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A Revolution In Agaricus Bisporus (Mushroom) Cultivation: Modern Strategies For Increasing Productivity

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Abstract: This study aims to analyze global technological advances in increasing productivity in the cultivation of Agaricus bisporus (champignon) mushrooms and to experimentally evaluate the use and effectiveness of the microalgae Chlorella vulgaris as a biostimulant in the conditions of Uzbekistan (Bukhara region).

Keywords: Agaricus bisporus (Champaign), Productivity management, Chlorella vulgaris, Bio-stimulant/Biofertilizer, Compost, Automation.

Introduction: The world population is increasing by several million every year, and it is estimated that the world population will reach 10 billion by 2050, causing problems such as an increase in their demand for food. Providing food for people is becoming more difficult every year, and in recent years, food products have been obtained in a short period of time through various methods. Urbanization is reducing farmland and creating a number of challenges in agricultural production. New technologies and strategies are needed to address these challenges. Several new methods and technologies are also being used in the production of chamoinyon, in particular, vertical farming and the use of microscopic algae to achieve high yields.

LITERATURE REVIEW

An automatic environmental control system has been developed for the industrial cultivation of Agaricus bisporus (champignon). The system accurately monitors parameters such as temperature, humidity, CO_2 levels, and compost condition. The results show that this system is effective in ensuring sustainability, productivity, and energy efficiency in mushroom cultivation. This method is considered a best practice based on a technological approach in industrialized mushroom cultivation. .[1] Sitka spruce bark was evaluated as an alternative casing material to replace peat in mushroom (Agaricus bisporus) cultivation. The study consisted of two experiments in which conventional peat-based casings were compared with bark-based casings. In the first experiment, the bark casing produced results that were statistically comparable to peat casing in terms of yield and quality. However, in the second experiment, bark-based casings did not perform as expected, with a significantly lower yield observed, indicating the limited effectiveness of the bark material. The study also reported several challenges associated with bark casings, including insufficient water retention and a longer cultivation period. Overall, the results suggest that bark-based alternative casing materials have some potential; however, further research is required to improve material stability and reduce contamination risks before commercial application.[2] The dynamics of microbial populations and enzyme activity during the preparation of compost substrate for Agaricus bisporus mushrooms were investigated. The study provides a detailed analysis of microbial succession and enzyme activity across the wetting, thermophilic, pasteurization/conditioning, and spawn-run stages of composting. The findings emphasize the critical importance of microorganisms in determining compost quality and mushroom yield.[3] (Agaricus bisporus) was studied in the compost treated with corn straw. It was studied how the composting process affects microorganisms and how this, in turn, affects the quality of the compost and mushroom yield. In particular, the microorganisms that have the strongest effect on Agaricus bisporus were analyzed in depth.[4] The possibility of using composted grape waste mixed with peat as an alternative mulch material for mushroom production was investigated. The study compared this new material with mushrooms treated with traditional peat mulch in terms of yield, quality and biological efficiency. The results showed that the use of grape waste-based mulch material did not reduce yield compared to traditional peat, but increased the total number and size of mushrooms.[5] A mushroom compost quality assessment model was developed to predict the potential yield of Agaricus bisporus fruiting bodies. The model is based on the interaction of environmental factors during composting. The results showed that a partial least squares model including parameters such as pH, dry matter, ammonia, carbon, hydrogen, ash, Cu, Fe, and Na could accurately explain 90% of the variation in mushroom yield.[6]

In Uzbekistan, mushroom cultivation in basements is a sustainable way to address food security and land scarcity. Scientific studies show that basement conditions (e.g., due to stable temperature and humidity) are more favorable for mushroom cultivation. This reduces energy consumption and costs. When combined with a sharing economy, this practice can contribute to environmental sustainability and economic growth.[7] The aim is to sustainably grow Agaricus bisporus mycelium using agro-industrial wastes, namely corn cob and defatted soybean meal. This method was found to support mushroom growth and the combination of the two resulted in high biomass yields. UV irradiation of the grown mycelium also significantly increased the vitamin D2 content, while it was also found to be rich in protein, fat and essential minerals. This suggests that mycelium is a promising route for nutritional enrichment and contributes to food security through the recycling of agricultural waste.[8] The suitability of used mushroom substrate (compost) for mushroom cultivation was studied. Researchers used different ratios of peat and old substrate (peat + Old substrate (1/1), peat + Old substrate (1/2), peat + Old substrate (2/1) as mulching material. The results showed that the types of mulching material had a positive effect on stem length, hardness, and mushroom number. These findings indicate the potential for efficient waste utilization in mushroom cultivation.[9] Recent research in the cultivation of Agaricus bisporus has led to significant advances in genetics, substrate and technology. These advances are aimed at making production sustainable for humans, the economy and the environment. The focus is on high yields, biological control, energy efficiency and technological innovations, which serve to increase efficiency by reducing pesticide and energy consumption.[10] Compost bacteria and fungi (especially Mycothermus thermophilus) play an important role in mushroom cultivation. They are involved in composting, nutrient recycling, and mushroom production, but some can also cause diseases.[11]

Artificial intelligence to analyze data on environmental (temperature, humidity) and cultural factors in mushroom (champignon) cultivation and predict future yields.[12] Despite the discovery of new genetic material over the past two decades and the improved understanding of the genetic basis of important traits (e.g., disease resistance and yield), it is noted that few new commercial varieties of mushrooms have been developed. This is due to the unique life cycle of the mushroom and the complexity of selection.[13] More than 100 countries cultivate Agaricus bisporus, and the amount of mushrooms produced is growing by up to 7% annually. Mushroom cultivation is mainly carried out in several developed countries in Europe and America, where mechanization and automation are used.[14] China, the Netherlands, Poland, Spain, France, Italy, Ireland, Canada, and the United Kingdom produce about 40 million tons of mushrooms in 2019. The mushroom market is expected to expand at a compound annual growth rate of 6.74%, from 15.25 million tons in 2021 to 24.05 million tons in 2028.[15] The global mushroom market, divided into many edible species such as Agaricus bisporus, Pleurotus ostreatus, Lentinula edodes, and others, has been growing steadily over the past few years [16] Agaricus bisporus is a species of mushroom that is widely consumed by people around the world due to its health benefits. Literature suggests that growing champignons is cost-effective, as they are an indoor crop that does not require a lot of space or expensive infrastructure.[17]The recent stagnation of biotechnology in mushroom cultivation as a global mainstream and the potential economic and environmental benefits of sustainable support are still not widely recognized. Many technological developments have been made in the production of tuberous seeds and in rapid composting methods for Agaricus bisporus.[18] Based on FAOSTAT 2022 data, from 1990 to 2020, world mushroom production increased 13.8 times, reaching 42.8 million tons. [19]

Traditional mushroom cultivation is dependent on natural conditions and local resources, and unlike modern commercial methods that often use the environment and various substrates, mushroom cultivation often uses agricultural wastes such as wheat straw, rice straw, and sawdust. These materials serve as substrates for mushroom growth, providing an environmentally and economically efficient method of production. [20]

The era of modern technologies in mushroom production

Smart mushroom farming uses artificial intelligence, cognitive technologies, and the Internet of Things (IoT) to support digital entrepreneurship and improve farming. [21] Sustainable agriculture is challenging due to climate change, population growth, and limited arable land. There is an urgent need to develop modified crops that are more productive, of higher quality, and resilient to various biological and environmental challenges. Mushroom growers rely on many workers to hand-pick their produce. Recruiting and retaining workers is difficult due to the long hours and demanding workload. Figure 1 shows a modern mushroom laboratory; however, vertical farming can be implemented where land is a major constraint. Compared to the traditional huts in which mushrooms were previously grown, modern automation has been installed to provide the necessary environment for mushroom growth in all seasons.

Figure 1 illustrates the cultivation of Agaricus bisporus using the traditional vertical method.

For these advanced farms to be sustainable, producers must maximize profits; this is driving mushroom producers to integrate automation and artificial intelligence. [22] Agricultural automation has many benefits, including real-time monitoring, reduced labor, higher accuracy, resource optimization, and higher crop quality [23]

Application of green algae in A. bisporus

The effect of blue-green algae (cyanobacteria), in particular Anabaena vaginicola , (Agaricus bisporus) on the cultivation was studied. In the study, the algae culture was sprayed on the covering soil at the stage of primordia formation of the fungi and before the first, second, and third sets. The results showed that the use of cyanobacteria as a biofertilizer significantly increases the yield and quality of the fungus. In particular, the content of dry matter and protein increased significantly in the first set. The presence of phytohormones such as Indole 3-acetic acid (IAA) and Indole 3-butyric acid (IBA) was detected in the algal bioculture by HPLC. At the same time, the nitrogenase activity of the algae was also measured. The article proposes the production of stimulating substances such as phytohormones and the chemical composition of the algal extract as the main factors affecting the growth and quality of the fungi.[24] Different doses of Cladophora glomerata (Cld) and Arthrospira platensis (Spr) algae were used in Agaricus bisporus (white button mushroom) cultivation in a private enterprise in Korkuteli district of Antalya province between 28.04.2021 and 10.07.2021. The study analyzed the effects of algae on mushroom yield, average weight and dimensional characteristics. According to the general observation, the groups treated with algae showed better results compared to the control group. In particular, the Cld 250 dose increased the yield by 7% and the Spr 250 dose increased the yield by 15%. The study recommends algae as an effective supplement for increasing yield in mushroom cultivation.[25] Several scientists have applied blue-green algae to increase mushroom yield (Riahi, H., Shariatmadari and

TURUNÇOĞLU, M. (2023). These algae cause a few percent increase in yield. The increase in yield and quality of Agaricus bisporus (champignon) mushroom was studied when the cyanobacterium Anabaena vaginicola was used. Cyanobacteria were sprayed on the spore layer at the primordia stage. According to the conclusions, the yield and protein content increased significantly, and auxin and nitrogen fixation activity were also detected in cyanobacteria. Treatment with cyanobacteria can be effective as a biostimulant and biofertilizer in mushroom cultivation. This method is considered environmentally and economically promising.[26]

METHODS

Agaricus bisporus (champignon) cultivation uses compost and substrate as the main medium, and various materials are used. Materials used in compost preparation: Straw (wheat,) Rich in organic matter, provides strength. Supports microbiological activity.

Figure 2. A- Compost treated with Chlorella vulgaris B - Compost treated with plain water

Chicken manure. Source of nitrogen. Saturates compost and enhances mushroom growth.

Horse manure. This is also a source of nitrogen. Rich in organic matter, Has a warming effect and is considered the best organic fertilizer for compost.

Cattle manure. Rich in organic matter, Contains natural trace elements, Widely available in the soil, gypsum ($CaSO_4$) Stabilizes the pH of the compost. Improves the physical properties of the compost.

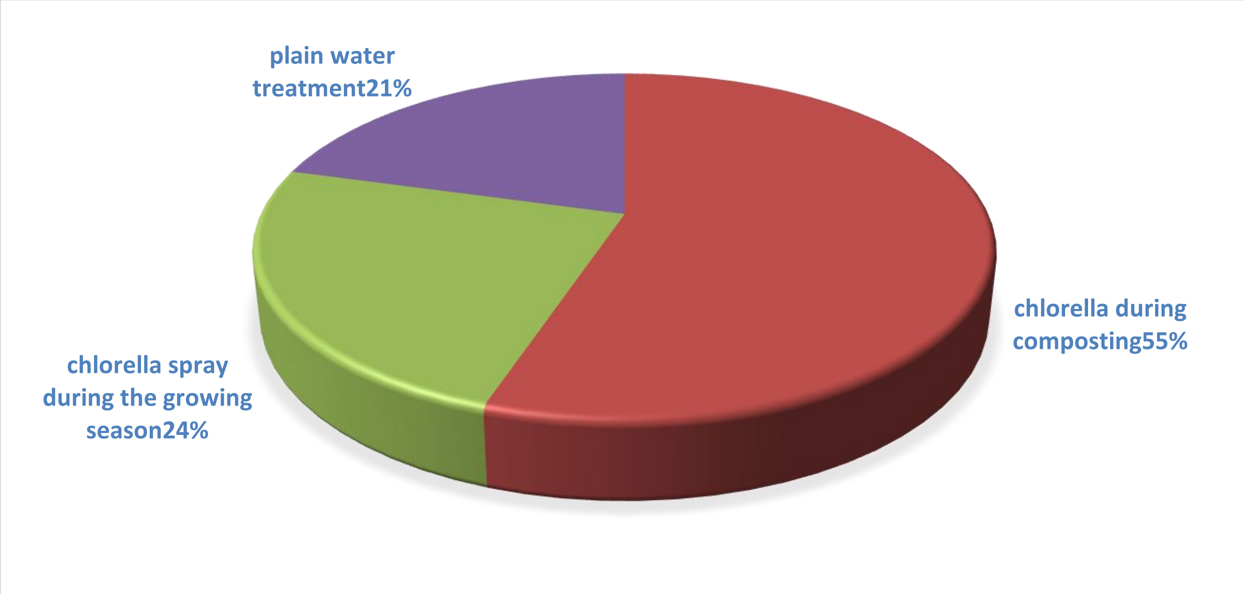
Water. Necessary to maintain the percentage of moisture. Activates microbiological processes. Air circulation (ventilation). Necessary for aerobic microorganisms in the compost. Prevents rotting of the compost

Materials used in cover soil: The peat retains moisture for a long time. It creates a favorable environment for the development of mushroom fruit bodies. Limestone (dolomite) regulates pH. Improves air circulation, retains water.

Innovative additions: Microalgae and cyanobacteria (e.g. Chlorella, Anabaena) are used as biostimulants and biofertilizers. They produce phytohormones (auxins). They increase yield and quality.

Research location and conditions

The experiment was conducted in the mycology laboratory at the Faculty of Natural Sciences and Agrobiotechnology of Bukhara State University. This laboratory was carried out in the months (February-May 2025). The experiment was carried out on 3 types of composts: Experiment 1: compost treated with horse manure. Experiment 2: compost prepared with chicken manure. Experiment 3: compost prepared with cattle manure and each of them was treated with a suspension of chlorella algae. In this case, mushrooms were grown on 1 m² of compost for each experiment and for the control. Chlorella was added to the compost and sprayed onto the substrate during the watering phase.



In this diagram, the highest productivity corresponds to the use of algae during the composting period.

Materials used

Mushroom Type: Agaricus bisporus (Sylvan A15 or Amitsel strain).

Compost composition: wheat straw, chicken manure, horse manure, cattle manure, peat, water (fermented) and as an additional compound green algae (microalgae) Chlorella vulgaris - grown in a photobioreactor. Forms of microalgae treatment Liquid spraying (1:0.5 water-algae suspension, i.e. 100 l of water: 50 l of chlorella suspension) during the growth phase, irrigation.

Measurements (parameters) The following indicators were evaluated during the study:

Yield (kg/m²),

Average mushroom weight,

Cap diameter and stem length

Dry matter (%)

Protein content (by Kjeldahl method)

Soil N, P, K, pH and moisture

Phytohormones in microalgal content (IAA, IBA – by HPLC)

RESULTS

During this study, significant differences were observed between the groups treated with green algae and the control group. The following results were recorded in the control and experimentally grown champignons: The first harvest period was shortened, i.e., 38-40 days in the control mushrooms and 32-34 days in the experimental ones. There were a number of changes in the chemical composition, in particular, the amount of protein increased. In the control, the percentage of protein (dry matter) was 28-30%, but in the experiment, this indicator was slightly higher, namely 34-36%. The yield in the group treated with a dose of 56 g of Chlorella increased by 15%. The average yield in the control group was 12-14 kg/m², and in the group treated with algae it was 16-18 kg/m². Mushroom quality parameters: Cap diameter: 4.9–5.5 cm (4.6 cm in the control), Stem length: 3.3–3.7 cm (2.8 cm in the control), Average weight: +10–14% heavier in the group treated with algae, : Dry matter: 9.7–10.4% in the group treated with Chlorella, 8.2% in the control Statistical difference ($P < 0.05$) Statistically significant differences were noted in terms of yield, weight, protein and dry matter by the types and doses of algae used. In conclusion, the results of the study showed that treatment with the green algae Chlorella significantly increased the yield and quality indicators in the cultivation of Agaricus bisporus (mushroom). It was studied in the conditions of the Bukhara region. .This is one of the modern methods of champignon production in the dry climate of Uzbekistan. As a result of experiments conducted in laboratory and field conditions, the yield in the group treated with Chlorella vulgaris suspension, in particular, in which a dose of 56 g of Chlorella was applied, increased by 15% compared to the control group, which was reflected in an increase in yield from an average of 13 kg per square meter to 15-16 kg.

DISCUSSION

The study demonstrated that the biostimulatory power of microalgae significantly affected the compost of "Agaricus bisporus" (champignon), increasing its yield and quality.

1. Analysis of the results obtained

High Yield Growth: According to experiments, the highest yield was observed when treated with a 0.05%

concentration of Chlorella vulgaris, i.e. an increase of up to 15% compared to the control group. This high yield results in growth, and these processes are explained by the ability to produce indole-acetic acid (IAA) and other phytohormones. These biostimulants led to the rapid and efficient penetration of mycelium into the compost during mushroom production, resulting in the production of more additional bodies. The size of the champignons was also significantly larger in the experiment than in the control. Increased protein: This may be due to the compost absorbing nitrogen compounds and other micronutrients contained in Chlorella vulgaris, which are added to the additives, and the microalgae itself serving as an additional source of energy.

CONCLUSION

From this experience, it can be concluded that the Republic of Uzbekistan has achieved high yields through the use of microalgae "Chlorella vulgaris" in the cultivation of mushrooms, especially in the Bukhara region (Agaricus bisporus).

The most optimal result was obtained by adding a 0.05% concentration of the Chlorella vulgaris biostimulant to the compost, this additive increased the yield by 15% compared to the control and had a positive effect on the cultivated product in all respects (up to the protein content), and it was found that it is possible to grow mushrooms in a shorter period of time. Due to the high yield achieved through the use of algae, it serves as a new innovative direction for providing the population with mushroom products. The innovative strategy serves as a strong basis for creating momentum to achieve additional productivity by combining future computer technologies and microbiological methods.

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