J.Mycopathol.Res. 62(2) : 261-273, 2024, ISSN : 0971-3719 (Print), 2583-6315 (Online) 10.57023/JMycR.62.2.2024.261

REVIEW

Production technology and reality based challenges in button mushroom production in Odisha

SOUPTIK KARMAKAR [1&2] AND SIDDHARTHA DAS [1*]

[1]Department of Plant Pathology, M S Swaminathan school of Agriculture, Centurion University of Technology and Management, Paralakhemundi, Odisha 761211

[2]Department of Seed Science & Technology, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha 51003

Received : 16.02.2024 Accepted : 21.04.2024 Published : 24.06.2024

Mushrooms are generally recognised for their high protein content, low fat and of great economic value. Nowadays, when human being is concerned about cholesterol and health issues mushroom plays a very important role. Several kinds of edible mushrooms are available in our country, but Oyster mushroom, Milky mushroom, Button mushroom and Paddy Straw mushroom are the most preferable species. The majority (80%) of the market is dominated by button mushrooms, with the remaining 20% going to tropical mushrooms like oyster, paddy straw, and milky mushrooms. Within these four species the highest demand is confined to Button mushroom (*Agaricus bisporus*) and it can be cultivated widely as people like it most. Even though the rate of mushroom production has increased, there are still some issues that mushroom farmers must address in order to advance the industry. These issues include a lack of production houses, a shortage of spawn of high quality, a lack of funding, a lack of equipment, a lack of market facilities, a lack of storage facilities, among others. The potential to increase mushroom output across our country is huge. Development in this sector can boost the rural economy, diversify the economy, and create more job possibilities, taking into account the state of the nation's economy. The main aim of the article is to put together all the major issues related to Button mushroom cultivation in Odisha and its major challenges.

Keywords: Button mushroom, *Agaricus bisporus*, challenges, production, demand, rural economy

INTRODUCTION

Our economy's main source of strength is agriculture. Nowadays, a large number of agricultural crops are cultivated by which our country has got the ability to achieve a food security. It is possible only by producing around 230 to 250 million tonnes of consumable grains. Though, the fight for achieving the food security has been achieved but for achieving nutritional security the war is going on.

Henceforward, the major issues will be increasing population, climate changing, lack of agricultural land, unavailability of water and the need for quality foods. Mushroom growing is able to address these concerns because they can ensure food and nutritional security. Mushroom can be considered as a food which can fulfil the requirement of quality food and it can also fulfil the nutritional requirements. To fulfil evolving human needs, it is necessary to promote both mushroom production and consumption. Today, mushroom marketing is very significant since more and more people are turning to vegetarian diet for healthy living and mushrooms offer a protein rich diet (Padhi *et al*. 2015; Bhushan *et al*. 2018; Grimm *et al*. 2018). Production technology of consumable mushrooms involves a biotechnological approach which converts different agricultural wastes into good quality proteins. Mushroom farming provides a great opportunity by reusing the waste products and generates an opportunity to use the wastes which are useless products of fields. The cultivation of

*Correspondence: siddhartha.das10@gmail.com

mushrooms is a low-cost and eco-friendly approach, in which the farm wastes can be utilized as a raw material. As a labor-intensive job, it can also create employment. Mushroom cultivation is very much beneficial for the youth as of today because unemployment is increasing at an increasing rate beside that it also helps in generating income to the rural women and to the backward classes of our country (Munsi *et al.* 2010). Enormous nutritional and medicinal values of mushrooms have been reviewed (Barman *et. al*., 2018, Thakur and Singh, 2020)

The cultivation of mushrooms is now growing more and more popular, and it is being done in more than a hundred nations. Production is also rising day by day at a pace of 5-6 % annually. According to the FAO, there are currently over 3.6 million tonnes of mushrooms produced worldwide. China is one of those country who is cultivating more than 20 various types of mushrooms. Nowadays mushroom cultivation is the 6th largest industry of China. In India, mushroom production has raised from 5000 tonnes as of 1990 to 1,20,000 tonnes as of 2013. As of today, the most popular cultivated species are button and oyster mushroom comply with milky and paddy straw mushroom. Nevertheless, nearly 75% of all mushrooms produced in our nation are button mushrooms (Padhi *et al*. 2015).

The Department of Plant Pathology, College of Agriculture, OUAT, Bhubaneswar, started doing research on edible mushrooms in Odisha since 1972 with the primary goal of developing sustainable production methods for mushroom farming. After fulfilling their objective, the research team became more interested in producing high-quality spawn, and a new objective was later established by opening the "Centre of Tropical Mushroom Research and Training" in OUAT with financing from the government in 1991–1992. The creation of high-quality spawns, particularly paddy straw mushrooms, oyster mushrooms, milky mushrooms, and button mushrooms, has been the subject of extensive research. A technical assistance team was provided for establishing spawn production units and mushroom production farms. Different training programmes were arranged for the farmers for enhancing their knowledge regarding mushroom farming and also demonstrations were arranged regarding production of good quality spawn. As of today, the total mushroom production of Odisha is about 12,334 tonnes per annum which is 10% of the country's production (Padhi, 2015; Chang, 2005).

Throughout the world, mushrooms have been a staple diet in a variety of cultures. Mushrooms have many different qualities, but they also have some therapeutic and pharmacological value in addition to helping to meet the demand for high-quality foods. Mushrooms are referred to as "vegetable meat" since they can act as a protein supplement for health. Besides that, the carbohydrate and fat contents of our consumable mushrooms are generally very less. So, they can be consumed as a low-caloric diet which is very much beneficial to diabetic patients. Also, mushrooms can be considered as an ideal food for the patients who are having diabetes as it lacks in starch content. For the persons who are thinking of reducing fat for them also mushrooms can be a better option. Additionally, mushrooms include polysaccharides, which have anti-tumor and other immunological effects. Like most vegetables, mushrooms also contain vitamins. When compared to fruits and vegetables, mushrooms have a larger concentration of minerals. Since ancient times, people have been using mushroom for variety of purposes. Edible mushrooms are renowned for their delicacy and play a key role in the cuisine of many different cultures (Muhammad *et al*. 2021; Shah *et al*. 2013; Wasser and Aavia, 2008). This mushroom's significance in the cosmetics sector is also proven in a number of studies. Its ingredients improve facial characteristics by managing a range of skin issues (Shbeeb *et al.* 2019; XuJie *et al.* 2008; Chang and Wasser, 2012).

Mushrooms are being studied as an environmental cleansing technique that can be utilised to trap heavy metals released into natural water bodies as industrial effluents in addition to their nutritional value (Nilanjana, 2005). Heavy metals from the substrate can be biosorbed by mushrooms through the roomy mycelium. Numerous bacteria and plant materials have also been identified to exhibit this behaviour (Nilanjana *et al.* 2008; Innocent *et al*. 2009). The result of

physical-chemical interactions between metal ions and species-specific biological molecules, which primarily contain chemical groups like carboxyl, carbonyl, amino, amide, sulphonate, phosphate, and hydroxyl, is biosorption.

The developed countries like USA, Japan and China are preparing a large number of medicines from mushrooms which is generating a higher amount of revenue. This is another aspect of the beneficial use of mushrooms which is expected to gain more popularity in the coming days; hence mushrooms production as food and medicine should co-exist other and not compete with each other (Munsi *et al*. 2010).

As of now there are 2000 species which are edible but, there are only 80 species which can be experimentally cultivated. There are around 20 species which can be commercially cultivated but only 5 species are there which can be produced at a large scale and 20 economically viable species are there. Between the mushrooms which are commercially grown button mushroom is mostly cultivated. The white button, or *Agaricus bisporus*, is the species that is typically farmed in most mushroom farms. It is a member of the family Agaricaceae and the class Basidiomycetes. The production of button mushrooms was once limited to the winter months, but thanks to ongoing technological advancements; it is now possible to do so year-round in our nation (Munsi *et al*. 2010). The first button mushroom cultivation was documented in France in the 18th century, and at the end of the 19th century, mushrooms were produced extensively in France. Effect of different compost formulations and casing materials on Button mushroom production have been evaluated by Barman *et al*, (2017).

As the button mushroom is being the common variety among all, it can achieve a higher purchasing rate. It contributes about 90% of the nation's total production, compared to its global contribution of about 40%. The Indian subcontinent is renowned for its diverse agro-climatic zones and a variety of habitats that support a high biodiversity of mushrooms. The beginning of the commercial production took place in mountainous regions of India with temperatures between 17 and 18^0C, such as Chail in Himachal Pradesh, Kashmir, and Ooty in Tamil Nadu. Himachal Pradesh, Punjab, Haryana, Uttar Pradesh, Maharashtra, Tamil Nadu, Karnataka, and Andhra Pradesh are the main states that produce mushrooms.The sum total of white button mushroom producing in our country is around 94676 metric tons. Punjab and Haryana is producing about 8600 metric tons of button mushroom which is around 10 % of our total production. (Sharma *et al.* 2017; Singh *et al.* 2021).

Agro-climatic requirements

In our nation, white button mushrooms are grown in shade-nets where the environment can be managed, and they are typically grown in the winter. White button mushroom requires about 20 to 28 ^{0}C during the initial stages and 12 to 18 ^{0}C during their maturity. Furthermore, the cultivation of button mushrooms also needs 80 to 90% of relative humidity and also, we have to maintain proper ventilation through their growing period.

The most suitable time for growing button mushroom is throughout the winter season and the best place where it can be grown is the northern hills of our country. Anyhow, the advancement of the technologies has brought the opportunity to cultivate mushroom throughout the year in any region.

Production technology of button mushroom

The production procedure of button mushroom involves the succeed steps:

I. Preparation of spawn
II. Preparation of the compost
III. Spawning
IV. Spawn running
V. Casing
VI. Fruiting

Preparation of spawn

The spawn i.e. the seed of mushroom is being produced from tissues of identified strains of mushrooms or directly from the culture which is giving vigorous fruiting under sterile conditions.

The pure culture which is very essential for the spawn production can be produced under laboratory conditions. In general, for producing spawns the best quality fruiting culture is identified at first and then it is brought from various places within the country or from other countries for getting maximum yields. A good quality spawn must consist of characteristics like good flavour, good texture and it should give higher yield as comparing to the locally available strains.

Isolation of the fungus

There are three different methods by which the mushroom mycelium can be isolated.

Spore method

The spore method is commonly used for mushroom spore collection. This process is also known as spore printing. The cap of a healthy, disease-free mushroom is removed using this technique, and the surface is then cleaned with a cotton swab dipped in alcohol. Then, the cap is placed on a clean, sterilised sheet of paper, a clean glass plate, or the surface of the clean glass slides. It is important to completely disinfect the surface of the working area. Place a glass jar, a clean glass, or a cup on the cap surface to stop airflow. Within 24 to 48 hrs, spores will fall on the white paper or slide surface exactly like the radial symmetry of the gills. By cutting and folding the paper, the spore print can be kept on it for a longer period of time (Mane and Sindhe, 2019).

Tissue Culture

Before inoculating aseptically on a Petri plate or tube with adequate culture medium, a tiny portion of the pileal region is cut with the aid of a sterilised blade or scalpel, washed several times in sterilised distilled water, and dried in a clean tissue paper. The inoculated Petri plates are incubated at 25±1^{0}C for 6-12 days, and the mycelial growth is monitored at various intervals. After ensuring that the culture is pure and true to type (Fig 1A), only the Petri plates or glass tubes with pure growth should be kept for further use. All other Petri plates or glass tubes should be discarded (Mane and Sindhe, 2019).

Sub-culturing

In terms of the cleansing of germs, it is a crucial stage. Once formed using either the tissue culture technique or spore culture, the pure culture of edible mushrooms is carefully kept in a cool environment or a refrigerator. Sub-culturing is finished every now and then by aseptically transferring a little portion of an ascending pure culture together with the culture medium into test tube slants containing the same or another suitable medium. These rapidly grown pure culture can be used to create master cultures for manufacturing marketable seeds on a wide scale (Mane and Sindhe, 2019).

Mother spawn & commercial spawn preparation

Laminar air flow and sterile conditions are used during mother culture preparation. Appropriate substratum (wheat, sorghum, or rye) that provides sustenance to the mycelium is injected with pure cultures of mushrooms taken from stored cultures. 15 l of water and 10 kg of wheat are cooked together for 20 mins. After the water has been removed, the grains are dried for 6–8 hours in an oven or on a wire mesh pan. Currently, grains are combined with gypsum (calcium sulphate) and chalk powder (calcium carbonate) at a dry weight basis ratio of 2-3% and 0.5-1%, respectively. 200 g of gypsum and 50 g of chalk powder are required for 10 kg of dry wheat grains. By doing so, it stop grains from clinging to one another but the pH of the medium needs to be checked. The grains are placed into bottles, which are then sterilised in autoclave for about 2 to 3 hrs after plugging it with non-absorbent cotton plugs. After that the sterilised bottles are allowed to cool. The mycelium of pure culture-colonized agar medium is added to bottles on the very next day as an inoculant. Bottles with inoculation are incubated at 24-26°C. Bottles are shaken erratically after a week of inoculation so that mycelial threads are broken and thoroughly mixed with the grains. After about 14 days of inoculation, the bottles are prepared as stock cultures for continuing the spawn multiplication. 40-50 grain bottles can be multiplied by one bottle of mother spawn (Mane and Sindhe, 2019) (Fig. 1B).

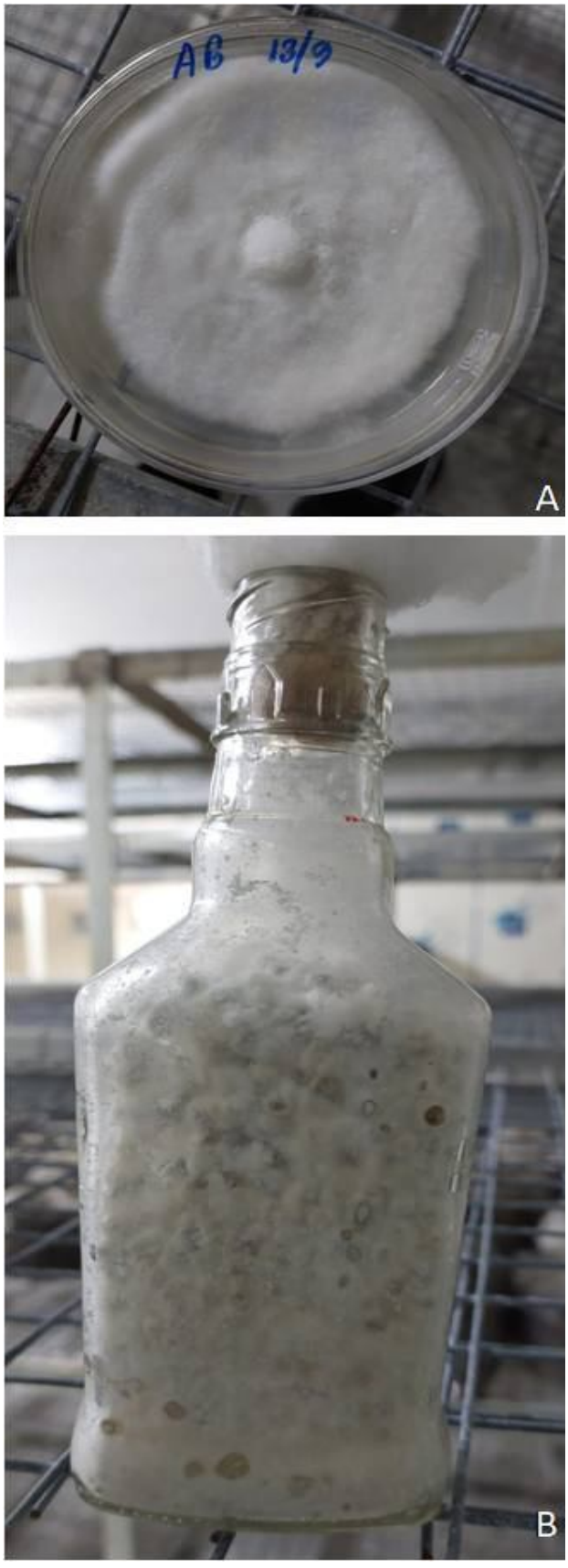

Fig 1. (A) Pure culture and (B) Mother spawn of *Agaricus bisporus*

Qualities of an Effective Spawn

(i) The mycelium around each grain used as spawn substrate needs to be properly coated.
(ii) The mycelium growth in the spawn bottles should be strand-like rather than cottony or fluffy.
(iii) New spawn generally has a whiter growth, but as the spawn matures, it turns brown.
(iv) The spawn bottles shouldn't have any slimy growth, which is a sign of bacterial contamination.
(v) The spawn bottles shouldn't include any green or black spots. Such patches are a sign that the spawn is mould-contaminated.

Richification of mother culture

To produce commercial spawn, a large number of other grain bags or bottles manufactured using the same procedure are inoculated with master spawn or master culture bottles.

Typically, a small amount of mycelial coated grains from one master culture bottle or bag will be aseptically inoculated into a number of grain bags in front of the HEPA (High Efficiency Particulate Air) filters of a Laminar air flow, and then the grains will be incubated for about two weeks in a room at 24-26°C temperature. The prepared commercial spawn is utilised as seed to inoculate the compost beds (Mane and Sindhe, 2019).

Preparation of the compost

The compost which is a very essential component of button mushroom is a decomposed component. The composting process involves microbial degradation of different wastes of plant origin. The compost in which button mushrooms are being grown is generally prepared with various plant wastes like; sugarcane bagasse, wheat straws and rice bran. Different kind of salts like gypsum, MOP, superphosphate and urea is required for the compost preparation.

About 220 g of raw materials are required for producing 1 kg of button mushroom. For making each ton of compost it must be provided 2.0 kg of phosphate, 6.6 kg of nitrogen and 5.0 kg of potassium after that it is being converted

into1.98% N, 0.62% P and 1.5% K. In a good substrate the C:N ratio should be 25-30:1 during staking and 16-17:1 during the final stage (Fig. 2A).

The composting of button mushroom is generally carried out by two methods: (a) The long method of composting takes around 35 to 40 days and (b) the short method of composting takes around 22 to 26 days.

Short method of composting

For the composting process it requires a floor which must be cleaned properly and it must be cemented, under a shade or in open condition. In case of open condition, the heap must be covered for avoiding rain water. The room where composting has to be done must be well ventilated.

On the very beginning stage of composting, the paddy straw needs to be cut into pieces of 20 to 30 cm size. After that the paddy straw needs to be arranged in a layer after layer manner and then water is applied. Later on, fertilizers, molasses and wheat brans are added with it. After that it should be mixed properly and then form a stack (it should be 5 feet in height and 5 feet in width) and it should be piled up using a wooden mould. On the second day, the stack is flipped and watered once more.The turning has to be given in such a manner that every portion of the compost must come in the centre where faster decomposition occurs and compost is subjected to maximum heating which is necessary for avoiding any kind of pests and diseases.The 2nd turning of the compost should be done on the 4th day of composting and gypsum should be applied on the same day only. After that it has to be moisturized again. On the 12th day, the 3rd turning need to be given and we have to make sure that the colour of the compost should be dark brown (Table 1). On that stage there must be a very strong smell of ammonia.

In the later stage, pasteurization is carried on. The compost which was prepared by the microbial fermentation procedure must be pasteurized for ensuring that there is no foreign microbe which can spoil the compost. The other aim of the pasteurization process is to convert the ammonia into protein. This process should be done in a steaming chamber or in a pasteurization chamber, in which the temperature can be set around 60°C for around 4 hrs. After the composting process is over, the final compost should be in granular form and it should contain at least 70 % of moisture and the pH should be around 7.5. The final compost must be dark brown in colour, have a pleasant, unobtrusive smell, be free of ammonia, and be devoid of all insects and nematodes. Final compost temperature should drop down again at 25°C (Rohini and Rathod, 2021).

Long method of composting

In the areas where the facilities of pasteurization is unavailable there long method of composting is generally carried on in the long method, the compost is turned for the first time after 6th day of composting. For the 2nd time the turning is given after 10 days of the composting and then gypsum is applied on the same day (Fig. 2B). Respectively the 4th, 5thand 6th turnings are given on the 17th, 20th and 23ndday. On the 26thday, the compost is being turned for the 7th time and simultaneously 10% Benzene hexachloride is applied in the compost (approximately 125 g) and on the 28thday of composting the 8th turning is given after ensuring that there is no further smell of ammonia. It should be given a number of turnings more if any smell of ammonia is there (Table.2).

Table 1: Turning duration and interval

Day 2	1st turning
Day 4	2nd turning and addition of Gypsum
Day 12	3rdand the final turning

Table 2: Consecutive turning procedure

Day 6	1st turning
Day 10	2nd turning
Day 17	4th turning
Day 20	5th turning
Day 23	6th turning
Day 26	7th turning
Day 28	8th turning and addition of Benzene hexachloride

Spawning

After the composting process, the compost is ready for the spawning with mushroom mycelium. After the composting the next step is applying spawn in the compost and it is known as spawning. In general, the rate of applying compost is 0.5% as per the weight and then we have to mix it properly.

Methods which are generally continued for the spawning are discussed further:

(I) Spot spawning: The spawn is often placed on 5 cm deep holes dug in the compost with a space of about 20–25 cm in this type of spawning technique. The holes are again sealed with compost once the spawning process is completed.

(II) Surface spawning: In this type of spawning method, spawn is sprinkled over the outermost layer of the compost in the outermost compost and then mix it properly.

(III) Layer spawning: In this style of spawning, the spawn is applied to the compost in 3–4 layers. The spawning of the top layer has also been done. The mixing rate of spawn with the compost is 500 to 750 g per 100 kg of the substrate.

Spawn running

After spawning, the prepared compost is placed in PP bags, trays, or shelves as part of the spawn running process.They should be covered by a newspaper or via PP sheet. The mycelium will grow from the inoculated spawn and it will take about 2 weeks to form a colony.

For the spawn running around 23 ± 2°C must be maintained in the room. Higher temperatures are bad for the spawn's growth, while any temperature below those required for the purpose will hinder the spawn run. A greater than normal CO_2 content would be advantageous for the spawn running, and the relative humidity should be approximately 90%.

Casing

After the spawn run is complete, the compost beds should have a soil (i.e. casing) layer applied to them in order to encourage fruiting.The casing soil must be highly porous, capable of retaining water, and have a pH between 7 and 7.5. Peat moss, which is regarded as the best casing material, is not readily accessible in India; instead, mixes such as garden loam soil and sand (4:1), decomposed cow dung and loam soil (1:1), wasted compost (2–3 years old), sand and lime are more frequently applied (Fig. 2C).

The casing soil needs to be either steam sterilised, formaldehyde and Bavistin treated, or pasteurised (at around 66–70°C for 7-8 hrs) before application. Before applying it as a casing material, the treatment should be completed at least 15 days in advance. After completion of casing, the room is once more kept at a temperature of 23 to 28°C and a relative humidity of around 85 to 90% for eight to ten days. For their reproductive growth, low CO_2 concentration is beneficial. Case run of mycelia was observed after 10-12 days of the post application stages (Fig. 2D).

Fruiting

The fruiting body initials, which firstly appear in the form of pin heads and begin growing, gradually develop into button stage under favourable conditions (Fig. 7 A & B). The suitable temperature range is 23 ± 2°C for about 7 days and then 16 ± 2, moisture (1-2 gentle sprays each day), humidity (more than 85%), proper ventilation and CO2 concentration (0.08-0.15%)(Fig 2 E & F).

Harvesting and yield

In most cases, harvesting is done during the button stage. For harvesting, caps with a diameter of 2.5 to 4 cm are excellent. Three weeks after casing, the first produce starts to appear. Light twisting is necessary to collect mushrooms without damaging the substance that surrounds them. Following harvesting, the beds' openings should be filled with new, sterilised casing material, and it has to be watered once more. Within two months, one can acquire 10–14 kg of fresh mushrooms for every 100 kg of fresh compost. In general, the short method of compost preparation under favourable conditions produces a higher output (15-20 kg per 100 kg of compost).

Processing

Drying of mushrooms under sun is the most crucial phase after harvest and is one of the oldest and easiest techniques that mushroom producers typically use. Modern preservation techniques including cabinet drying, canning, pickling, freeze-drying, and irradiation treatment are being developed as a result of the challenges associated with drying specific types of mushrooms. The button mushroom can be used to make a variety of items. These include mushroom candy, mushroom soup, and mushroom powder (Munsi *et al*. 2010).

Marketing

Numerous variables like as labour costs, raw material prices, site circumstances, marketing opportunities, etc. affect cultivation costs significantly from one location to another. Fresh, canned, or freeze-dried mushrooms are the three main forms in which they are offered. Fresh mushrooms are sold at the market in low density plastic bags. They hardly last for more than two days. Although canned and freeze-dried mushrooms can last even a year, the latter method is highly expensive.

Fig. 2. Cultivation process of button mushroom (A) compost mix, (B) addition of gypsum in the compost (C) preparation of casing soil, (D) case run, (E&F) fruit bodies of *Agaricus bisporus* on the cultivated beds

Problems in Mushroom Cultivation in Odisha
Diseases of Mushroom

When button mushrooms are produced, different kinds of harmful fungi are found in the composting process as well as in the casing material. While some of them influence the spawn run and operate as rival moulds, others typically attack the fruiting bodies at different stages of development. Depending on the stages and severity of the infection, the quality of the compost, and the immediate environmental conditions, these types of moulds entirely destroy the fruiting bodies.

These parasite moulds may develop if the compost pasteurisation (PHASE-II) and casing processes are not carried out correctly. It can also happen if the mushroom growers are inexperienced or unskilled, which can lead to a condition where various parasitic moulds, weed fungus, and deformities may arise (Munsi *et al*. 2010).

The most common diseases and abnormalities of button mushroom are as follows:

Weed fungi or competitors
***Green mould* (*Trichoderma viride*):**

This type of mould appears as thick cushiony white patches with greenish fungal growth on spawned and cased bags which later gradually changes to bluish green in colour. The spawn-run is significantly impacted if the fungus attacks the spawned trays. Green mould also visible on spawns (Fig. 3A). The pin-head growth of mushrooms is typically delayed if this type of fungus develops on the casing soil.The green mould fungus is a vigorous colonizer of organic material and the dead mushroom tissue. High relative humidity and improper pasteurisation during composting are further factors contributing to the spread of this illness. This fungus' spores can also be dispersed by water and the air (Chang and Miles, 2004; Munsi *et al*. 2010).

***False truffle disease* (*Pseudobalsamia microspora or Diehliomyces microspora*)**

This type of disease appears more during summer. This fungus's fruiting body has a

spherical, cream-colored, wrinkled and convoluted surface that resembles a brain-like structure in mushroom growth beds. The mushroom growing in the outermost layer of the casing soil looks fused. When these bodies are fully developed, their colour turns to a reddish brown, and they release spores. The primary causes of this condition are a lack of ventilation and high relative humidity. The two important control measures are to minimize the temperature fluctuations and to provide adequate ventilation. The temperature during the spawn-run should not exceed 22°C. High relative humidity in mushroom shade-nets must be avoided to overcome this disease (Chang and Miles, 2004; Munsi *et al*. 2010).

***Brown plaster mould* (*Populaspora byssina*)**

On the top of the casing material, this disease manifests as huge, round white mould patches. These patches on the later stages turn brown and form powdery granules which can be easily recognized under a lens. This fungus can also colonize the compost. The appearance of fungus is associated with the wet composting. For controlling of this disease we have to prepare the compost in proper manner. Also, we need to maintain proper watering and suitable temperature during the spawn-run and cropping period (Chang and Miles, 2004; Munsi, *et al*. 2010).

***Inky caps* (*Coprinus* spp.)**

The fungi appears with long slender stalks and thin cap either on the heap of compost or in the compost bags before casing (Fig. 3B). This fungus develops very fast and then decays in a black coloured liquid. The mycelium of this fungus is grey in colour and it cannot be distinguishable from the mushroom mycelium. Inky cap appearance is as an indication of under-composting and presence of excessive ammonia in the compost. The fungi can deplete the food material from the compost and affects the spawn-run as well as the yield (Munsi *et al*. 2010)

***Cinnamon mould* (*Peziza* spp.)**

The presence of Cinnamon mould is attributed to the use of peat in the casing material. This

Fig.3 : (A) Green mould, (B) Inky cap on button mushroom bag

mould generally appears as small dark brown, gelatinous cup-shaped circular structures (i.e.apothecia) which are about 1 cm long. In most of the cases few solitary fruiting bodies are produced but in some cases un-restricted growth of fungus may appear as circular colonies which are initially greyish white but soon turn to brown in colour (Chang and Miles, 2004; Munsi *et al*. 2010).

***Parasitic moulds* (*parasitic diseases*)**

***Wet bubble disease* (*Mycogone perniciosa*)**

In this disease mushrooms are generally attacked at the base of the stalk and disease may cause brown discoloration and then decay. Wet bubble disease can be characterized by the development of white felt like mycelial growth on fruiting bodies. It spreads rapidly and affect the entire cap. The sporophores of this disease are eventually reduced to a white, soft and mass, which emits foul smell. The growth of deformed masses of mushroom tissues, which start out white and fluffy but later turn brown and decompose, is another symptom of the disease. When mature, these twisted masses, also known as “Sclerodamoid masses,” can grow to a length of up to 10 cm (Munsi, *et al*. 2010)

***Dry bubble disease* (*Verticillium fungicola, V. malthousei, V. psalliotae*)**

The symptoms of dry bubble disease vary with different stages of mushroom. Early infections of the disease manifest as tiny, unexpanded lumps of tissue up to 2 cm in diameter. They are not perfectly developed in the latter stages, with poorly differentiated caps, deformed stipes, and titled caps. Such afflicted mushrooms have a fine, white-gray mycelial growth covering them, and

they also exhibit discoloration. Occasionally, fully formed mushrooms will develop little outgrowths that resemble pimples from the top of the cap or bluish-gray spots on the surface of the cap. These patches frequently have a yellow or bluish-grey halo surrounding them. Contaminated casing material is the most common source of this *Verticillium fungicola*. Primary source of disease inoculation can occur through air borne spores as well as by the spores carried by the flies and mites (Munsi *et al*., 2010).

Cobweb disease (Cladobotryum dendroides syn. Dactylium dendroides)

Cobweb disease is so named because it exhibits the typical coarse mycelial development. Mushrooms maybe attacked at any of the developmental stages. The pathogen more rapidly colonizes mushroom which eventually turns brown and got rotten. The colour of the mycelium changes to pink to red in colour and the cobweb like structure is replaced by a mycelium. Brown or pink-brown spots with poorly defined edge can be seen (Munsi *et al*., 2010).

Insect pests

Many insect-pests of the order Diptera attack the mushrooms. The Phorid fly and the Sciarid fly were among them; additionally, mites are becoming a major issue. Rats are a serious issue because they devour the bags and the spawn layers.

Flies: (i) Phorid fly: *Megaselia halterata* and *Megaseliatam ilnodolensis,* (ii) Sciarid fly: *Lycoriella malli*,(iii) Cecids or gall midges (*Heteropeza pygmiae, Mycophilas peyeri*)

Damage symptoms: The larvae feed on the mycelium and cause rotting patches in the growing mushroom beds. Young buds are also eaten up by the young larvae. They also make tunnels inside the grown-up mushroom and cause rotting of the mushrooms.

Beetles: (i) Black beetle: *Sacphisoma nigrofaceatum*, (ii) Brown beetle: *Sacphisoma pictummotschulsky*

Damage symptoms: Both black and the brown beetle feed on the young buds and grown-up mushrooms by scrapping on the tissues. These beetles also transmit the bacterial blotch disease.

Spring tails: Their scientific names are *Lepidocyrtus cyaneus* and *Isotoma simplex*. These are tiny insects with stout antennae and they feed on the mycelium and on the mushroom buds.

Nematodes: Nematode infestation is a major issue in case of button mushrooms. The most commonly noticed nematodes are: *Ditylenchus mycelophagus* and *Aphelenchoides composition*.

Mites: In addition to insects, mites can also severely affect the mushroom spawn as well as the growing mushroom buttons. Some important mites are (i) Tarsonemid mite- *Tarsonemus myceliophagu*s and *T. floriculus* which feed on the mycelium and transmit the diseases. (ii) Tryoglyphid mite- *Tyrophagus lintneri* and *Tyrophagus longior*.

Major problems during production:

- Lack of shade-net houses
- Unavailability of capital
- Unavailability of good quality spawn
- Higher price of the raw materials
- Higher temperature in summer is a major issue
- Heavy rainfall during the monsoon period
- Lack of trained and experienced labour is one of the major issue during production

Major problems during marketing:

- Lack of market facilities
- Higher rate of transportation cost
- Limitation of wholesale markets
- Absence of advanced storage facilities is a very serious issue
- Lack of advertisement is one of the major issue regarding mushroom cultivation

Improper initiation strategy

For both the domestic and international markets, button mushrooms continue to be the most common among all**.** Its cultivation is being done by Hitech projects, medium scale units and also by the seasonal farms. Initially when Hitech

projects were set up, they faced several problems such as, quality of raw materials used, paddy straw-based compost was difficult to produce quality compost, casing material and spawn and high cost of imported machineries and equipments. This resulted in inconsistent yields or even crop failures and high cost of production.

Chlorinated or contaminated water

Using of contaminated water in mushroom production is a major issue in Odisha.

Spawn contaminated

Contamination of spawn is a very serious issue in mushroom production and it badly affects the production.

High cost of energy

High cost of energy for year rounds production is also a major issue in production of mushrooms.

Constant monitoring

For cultivating button mushroom we have to keep a close eye on everything of the production process and constant monitoring is needed.

Laborious work

It is a very laborious process unless you're using machines but then also its laborious. And also skilled labour is required for maintaining the production process.

Difficulty in selling mushrooms

Selling mushrooms in market isn't that easy. If you don't have experience or resources or channel to sell your mushrooms - you will end up wasting lot of them as you can't consume all of them and that's not commercially profitable also.

Beside this, export market was also affected due to availability of cheap Chinese product.

The absence of facilities for creating compost of high-quality, casing soil, spawn, and processed commodities is a serious issue.

CONCLUSION

Button mushroom is considered to be more popular mushroom for its delicious taste and greater self life. Its production is ranked first on a global scale. Being a temperate mushroom, production can be carried out either seasonally throughout the winter or year-round in a controlled setting. Production of oyster and paddy straw is at its highest in Odisha. Recent attempts at growing button mushrooms indoors have proven successful. With 110 tonnes produced annually as of today, Odisha has recently begun commercial production; nevertheless, this number is expected to rise steadily in the future.

The problems which are encountered during the production process of button mushrooms are more as compared other kinds of mushrooms. If we overcome those problems, it is one of the most valuable and profitable production at the present time. As long as there are more obstacles to overcome and the likelihood of failure is higher, the rewards for achievement will also be larger. To boost the possibility that mushroom growing will be successful, there are certain helpful steps. Some mushroom producers have discovered a means to artificially generate environmental stress and stimulate the fruiting period. In general, fungi can only be found in the vegetative stage, where they can feed for a few weeks. However, if a severe cold spell occurs, they will undoubtedly go into fruition. This is a man-made method that can be used to stimulate production. During this process, they learn genetically that winter has arrived, and they believe that this is their final opportunity to produce. To improve the output, we have to thoroughly inspect the substrate beforehand. Make sure all the raw ingredients are in good, fresh condition before spreading the substrate out thoroughly, mixing it and packing it once more. Before beginning of the pasteurisation process, we must verify the pasteurisation method, remove all of the air from the area, and ensure that there is constant steam. The mycelium needs appropriate light for optimal growth, so we must offer it. Like this, we can maintain certain conditions which will enhance the fruiting as well as its production rate.

Challenges associated with button mushroom production underscore the intricate nature of cultivating this popular fungus. Despite its seemingly simple appearance, the journey from spore to mature mushroom is fraught with obstacles that demand careful consideration and strategic solutions. The susceptibility of Agaricus bisporus to diseases, the intricate environmental requirements, and the ever-looming threat of contamination all contribute to the complexity of the cultivation process. Moreover, the market demands for year-round production and the need for sustainable practices further intensify the challenges faced by growers. Nevertheless, in acknowledging these hurdles, one must also recognize the resilience and adaptability of the agricultural community. Researchers, farmers, and industry professionals are actively engaged in the development of innovative technologies, improved cultivation methods, and disease-resistant strains to overcome these challenges. The ongoing commitment to research and development, coupled with advancements in technology, holds the promise of transforming the landscape of button mushroom production.

Efforts to combat diseases and contamination involve a multifaceted approach, encompassing both biological and technological interventions. Biocontrol measures, such as the use of antagonistic microorganisms and organic amendments, are gaining traction for their environmentally friendly and sustainable attributes. Concurrently, advancements in sterilization and sanitation practices, including the use of automated systems and improved substrate formulations, contribute to minimizing contamination risks. The integration of precision agriculture and data analytics further enhances the industry's ability to optimize environmental conditions, fostering more efficient and consistent mushroom cultivation.

Addressing the seasonal limitations of button mushroom production requires a strategic blend of traditional and modern techniques. Controlled environment agriculture, encompassing sophisticated climate control systems and substrate formulations, enables year-round cultivation. Additionally, the exploration of alternative substrates and innovative cultivation methods, such as vertical farming and hydroponics, offers potential solutions to mitigate the impact of external climatic variations on production. The adaptability of the industry to embrace these technological innovations underscores its commitment to meeting the increasing global demand for button mushrooms while minimizing the environmental footprint.

Sustainable practices are emerging as a central theme in the contemporary discourse on mushroom cultivation. As consumers become more conscious of the ecological impact of their choices, the mushroom industry is responding by exploring eco-friendly alternatives. From the utilization of renewable energy sources to the development of biodegradable packaging, the commitment to sustainability extends beyond the cultivation process into the entire supply chain. This shift not only addresses environmental concerns, but also positions button mushrooms as a socially responsible and ethical choice in the marketplace.

Challenges in button mushroom production are not insurmountable barriers but rather catalysts for innovation and improvement. The synergy between scientific research, technological advancements, and sustainable practices provides a roadmap for the industry to navigate the complexities of cultivation successfully. As global demand for button mushrooms continues to rise, the resilience and adaptability of the agricultural sector will play a pivotal role in ensuring a consistent and sustainable supply. By addressing challenges head-on, embracing cutting-edge technologies, and adopting environmentally conscious practices, the future of button mushroom production holds promise for both growers and consumers alike. The journey from spore to harvest may be intricate, but with a commitment to innovation and sustainability, the button mushroom industry is poised for a flourishing and resilient future.

DECLARATIONS

Conflict of interest: Author declares no conflict of interest.

REFERENCES

Barman, S., Acharya, A., Chakraborty,U., Chakraborty, B.N. 2017. Evaluation of the effect of different compost formulations and casing materials on Button mushroom production. *Int. J. Sci. Nature* **8**: 377-385.

Barman,S., Chakraborty, B.N., Chakraborty, U. 2018. Edible mushroom: Boon to human health and nutrition. *J. Mycopathol. Res*. **56:** 179-188.

Bhushan, A., Kulshreshtha, M. 2018. The medicinal Mushroom Agaricus bisporus: Review of phytopharmacology and potential role in the treatment of various diseases. *J. Nature Sci. Med.* **1**:4

Chang, S.T., Miles, P.G. 2004. *Effect and environmental impact*. CRC Press, Boca Raton. pp 451.

Chang, S.T. 2005. Witnessing the development of the mushroom industry in China. *Acta Edulis Fungi* **12**:3–19.

Chang, S.T., Wasser, S.P. 2012. The role of culinary-medicinal mushrooms on human welfare with a pyramid model for human health. *Int. J. Med. Mushrooms* **14**:95–134.

Thakur, G.M., Rathod, M.G. 2021. Spawn preparation techniques in Mushroom cultivation. *Research insights of Life Science Students Biotechnology*, **3**:712 – 714.

Thakur, M.P. , Singh, H.K. 2020. Potential of macrofungi in waste management, human health and social upliftment: A review. *J. Mycopathol. Res.* 58:1-14.

Grimm, D., Wosten, H. A. 2018. Mushroom cultivation in the circular economy. *Appl. Microbiol. Biotechnol.* **102**:7795–7803.

Innocent, O., Emmanuel, A., Thomas, A. 2009. Biosorption of heavy metal ions from aqueous solutions using a biomaterial. *Leonardo J. Sci.* **48**:58-65.

Mane, R.S., Sindhe, M.B. 2019. The Mushroom Cultivation and Production. Lap Lambert Academic Publishing, pp 43-56.

Muhammad, U., Ghulam, M., Allah, D. 2021. Nutritional, Medicinal, and Cosmetic Value of Bioactive Compounds in Button Mushroom (*Agaricus bisporus*): *A Review. Appl. Sci.*, **11**:5943.

Munsi, N.A., Hassan, Gb., Ghani, M.Y., Kauser, S., Mugbal, N. 2010. Button Mushroom Cultivation, Research Gate, pp 1-28

Nilanjana, D. 2005. Heavy metals biosorption by mushrooms. *Natural Prod. Radiance*. **4**: 454–459.

Nilanjana, D., Karthika, P., Vimala, R., Vinodhini, V. 2008. Use of natural products as biosorbent of heavy metals – An overview. *Natural Prod. Radiance*. **7**: 133–138.

Padhi, S., 2015. Mushroom cultivation in Odisha: challenges and opportunities, *Envis Newsletter* 41: 1-7.

Rohini, B.G., Rathod, M.G. 2021. Sterilization and disinfection of agro-waste for mushroom cultivation. Research insights of life science students, *Biotechnology* **3**:710 – 711

Shah, S., Nasreen, S., Kousar, S. 2013. Efficacy of fungicides against *Trichoderma* spp. causing green mold disease in oyster mushroom (*Pleurotus sajor-caju*). *Res. J. Microbiol.* **8**: 13-24.

Sharma, V. P., Annepu, S. K., Gautam, Y., Singh, M., Kamal, S. 2017. Status of mushroom production in India. *Mushroom Res.* **26**:111-120.

Shbeeb, D.A., Farahat, M.F., Ismail, H.M. 2019. Macronutrients analysis of fresh and canned *Agaricus bisporus* and *Pleurotus ostreatus* mushroom species sold in Alexandria markets, *Egypt. Prog. Nutr.* **21**:203–209.

Singh, S. K., Kumar, D., Abrol, S. 2021. Button Mushroom: Cultivation, Utilization and Processing, *Just Agric.* **1**:1-6.

Wasser, S.P., Akavia, E. 2008. Regulatory Issues of Mushrooms as Functional Foods and Dietary Supplements: Safety and Efficacy. Mushrooms as Functional Foods; Wiley: New York, NY, USA, pp. 199–221

Xu Jie, H., Na, Z., SuYing, X., Shu Gang, L., BaoQiu, Y. 2008. Extraction of BaChu mushroom polysaccharides and preparation of a compound beverage. *Carbohydr. Polym.* **73**:289–294.