faster mycelial multiplication, uniform inoculum distribution, reduced incubation time, and improved mechanization potential. These systems are now increasingly being adopted in commercial mushroom industries worldwide. In addition to liquid culture technologies, modern mushroom spawn laboratories utilize advanced sterilization systems, laminar airflow chambers, molecular diagnostic tools, bioreactors, cryopreservation methods, artificial intelligence-assisted monitoring systems, and precision fermentation techniques to enhance spawn quality and contamination control. Such innovations have transformed spawn production into a sophisticated branch of agricultural biotechnology. This review highlights the historical evolution of mushroom spawn production, different types of spawn, traditional grain spawn techniques, liquid culture systems, contamination management strategies, recent biotechnological advancements, economic significance, and future prospects of commercial mushroom spawn production. The review also emphasizes the importance of sustainable and efficient spawn technologies in meeting the growing global demand for edible and medicinal mushrooms.

Keywords: *Mushroom spawn, Grain spawn, Liquid culture, Mushroom biotechnology, Mycelial growth, Edible mushrooms, Fermentation technology, Commercial mushroom cultivation*

1. INTRODUCTION

The cultivation of edible mushrooms is being developed into a rapidly expanding global agricultural industry with the growing publicity of mushroom as the mushrooms are nutritious, medicinal and environmentally friendly food. The mushroom industry depends mainly on the spawn quality, as the spawn is the vegetative propagating material used in the form of substrate for production of the fruiting body. Quality spawn leads to fast colonization, higher biological efficiency, lower risk of contamination and uniform performance of the crop. Mushroom spawn production has a history of a few technology shifts. The first producers of mushrooms utilized natural sources of inoculum like wild mycelium and compost transfer methods. These traditional procedures were displaced by pure culture methods and grain spawn production in the beginning of 20th century. There have been significant advances in spawn technology today, utilizing biotechnology, sterile techniques, and industrial fermentation processes). Traditional grain spawn products consist of fungal mycelium grown on sterilized cereal grains, such as wheat, rye, sorghum, millet, or corn. These grains offer a critical source of nutrition and physical support for fungal growth. Grain spawn was gaining immense popularity due to its easy preparation and low cost and its efficient support for robust mycelial growth. Nevertheless, with the growing commercial demand of the mushrooms, some defects of grain spawn production were exposed, such as easy contamination, non-uniform moisture content, short shelf life, and poor scalability in industrial production. With more recent advances in liquid culture and submerged fermentation, novel applications in mushroom production are emerging. As reversed from traditional grain spawn, liquid spawn has faster mycelial growth, shorter colonization time and better scalability compared to traditional grain spawn. These advances are particularly significant for the new generation of mushroom farms that depend on efficiency, uniformity and strict contamination control. In this context, this review is intended to review the development and evolution of techniques for the production of spawn and evaluate traditional and current practices followed by an analysis of recent trends that may dictate the future mushroom spawn technology.

2. HISTORICAL DEVELOPMENT OF SPAWN PRODUCTION

2.1 Early Spawn Production Methods:

The first commercial producers of mushrooms were dependent on natural spawn collected from forest soils or from old compost. Such methods were not genetically stable, and were often contaminated and had erratic yields. Adoption of pure culture methods in the early 1900s was a milestone. Scientists were starting to isolate mycelium under sterile conditions and transfer it to sterilized substrates, such as saw dust or straw. This innovation laid the groundwork for today's spawn production. Investigators found that sterilized cereal grains contain everything a fungus needs for growth, and that grains provide a physically ideal matrix for the fungi. Grain spawn rapidly became the conventional inoculant in commercial mushroom culture all over the globe.

2.2 Development of Solid Spawn Systems:

In mushroom cultivation, spawn system was wholly solid for decades or several years. Solid, such as manure spawn, brick spawn, grain spawn. Out of all these, grain spawn is the most popular as it has more nutrients.TRADITIONAL GRAIN SPAWN TECHNOLOGY

2.3 Principle of Grain Spawn:

Sterilized grain that is colonized by

mushroom mycelium is the grain spawn. The Commonly used cereals such as wheat, sorghum, millet, oats and rye. Grains act as a nutrient dense substrate that mycelium can rapidly grow on. Grain spawn continues to be popular because it gives plentiful carbohydrates and nutrients Gives many points of inoculation Is low cost and reasonably simple to prepare. Research shows that grain spawn is applied in most of the mushroom growing systems in the world and is the best option for the small growers.

2.4 Advantages of Grain Spawn:

The technique is simple to prepare and needs little equipment, so it can be readily adopted. It results in rapid colonization of the substrate, which can save time during cultivation. This method is more appropriate to be introduced to novice grower and to small farms because it is easy and inexpensive, though the risk is high. Besides, the required raw materials are easy to get, which makes the method both convenient and feasible.

2.5 Limitations of Grain Spawn:

Grain spawn has its drawbacks, even though it is very popular. It needs more time to make due to the necessity for adequate sterilization. There is an increased chance for contamination during manipulation as well, which could compromise the spawn quality. Also, the scalability to mass or industrial production is very limited. "Another disadvantage is that its shelf life is relatively short, so storage and long-term use are more difficult."

3. SAWDUST SPAWN

4. **Sawdust Spawn:** Sawdust spawn has been used for production of shiitake with good success, but sawdust substrate is more difficult to sterilize than moist wood chips. It has numerous merits, such as inexpensive and plenty raw materials. Suitable for log culture, longer shelf life than grain spawn. But one of the drawbacks to sawdust spawn is that it does not tend to colonize substrates as quickly as grain.EMERGENCE OF LIQUID CULTURE SYSTEMS

4.1 Concept of Liquid Spawn:

Liquid spawn is the proliferation of mushroom mycelium in a sterile nutrient broth under submerged fermentation. The medium is commonly composed of carbon sources (such as sugar, starch), nitrogen sources (such as yeast extract, peptone), and some necessary mineral salts. Liquid spawn technology has been studied over the last 40 years and is becoming more popular among commercial mushroom growers. Studies indicate that submerged fermentation is capable of yielding significant quantities of mycelial biomass in a short period of time, usually in the range of several days. Liquid spawn has been shown to colonize substrates more rapidly and can result in higher yields than conventional grain spawn. Advanced fermentation processes lead to improved mycelial biomass production and inoculum quality. These breakthroughs are revolutionizing the global mushroom industry, and in the process, indirectly benefiting sustainable agriculture through biotechnology.

4.2 Advantages of Liquid Culture: Liquid spawn has some important benefits including accelerated mycelial development and increased total biomass production, which lead to greater efficiency. It reduces the time of spawn run and allows high scalability with bioreactors. Besides, it can offer homogenous and consistent inoculum for better reproducible results and has great potential to be automated in large scale production system.

4.3 Limitations of Liquid Culture: Mushroom spawn production is transformed contemporary by methods of liquid culture. It has many benefits over the grain spawn techniques, but they also have certain limitations that tend to stop the application across all the industries that do cultivation of mushroom. Certain limitations with liquid spawn, such as having sterile conditions to avoid contamination. The Requirement of special equipments, which add to cost and complexity. Also , if it is not handled properly, it can lead to contamination.

5. BIOREACTOR-BASED SPAWN PRODUCTION

5.1 Submerged Fermentation Technology: The precise cultivation of mycelium in aqueous solutions is done in a bioreactor. Research has demonstrated that liquid spawn can be generated in a few days (three day) by using stirred-tank bioreactors. This has many advantages such as:

tight regulation of pH, temperature and supply of oxygen, high biomass yield, and applicability to industry. The controlled environmental conditions within bioreactors facilitate mycelial growth at a high rate, while inhibiting contamination and allowing for uniform quality of the inoculum. Given the ability to more rapidly produce spawn and the greater potential scalability of the method, this technology is beginning to play a more significant role for large-scale commercial mushroom industries and sustainable agricultural biotechnology practice.

5.2 Industrial Applications: Major mushroom producers are now utilizing bioreactors for mass spawn production enabling them to produce in the millions efficiently. It is also applicable to continuous production turns to maintain constant supply. It also minimizes the labor input by handling different phases of production.

6. QUALITY CONTROL IN SPAWN PRODUCTION

High-quality spawn should be genetically pure, contain dense, vigorous mycelial growth, be free from contamination, and colonize substrate efficiently for the best chances of success in cultivation. To keep up these standards quality control methods are needed such as molecular strain identification, sterility testing, and the application of environmentally controlled conditions.

7. FUTURE TRENDS IN SPAWN TECHNOLOGY

Robotics and automation may also find its way into future spawn production, increasing handling capacity and reducing labor. With process optimization, Artificial intelligence will also be involved to produce more output and stability. Advances in genetic strain development may introduce improved strains, while sustainable and “green” substrates will encourage best environmental practices in growing. In conclusion, it is anticipated that future spawn production systems will be dominated by liquid culture techniques in conjunction with biotechnology.

8. CONCLUSION

Spawn production technology has developed from basic natural inoculum procedures to complex liquid culture methods. Grain spawn is still a significant unscaled method of

propagation for cultivation, however liquid spawn is much more scalable and efficient in production terms. The combination of biotechnology, automation, and bioreactor technology is going to reshape the mushroom spawn production, enabling the sustainable, large-scale production of edible mushroom. Future advances in liquid spawn technology, automation, and precision biotechnology are anticipated to continue transforming the mushroom cultivation industry and contribute to global food security, economic development, and sustainable agriculture Recent advances in biotechnology, fermentation science, artificial intelligence, contamination management, and molecular diagnostics have revolutionized mushroom spawn production into a highly specialized field of agricultural biotechnology.These advancements are predicted to enhance sustainable mushroom production and contribute to subsequent food security and profitable agriculture globally.

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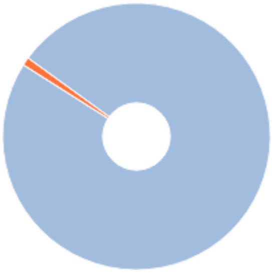

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