

MUSHROOM(AGARICUS BISPORUS) PROJECT

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Submitted By

M MANASA JYOTHI

[Y183223007]

N JOSHUA

[Y183223008]

P GOPI KRISHNA

[Y183223009] ✓

SHAIK KHADAR BASHA

[Y183223011]

Under the Esteemed Guidance of

MR, DR J RAMUDU B.ED, PHD.,

Professor

Department of Botany



V.S.R. GOVT.

DEGREE & P.G. COLLEGE

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V.S.R. GOVT.
DEGREE & P.G. COLLEGE

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UNIT-I

INTRODUCTION

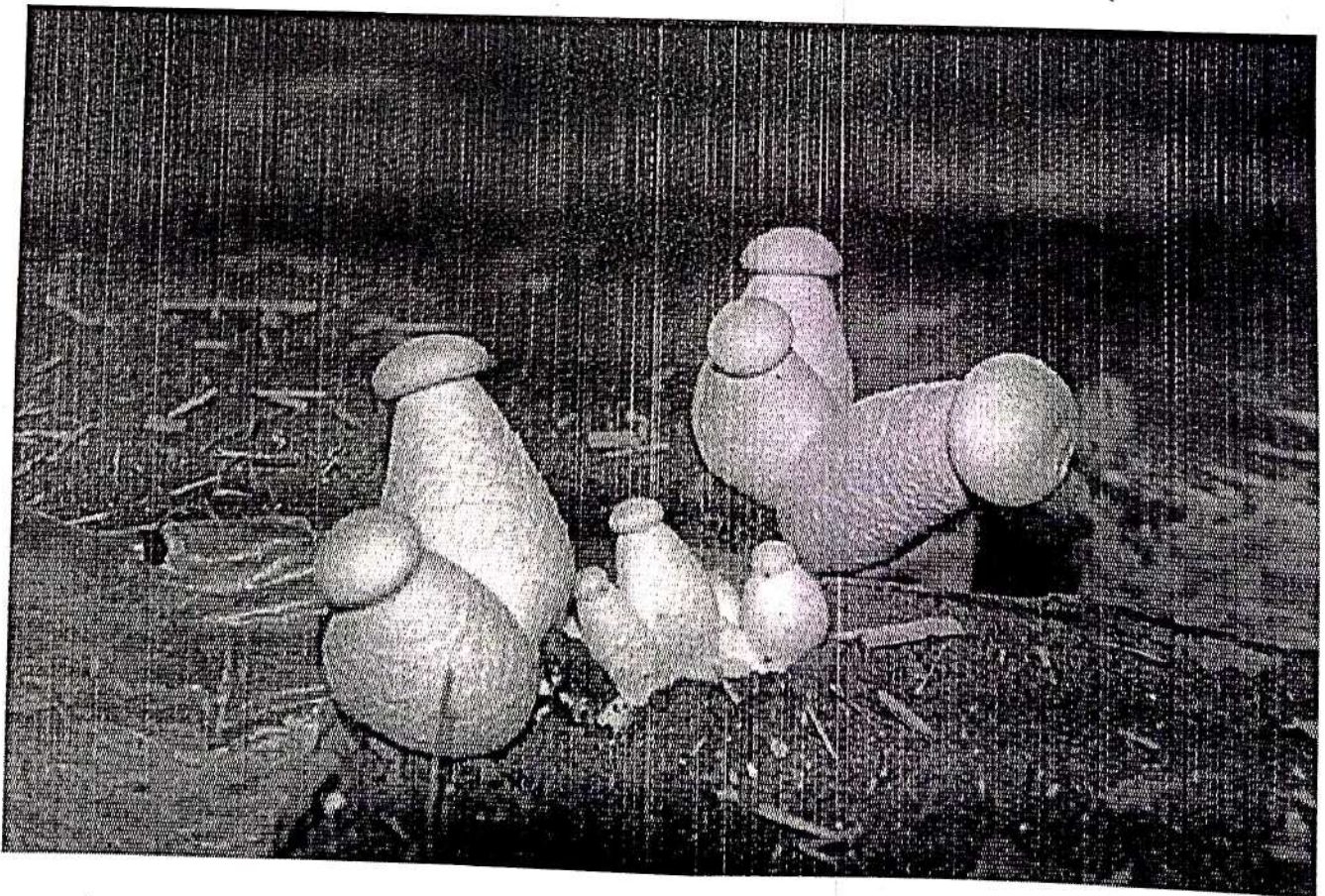
AND HISTORY

I.INTRODUCTION

In the present era of food shortage and energy crisis, it is everybody endeavor to augment the production /or conservation of items of food as well as better economics of their use. The emergence of food crisis due to the ever increase in the world population has led scientists and technologist to tap the available resources in finding alternative ways of producing cheap and quality food. Among the food sources for humans also comes microbes, of which fungi comprise the largest and most important group containing edible species of fungi/mushroom. The land is a limiting factor in the production of food, but it is of relatively little importance in production of mushroom. Consequently, expansion of mushroom culture can conveniently be marshaled to ease such global problems as energy crises, food shortages, malnutrition,' recovery and recycling of agricultural household and industrial waste, pollution as well as unemployment.

The mushroom is a form of plant life known as a fungus, a group of organisms, separate from plants and animals. Mushroom can be defined as a macrofungus with a distinctive fruiting body, which can either epigeous or hypogeous. The macrofungi have fruiting body large enough to be seen with naked eye (Chang, 1991).The world of mushroom has always been fascinating and mystic to man owing to their sudden appearance in numbers, groups, rings, bunches and also in isolation as individual. In nature, mushroom grows wild in almost all types of soils, on decaying- organic matter, wooden stumps etc. Man has been fascinated with this biological entity since ancient times and references about the mushrooms are available in most ancient literatures like Vedas and Bible. Theophrastus (372-287 BC), the Great Philosopher, wrote about food value of mushrooms during middle ages, when mushroom comprised royal

dishes for Greek and Roman Emperors. In fact, mushrooms have existed even long before man appeared on earth i.e. about 130 million years ago (Verma, 2002). Mushroom are fungi, which lack chlorophyll and cannot manufacture their own food in the presence of sunlight, as do green plants. However, mushrooms can produce a wide range of enzymes that degrade the complex substrate on which they grow, following which they absorb the soluble substance for their own nutrition. This absorptive nutrition is a characteristic of fungus (Chang, 1991). In case of mushroom, the seed (spores) has no sexual origin (Atkin, 1981). These spores, which are invisible to naked eye, send out exploratory root like fine threads (mycelium), which permeate the substratum and spread in all direction, producing fruit (the mushroom itself) without intermediate stem and leave stage. The mushroom fruit body may be umbrella like or of various other shapes, size and colour. Generally, it consists of a cap or pileus and a stem or stipe, but others may have additional structure like a veil or annulus and a cup or volva.



The new spores develop inside the cap (pileus) of the mushroom, which on germination produces root like threads in order to search for food. After absorbing the nutrition

from substratum, they transmit it to the mushroom for growth and development. The mushroom first appear as a tiny white ball and as it grows, a stipe is observed. Later the pileus begins to open up, tearing away the delicate membrane or veil by which its outer edge is attached to the stipe, producing or releasing millions of spores. These spores under favourable condition germinate on suitable medium giving rise to mycelium, which after mating (either with compatible mycelium or self mating) produces the fruit (mushroom itself), thus completing the life cycle.

In contrast to the green plants, most mushroom species are haploid. The diploid phase is normally transient and restricted to the basidium where meiosis occurs. The meiotic products migrate in the basidiospore of which there are characteristically four basidium. On account of such a life cycle and saprophytic nutritional habit, mushrooms in nature are generally found to grow in places where dead remains of plants or wooden logs are decaying and hence in forests, fields and meadows, mushroom grow in abundance. Although, majority of mushrooms are saprophytes, yet there are some which either grow upon living plants as parasite or in symbiotic association with living plants, like plant roots as mycorrhizas. Another way of categorizing the mushrooms is on the basis of their use /consumption by man. In another words mushroom can be roughly divided into five categories:

1. Those which are fleshy and edible mushroom category e.g. *Agaricus bisporus*,
2. Those mushrooms which are considered to have medicinal application are referred to as medicinal mushrooms e.g: *Ganoderma lucidum*,
3. Those which are proven to be, or suspected of being poisonous are named as poisonous mushrooms e.g. *Amanita phalloides*,
4. Those mushrooms which are toxic/ha dealbata and Ilucinogenic e.g. *Clitocybe* and dealbata and

5. Miscellaneous categories that include a large number of mushrooms whose properties remain less defined and are grouped together as 'other mushrooms'.

It has been estimated that out of 10000 species of fleshy fungi (Kendrick, 1985) about half of them are edible (Chang, 1993) and as many as 100 species are poisonous and therefore, consumption of wild mushroom require adequate precautions to avoid accidental death due to mushroom poisoning. The number of known species of fungi is about 69,000 and it is conservatively estimated that 1.5 million species actually exists (Hawksworth, 1991). Out of 69,000 known and described species of fungi, about 10000 are fleshy micro fungi. About 2000 species from more than 30 genera are regarded as prime edible mushrooms, but only 80 of them are grown experimentally, 40 cultivated economically and about 20 cultivated commercially and 4 to 5 are produced on an industrial scale, (Chang, 1990 b).

The earliest cultivated edible fungus was a species of *Auricularia*. Which was cultivated about 1000 years ago in China. The next species to be cultivated was *Lentinus edodes*. This was almost 900 years ago also in China. *Agaricus bisporus* the common white button mushroom was first cultivated in France during the period 1550-1650 (Atkin, 1981). *Volvariella volvacea*, the straw mushroom was first cultivated about 300 years ago in China (Chang and Miles, 1989). Tribal and hill people eat large number of naturally occurring edible fungi after collection from wild habitats. Large quantities of different edible mushrooms are also consumed in India, either fresh or after drying.

Four- edible fungi including *Volvariella* spp (Chinese or tropical or paddy straw mushroom), *Pleurotus* spp (Oyster or dhingri), *Lentinus edodes* (Shiitake) and *Agaricus bisporus* (white button, European or temperate mushroom) have been in cultivation for centuries in different countries. Though their commercial cultivation has become established as an industry only about the last decade. Some other species including *Flammulina velutipes* (enokitake), *Pholiota nameko* (nameko) *Auricularia* spp (Black ear, *Tremella fuciformis*

(jellyfungi), *Tuber melanosporum* (truffle) and *Calocybe indica* (Milky mushroom) have been exploited only in recent years.

Mushroom cultivation incorporate the principle of microbiology, environmental technology and solid-state fermentation in the conversion of domestic agricultural and organic waste materials into a healthy food for consumption. The technique for mushroom cultivation has taken a huge stride from primitive cave culture to the highly industrialized technology during the last three centuries, in which, advanced technology and equipments are being used. In overall view, the world production of cultivated edible mushroom was 3,763 thousand tons in 1989-90 (Chang, 1991) is now estimated over 5000 thousand tons (Verma, 2002). It is mostly confined to Europe (55%). North America (27%) and Eastern Asia (14%). There is particularly sharp increase in growth over the last few years, which is expected to continue in the future. Due to advances, both in basic knowledge and practical technology of mushroom biology, the significant impact on mushroom cultivation and production, can be considered worldwide, but must be implemented according to local material, labour and domestic conditions.

In India also, there has been slow, but significant increase in growth of mushroom research and development as is clearly evident from the fact the yield of mushroom has increased many folds during the last four decades i.e. from 2-3 kg/m² in 1964-65 to 25 kg/m² in 2000 (Shandilya, 2000). During the beginning of the century the estimated production is likely to cross 50,000 tones (Verma, 2002). However, this quantity is very meager, considering the huge market potential of this large and over populated country. In the developing countries like India, there is need to convert the surplus agricultural waste into nutritious food using simple, and inexpensive methods. Cellulose, hemicelluloses and lignin constitute about 80 per cent of total dry weight of straws. In addition, they also contain water-soluble substances and extractives. Most edible fungi possess good cellulose and hemicellulolytic enzymes system and

some in addition are highly lignolytic. Proper understanding and identification of such system will definitely help in the selection of mushroom strains that have an increased ability to bio-convert more of the substrate into fruit bodies. While India has been traditionally major mushroom growing country but it continues to hold a very small share in the world trade of mushroom which, it is estimated to be growing at an annual rate of 25 per cent. The present marketing trend in India is also more inclined toward export rather than exploitation of domestic market. Mushroom in the country has of late, made rapid progress in the last one decade but as compared to other countries productivity as well as per capita consumption in the country is one of the lowest. There are several gaps in our production technology resulting in low yields or crop failures. Major share of the mushroom produce is still coming from the cultivation under natural conditions by small farmers where consistent yields is a major problem. Cultivation technology and strain developed in other countries for cultivation of mushroom under sophisticated controlled conditions may not be suitable for our condition. Scientists should address themselves in evolving hardy strains and production techniques suited for our farmers and conditions. Besides developing technology for big entrepreneurs, low cost, labour intensive technology should be developed for small farmers and landless labourers which would go a long way in providing gainful employment and raising the income of these vulnerable groups.

II. HISTORY

Cultivated mushrooms are a unique horticulture crop. Although the growth and activities of microorganisms have many diverse and important effects in horticulture, cultivated mushrooms are the only horticultural crop whose harvest is a microorganism. In contrast to the cultivation of higher plants, which started in prehistorical times, the culture of fungi is a relatively recent innovation. The first known cultivation of a heterotrophic organism, the

Agaricus type of mushroom began in France during the period 1550-1650 (Atkin, 1981; Delmas, 1978; Poppe, 1978; Treshow, 1944) and from there the technique passed first to England and then to U.S.A. in the late 19th century.

The earliest known description of how to grow mushrooms was written by a Frenchman de Tournefort, and published in Paris in 1707. About 1900, the French were starting to grow mushrooms underground in the quarries round Paris. Horse manure was stacked in heaps and allowed to heat up naturally. The resulting compost was laid in long ridges and inoculated with spawn dug from meadows or mill tracks, where horses have been trampling.

English growers were quick to take commercial advantages of the extensive material supplies of wild spawn in this country and a century ago were exporting spawn to America, Germany, Denmark and even Australia. English brick spawn made from a mixture of horse manure, cow manure and loam was often contaminated by other moulds full of insects and of uncertain vigour and strain. In 1894, Constantin and Matruchot succeeded in making pure spawn in laboratory from mushroom spores. The process was patented, but does not appear to have been commercialized and in 1902, Miss Ferguson of Cornell described in detail method of germinated spores. As was to be expected, this method was exploited immediately, for Americans realized that it means it was now possible for the first time to select and guarantee a particular strain (Atkin, 1981).

In the United State in 1918, was marketed, Pure Spore Culture Bottle Spawn. It was produced by collecting spores from a mushroom selected for its size, colour and general appearance; germinating them under aseptic conditions and injecting them into a bottle of sterilized horse manure compost. According to Lindeberg (1944) mushroom cultivation above ground started in 1754. It is not known when the first house designed specially for mushroom was made, however, Callow in 1831, reported that a house of a peculiar construction after the German practice was introduced by Oldacre (gardener to the late Sir Joseph Banks)

warmed by the heat and recommended as one well adapted to the growth of mushroom throughout the year (Atkin 1981).

Callow (1831) described and sketched such a house in England in which he grew mushroom on a flat bed on the ground and on shelves one above the others on brackets attached to the walls. This is the earliest record known in which shelf beds are mentioned.

Cuthill (1857) discussed what had by then become as Oldacre mushroom house and were made on purpose with shelves having side boards from 9" to 1' deep, one shelf being placed above another about 2 feet apart with gangway down the middle. It was only during the last eighty years or so, that a 'Standard American' mushroom house was evolved to bring the growers within the reach of controlled temperature, humidity and aeration all the year around (Atkin, 1981).

The next big advance was the theory of greasiness propounded by Pizer in 1936, who at Wye College, discovered why, and how the addition of gypsum to all composts is now universally practiced with immense improvement in spawn growth. Concurrently (1936-1940) much study was in progress concerning diseases and competitive moulds, mainly by Ware, Glasscock and Bewley in England and by Lambert (1933, 1941) in America. Bewley and Lambert also did useful preliminary work on the relationship between soils and yield. Sinden (1932, 1936) patented his grain spawn process. Pest remained a serious menace despite the invaluable investigation of Thom Austin and Jery.

In 1945, Midland Group of Mushroom Growers stressed the need for:

1. Creation of national association.
2. Necessity for research particularly related to the provision of growing medium other than horse manure.
3. Test book on mushroom cultivation.

Mushroom Growers Association (MGA) was formed in 1945 by Mushroom Growers of England and Ireland. They took over from Midland Group of Growers and started 'The Mushroom Journal'. Edward (1950) working at Yaxley produced the formula for synthetic compost, which could replace horse manure commercially. Sinden and Hauser (1950) prepared synthetic compost, consisting of wheat straw, urea and other fertilizers where pasteurization became integral part, which was later termed as the 'short method of composting'. In 1954, Glass House Crop Institute was established at Littlehampton, Sussex after the closer of Mushroom Research Station at Yaxley. At this Institute systematic work on mushroom research was started and notable contributors were; Hussey and Wyatt (flies and mites), Hollings and Gandy (virus and bacterial disease), Flegg (casing and environment), Randle (nutrition), Elliot (genetics) and Nichols (storage).

In Denmark, Rasmussen (1962) produced startling result with pig manure, unorthodox methods of composting and other techniques and his work was continued by Beth (1969) in a new experimental plant near Copenhagen. In the course of the years this situation gradually changed and three principal methods of mushroom cultivation came into use, viz:

- On raised beds in caves, mainly in France, Italy and Belgium. The beds were later replaced by trays,
- In beds according to the multiple-zone system, particularly in the U.S.A. and later also in the Netherlands,
- In trays according to the multiple zone system, a method much used in England and later also some of the larger farms in many other countries. Single zone system of mushroom cultivation is also popular in most of the Asian countries. Mushroom growing situation remained stable up to 1970, because there were supporters of each of the above methods, however, in the meantime inventive people in various parts of the world were constantly looking for improved methods of mushroom production technology. The net result has been

very rapid development in the last few years in almost all spheres of mushroom research and developments. The rapid rate of development of mushroom production technology from primitive cave culture to a high tech industry is a success story itself. In overall view, the world production of cultivated edible mushroom was 2, 182 thousand tons and 3, 763 thousand tons in 1986 and 1989-90, respectively. In those 3 years mushroom production increased by 72.5% with annual increase of 24.5% (Chang and Miles, 1991). Although mushrooms are now being cultivated in more than 100 countries with an estimated total production of over 5 million tones, it is mostly confined to Europe, North America and Eastern Asia (Verma 2002).

HISTORY OF MUSHROOM CULTIVATION IN INDIA:

Through mushroom cultivation started many centuries ago; yet initial reference to the possibilities of mushroom cultivation in India was probably in 1886 when some specimens of mushroom were first identified by N. W. Newton and exhibited at the annual show of Agri. Hort. Society of India at Calcutta. Later, Dr. B. C. Roy of Calcutta Medical College carried out chemical analysis of the mushrooms prevalent in caves and mines in 1896-97. In 1908, Sir David Prain, instituted thorough search of edible mushroom in India. It was in the year 1921, when Prof. S. R. Bose from Bengal was successful in cultivating two agarics on a sterilized dung media, details of which were published in the Indian Science Congress held at Nagpur during 1926 (Chadha, 1994). However, the first successful attempt at cultivation of a paddy straw mushroom (*Volvariella stipitata*) was made by Thomas and his group at Coimbatore (Tamil Nadu) in 1943. In 1962, Bano et al obtained increased yield of paddy straw. However fir *Pleurotus* species on st systemic effort in cultivating button mushroom was made in 1961 in the State of H.P., where a scheme entitled, "Development of Mushroom cultivation in

Himachal Pradesh" was started at Solan by H.P. State Government in collaboration with I. C. A. R. In 1964, experimental cultivation of *A. bisporus* was started by CSIR and JandK Govt. in Srinagar. During 1965, Dr. E. F. K. Mantel, FAO, Mushroom Expert, assisted Dept. of Agriculture, H.P. in the construction of a modern spawn laboratory and a fully air-conditioned mushroom house. Research on evaluation of different strains and use of various agricultural waste and organic manure and fertilizers for preparing synthetic compost was undertaken.

In the year 1974, services of another FAO expert Dr. W. A. Hayes, were obtained for further improving the method of compost preparation, pasteurization and management of various parameters in mushroom house. New compost formulation, casing material and study of important parameters in the compost, use of spent compost and farm yard manure as casing soil, aeration and maintenance of proper environmental condition were also undertaken which raised the mushroom yield from 7 to 14 kg/m². In 1977, a 1.27 crores Mushroom Development Project was launched under the aegis of the U. N. D. P., by the Dept. of Hort. (H. P.) where in the services of Mr. James Tunney were made available at Solan. With the construction of bulk pasteurization chamber, he made ready pasteurized compost available to the growers of Shimla, Solan and Sirmour district of (H. P.). With the termination of UNDP, project in 1982, the dept. of Horticulture (H. P.) is successfully running the project.

Significant research work has been done at Mushroom Research Laboratory in the Dept. of Mycology and Plant Pathology, College of Agriculture, Solan affiliated to HPINV Palampur earlier and now under the aegis of Dr. Y. S. Parmar, University of Horticulture and Forestry, Nauni, under the dynamic leadership of Dr. R. L. Munjal. Outstanding contribution emanated in compost formulation, standardization of various parameters of spawn production technology, use of spent compost and farmyard manure as casing material and management of important insect pest, disease and nematodes affecting mushroom crop. In 1982, Indian council of Agriculture Research, sanctioned the creation of National Centre for Mushroom Research

and Training during VI plan on October 23, 1982 with the objectives of conducting research on problems of mushroom production, preservation and utilization and to impart training to interested personnel. The centre started functioning w.e.f. 8.6.1983. Simultaneously ICAR sanctioned six, all India coordinated mushroom Mushroom Improvement Project 1983 at GBPU of Agricultural and Technology Pantnagar (U.P.), PAU, Ludhiana (Punjab), TNAU., Coimbatore (TN), BCKVV Kalyani (WB), MPAU, College of Agriculture, Pune (MS) and C. S. Azad Univ. of Agriculture and Technology Kanpur (U. P.). In subsequent years, Kanpur and Kalyani centers have been deleted and IGKVV, Raipur (Chhatisgarh) has been added (Chadha, 1994).

In the recent years, the yield of mushroom has increased many folds as a result of outstanding research made by the mushroom scientist in India (Munjal, 1973, 1980; Shandilya 1977, Kaul and Kachroo, 1975. Bano 1976; Seth, 1976, 1981; Jandial and Kapoor, 1974; Vijay, 1996; Vijay and Sohi 1987; Vijay and Ahlawat 2001; Tiwari and Singh 1984; Tiwari and Pandey 1999; Sharma, 1994, 1997, Suman, 1982, 1993, 2003 and Dhar, 1976. With the introduction of improved technology of cultivation the yield of *Agaricus bisporus* has increased from 2-3 kg/m² in 1964-65 to over 25 kg/m² by 2000 (Shandilya, 2000).

UNIT-II

Review of Literature and Experimental

According to A. Peerally(1981) One of the main limitations in critical studies of the physiology of sporophore initiation and development in *Agaricus bisporus* is the lack of simple easily conducted laboratory techniques in petri-plates for the obtention of primordia and fruiting bodies, without utilizing compost, grain spawn or soil. Both compost and soil (or other casing material) are unpredictable in nature and they thus impose a serious constraint not only in normal production systems but also in experimentation concerning nutrition requirements and sporophore initiation.

So far the most elusive aspect in the life cycle of *Agaricus bisporus* is the fruiting process. *A. bisporus* forms abundant fruiting bodies when the colonized composts is cased with a layer of

unsterile soil or peat but not when maintained in rigidly sterile conditions. It has been argued that the inability of *A. bisporus* to fruit unless a casing layer is applied may well be the greatest asset of this fungus (Peerally, 1979), since profuse fruiting may be induced at will under commercial conditions,, thus avoiding unpredictable sporophore formation.

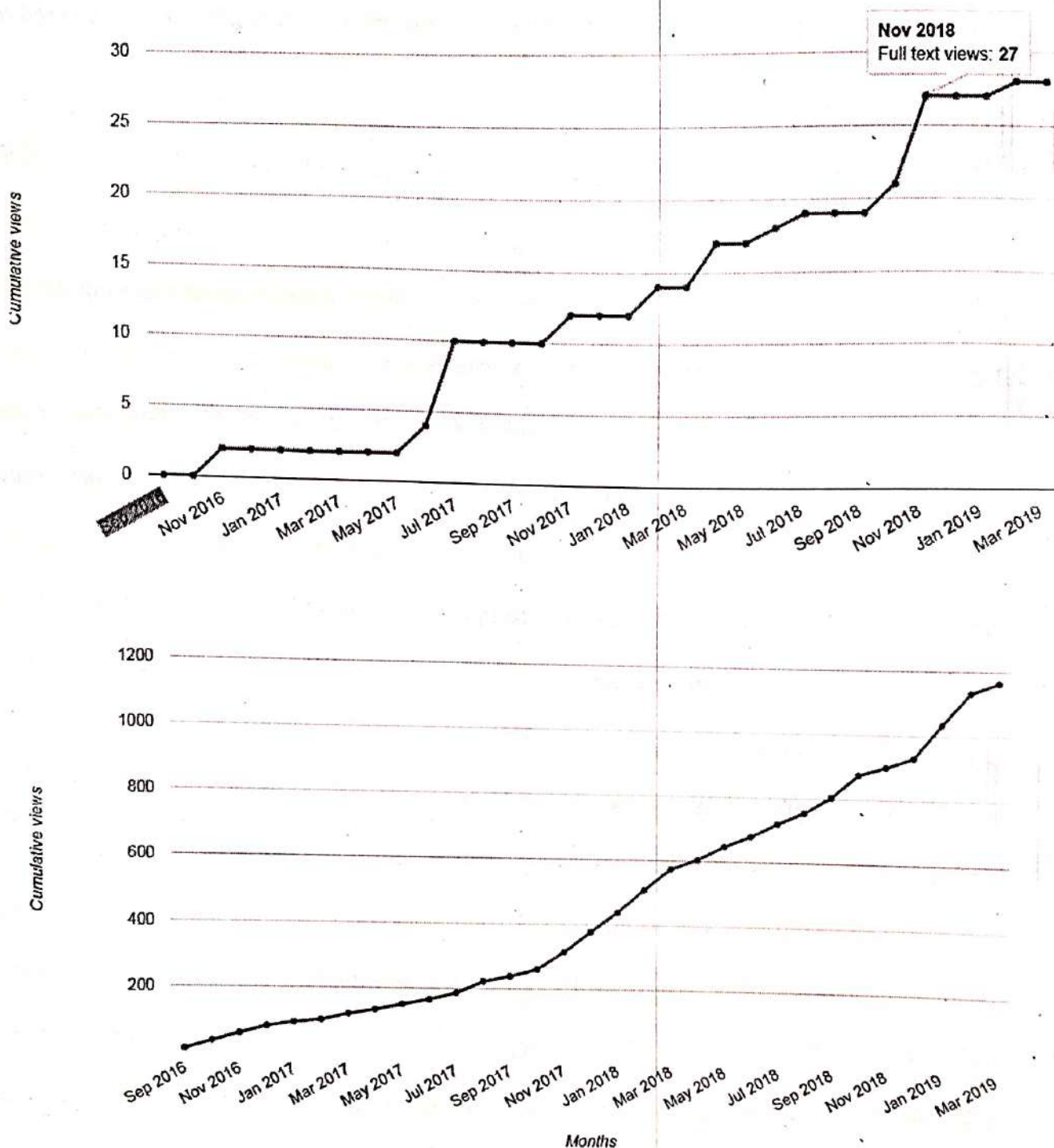
Attempts to develop techniques on fruiting in *A. bisporus* in small scale laboratory studies have been described by various authors. These reports involved cased grain spawn. (San Antonio, 1971), autoclaved substrates (Smith and Hayes, 1972), petriplate methods using soil (Eger, 1962; Peerally, 1979) or apetriplate agar technique (Hume and Hayes, 1972). The petri-plate techniques described differ fundamentally from the commercial system in their horizontal method of growth.

All these techniques have their own specific usefulness. A review of the literature reveals that studies on the physiology of sporophore initiation in *A. bisporus* have got bogged down, mainly on account of the lack of techniques which are simple and easily reproducible. It has been concluded by Peerally (1979) that the change which occurs in the life cycle of *A. bisporus* before the mycelium develops fruiting bodies involves a modification of the profusely branched vegetative mycelium into sparsely branched stranded reproductive mycelium mainly as a result of the action of bacteria present in the casing. Wood (1976), working in axenic agar cultures, observed that primordium formation was usually associated with strands but no primordia were obtained before complete colonization of the plate which took 3 to 4 weeks.

In an attempt to alleviate the bottlenecks which exist in these studies, efforts were made to develop a technique which permitted fruiting in purely agar cultures in the presence of a selected bacterial flora isolated from casing soil. The technique described in this paper achieved 40 to 60 percent success (presence of a single primordium per plate was considered successful) in two experiments' which were carried out. It must be pointed out that lack of sophisticated

laboratory equipment imposed some constraints in our work. Additional work is required to refine upon it.

Agaricus bisporus browning is a common and economically detrimental phenomenon, in which melanogenic phenols are enzymically processed into quinones, which evolve eventually to melanins. This review deals with the two fundamental sides of this process, enzyme(s) and phenolic substrates. Mushroom tyrosinase, the main polyphenol oxidase encountered in the *A. bisporus* sporophore, is treated in the first part. Its overall molecular architecture, isoforms, primary sequence and genetic background are considered. The presentation of tyrosinase catalytic features, including enzyme assays, kinetic properties, substrates and inhibitors, is followed by a comprehensive description of the active site and reaction mechanisms. Because of their relevance for studies of mushroom browning during development and post-harvest storage, the occurrence and properties of latent enzyme forms, as well as the location of tyrosinase and variations of its activity during the *A. bisporus* life cycle, are also reviewed. The second part deals with the substrates, particularly γ -L-glutaminy-4-hydroxybenzene (GHB) and its derivatives. Main data concerning the nature, obtention (by extraction or synthesis), spectrometric and chromatographic characteristics, chemical stabilities and biological properties of these typical Agaricaceae compounds are presented. Their distribution and levels according to the strains and flushes are described, as well as their variations during storage. Thirdly, the relationship between browning and the natural or pathogenic discolouration intensity is developed.



2. Experimental Study to Improve the Quality of Dehydrated Button Mushrooms (*Agaricus bisporus*)

Mushrooms are popular for their delicacy and flavour rather than food value. However, it is well established fact that they are excellent sources of minerals and vitamins such as B-complex and vitamin C. In addition, mushrooms contain 1.1–8.2% lipids, 4.0–8.1%

carbohydrates and 3–32% fibers on dry weight basis. It contains about 90% moisture. The present investigation was undertaken to study the effect of 10 min dipping or vacuum infusion pretreatments either in water or 0.05% KMS or 0.1% citric acid or 100 ppm ascorbic acid or 125 ppm EDTA or 0.4% CaCl_2 solutions on dehydration of button mushroom. The dried mushrooms were packed in polythene bags and kept at room temperature ($25 \pm 5^\circ\text{C}$). The rehydration proportion, non-enzymatic browning and microbial load increased while, no significant change in the organoleptic quality was observed during storage. The dried button mushrooms showed no significant change in quality during storage period of two months at room temperature. The dipping of fresh button mushrooms for 10 min in 100 ppm ascorbic acid solution followed by drying in tray at 60°C was the most effective pretreatment in producing quality dehydrated mushrooms.

UNIT-III

STEPS AND LIFE CYCLE

1. Phase I: Making Mushroom Compost

Phase I composting is initiated by mixing and wetting the ingredients as they are stacked in a rectangular pile with tight sides and a loose center. Normally, the bulk ingredients are put through a compost turner. Water is sprayed onto the horse manure or synthetic compost as these materials move through the turner. Nitrogen

supplements and gypsum are spread over the top of the bulk ingredients and are thoroughly mixed by the turner. Once the pile is wetted and formed, aerobic fermentation (composting) commences as a result of the growth and reproduction of microorganisms, which occur naturally in the bulk ingredients. Heat, ammonia, and carbon dioxide are released as by-products during this process. The use of forced aeration, where the compost is placed on a concrete floor or in tunnels or bunkers and aerated by the forced passage of air via a plenum, nozzles or spigots located in the floor has become nearly universal in the mushroom industry.

Mushroom compost develops as the chemical nature of the raw ingredients is converted by the activity of microorganisms, heat, and some heat-releasing chemical reactions. These events result in a food source most suited for the growth of the mushroom to the exclusion of other fungi and bacteria. There must be adequate moisture, oxygen, nitrogen, and carbohydrates present throughout the process, or else the process will stop. This is why water and supplements are added

periodically, and the compost pile is aerated as it moves through the turner.



The quality of raw materials used to make mushroom compost are highly variable and are known to influence compost performance in terms of spawn run and mushroom yield. The geographical source of wheat straw, the variety (winter or spring) and the use of nitrogen fertilizer, plant growth regulators and fungicides may affect compost productivity. Wheat straw should be stored under cover to minimize growth of unwanted and potentially detrimental fungi and bacteria prior to its use to produce compost.

Gypsum is added to minimize the greasiness compost normally tends to have. Gypsum increases the flocculation of certain chemicals in the compost, and they adhere to straw or hay rather than filling the pores (holes) between the straws. A side benefit of this phenomenon is that air can permeate the pile more readily,

and air is essential to the composting process. The exclusion of air results in an airless (anaerobic) environment in which deleterious chemical compounds are formed which detract from the selectivity of mushroom compost for growing mushrooms. Gypsum is added at the outset of composting at 40 lb per ton of dry ingredients.

Nitrogen supplements in general use today includes corn distiller's grain, seed meals of soybeans, peanuts, or cotton, and chicken manure, among others. The purpose of these supplements is to increase the nitrogen content to 1.5 percent for horse manure or 1.7 percent for synthetic, both computed on a dry weight basis. Synthetic compost requires the addition of ammonium nitrate or urea at the outset of composting to provide the compost microflora with a readily available form of nitrogen for their growth and reproduction.

The initial compost pile should be 5 to 6 feet wide, 5 to 6 feet high, and as long as necessary. A two-sided box can be used to form the pile (rick), although some turners are equipped with a "ricker" so a box isn't needed. The sides of the pile should be firm and dense, yet the center must remain loose throughout Phase I composting. As the straw or hay softens during composting, the materials become less rigid and compactions can easily occur. If the materials become too compact in the traditional Phase I process, air cannot move through the pile and an anaerobic environment will develop. The problem of an anaerobic center core in the compost has largely been overcome by using forced aeration.

Turning and watering are done at approximately 2-3 day intervals, but not unless the pile is hot (145° to 170°F). Turning provides the opportunity to water, aerate, and mix the ingredients, as well as to relocate the straw or hay from a

cooler to a warmer area in the pile, outside versus inside. Supplements are also added when the compost is turned, but they should be added early in the composting process. The number of turnings and the time between turnings depends on the condition of the starting material and the time necessary for the compost to heat to temperatures above 145°F.

Water addition is critical since too much will exclude oxygen by occupying the pore space, and too little can limit the growth of bacteria and fungi. As a general rule, water is added up to the point of leaching when the pile is formed and at the time of first turning, and thereafter either none or only a little is added for the duration of composting. On the last turning before Phase II composting, water can be applied generously so that when the compost is tightly squeezed, water drips from it. There is a link between water, nutritive value, microbial activity, and temperature, and because it is a chain, when one condition is limiting

for one factor, the whole chain will cease to function.



Phase I composting lasts from 6 to 14 days, depending on the nature of the material at the start and its characteristics at each turn. There is a strong ammonia odor associated with composting, which is usually complemented by a sweet, moldy smell. When compost temperatures are 155°F and higher, and ammonia is present, chemical changes occur which result in a food rather exclusively used by the mushrooms. As a by-product of the chemical changes, heat is released and the compost temperatures increase. Temperatures in the compost can reach 170° to 180°F during the second and third turnings when a desirable level of biological and chemical activity is occurring. At the end of Phase I the compost should: a) have a chocolate brown color; b) have soft, pliable straws, c) have a moisture content of from 68 to 74 percent; and d) have a strong smell of ammonia. When the moisture,

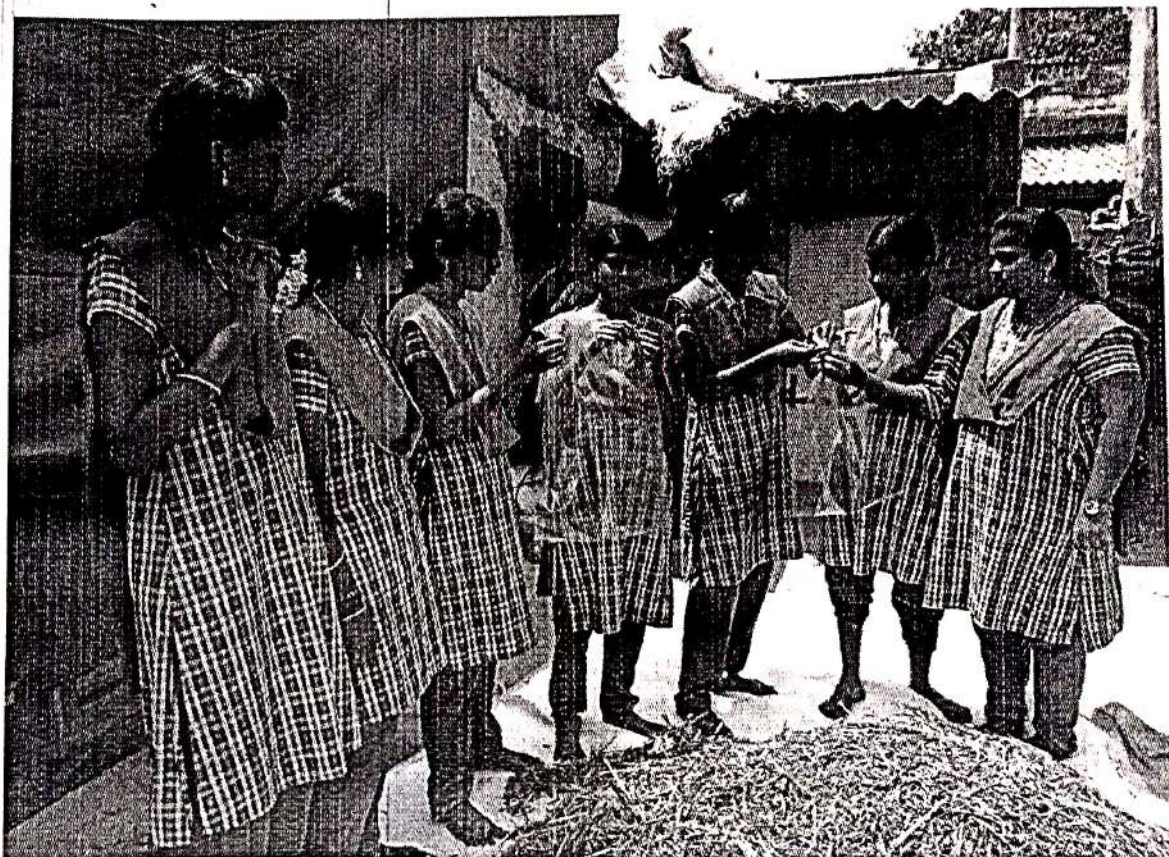
temperature, color, and odor described have been reached, Phase I composting is completed.

2. Phase II: Finishing the Compost

There are two major purposes to Phase II composting. Pasteurization is necessary to kill any insects, nematodes, pest fungi, or other pests that may be present in the compost. And second, it is necessary to condition the compost and remove the ammonia that formed during Phase I composting. Ammonia at the end of Phase II in a concentration higher than 0.07 percent is often inhibitory to mushroom spawn growth, thus it must be removed; generally, a person can smell ammonia when the concentration is above 0.10 percent.

Phase II takes place in one of three places, depending on the type of production system used. For the zoned system of growing, compost is packed into wooden trays, the trays are stacked six to eight high, and are moved into an environmentally controlled Phase II room. Thereafter, the trays are moved to special rooms, each designed to provide the optimum environment for each step of the mushroom growing process. With a bed or shelf system, the compost is placed directly in the beds, which are in the room used for all steps of the crop culture. The most recently introduced system, the bulk system, is one in which the compost is placed in an insulated tunnel with a perforated floor and computer-controlled aeration; this is a

room specifically designed for Phase II composting.



The compost, whether placed in beds, trays, or bulk, should be filled uniformly in depth and density or compression. Compost density should allow for gas exchange, since ammonia and carbon dioxide will be replaced by outside air.

Phase II composting can be viewed as a controlled, temperature-dependent, ecological process using air to maintain the compost in a temperature range best suited for microorganisms to grow and reproduce. The growth of these thermophilic (heat-loving) organisms depends on the availability of usable carbohydrates and nitrogen, some of the nitrogen in the form of ammonia. These microorganisms produce nutrients or serve as nutrients in the compost on which the mushroom mycelium thrives and other organisms do not.

Completing Phase II in tunnels has become more popular in recent years. Tunnel composting has the advantage of treating more compost per ft² compared to more expensive production rooms. When coupled with bulk spawn run, tunnel composting offers the advantage of more uniformity and greater use of mechanization. However, transfer of the finished compost from the pasteurization tunnel to the bulk spawn run tunnel may increase the risk of infestation of unwanted pathogens and pests compared to compost that remains in the same room. Thus, higher levels of sanitation may be required with tunnel composting compared to in-room composting.

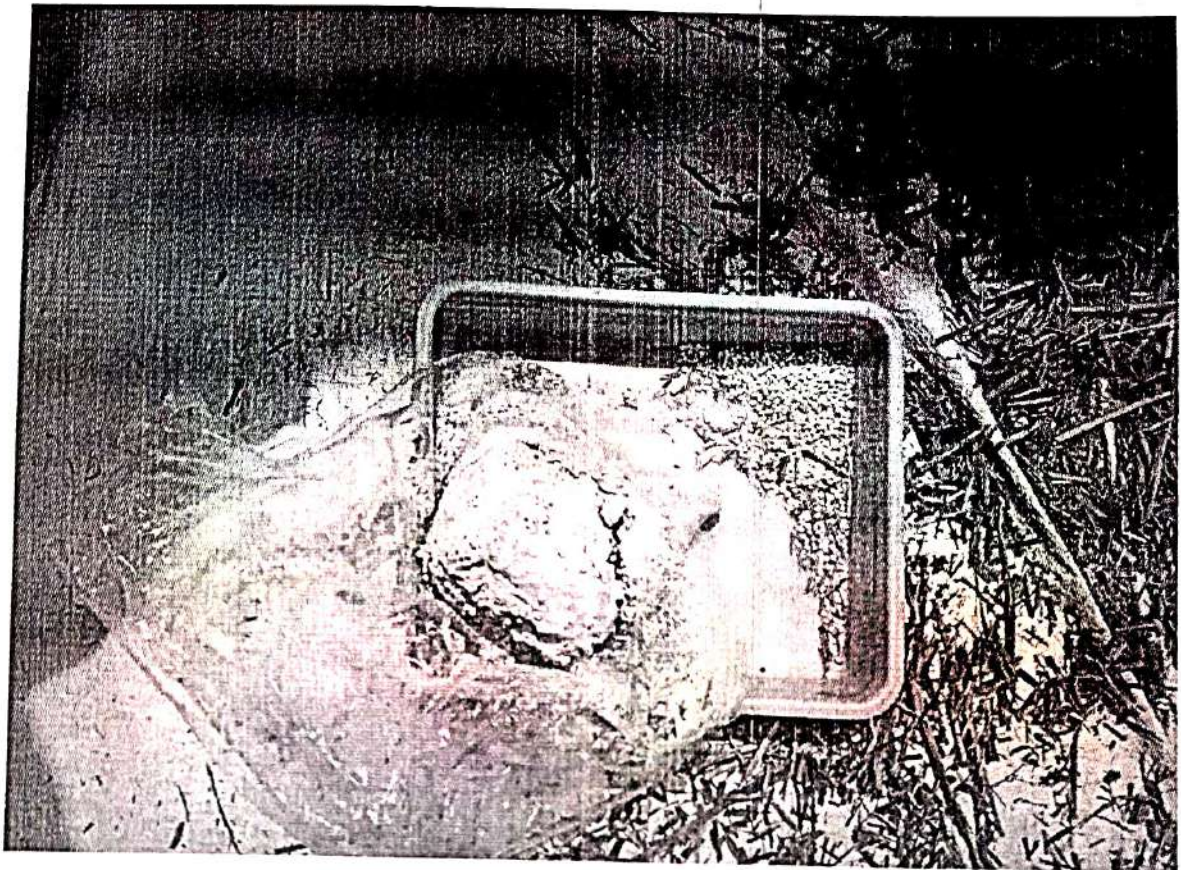
It is important to remember the purposes of Phase II when trying to determine the proper procedure and sequence to follow. One purpose is to remove unwanted ammonia. To this end the temperature range from 125° to 130°F is most efficient since de-ammonifying organisms grow well in this temperature range. A second purpose of Phase II is to remove any pests present in the compost by use of a pasteurization sequence.

At the end of Phase II the compost temperature must be lowered to approximately 75° to 80°F before spawning (planting) can begin. The nitrogen content of the compost should be 2.0 to 2.4 percent, and the moisture content between 68 and 72 percent. Also, at the end of Phase II it is desirable to have 6 to 8 lb of dry compost per square foot of bed or tray surface to obtain profitable mushroom yields. It is important to have both the compost and the compost temperatures uniform during the Phase II process since it is desirable to have as homogenous a material as possible.

3. Spawning

As a mushroom matures, it produces millions of microscopic spores on mushroom gills lining the underside of a mushroom cap. These spores function roughly similar to the seeds of a higher plant. However, growers do not use mushroom spores to 'seed' mushroom compost because they germinate unpredictably and therefore, are not reliable. Fortunately, mycelium (thin, thread-like cells) can be propagated vegetatively from germinated spores, allowing spawn makers to multiply the culture for spawn production. Specialized facilities are required to propagate mycelium, so the mushroom mycelium remains pure. Mycelium propagated vegetatively on various grains or agars is known as spawn, and commercial mushroom farmers purchase spawn from companies specializing in

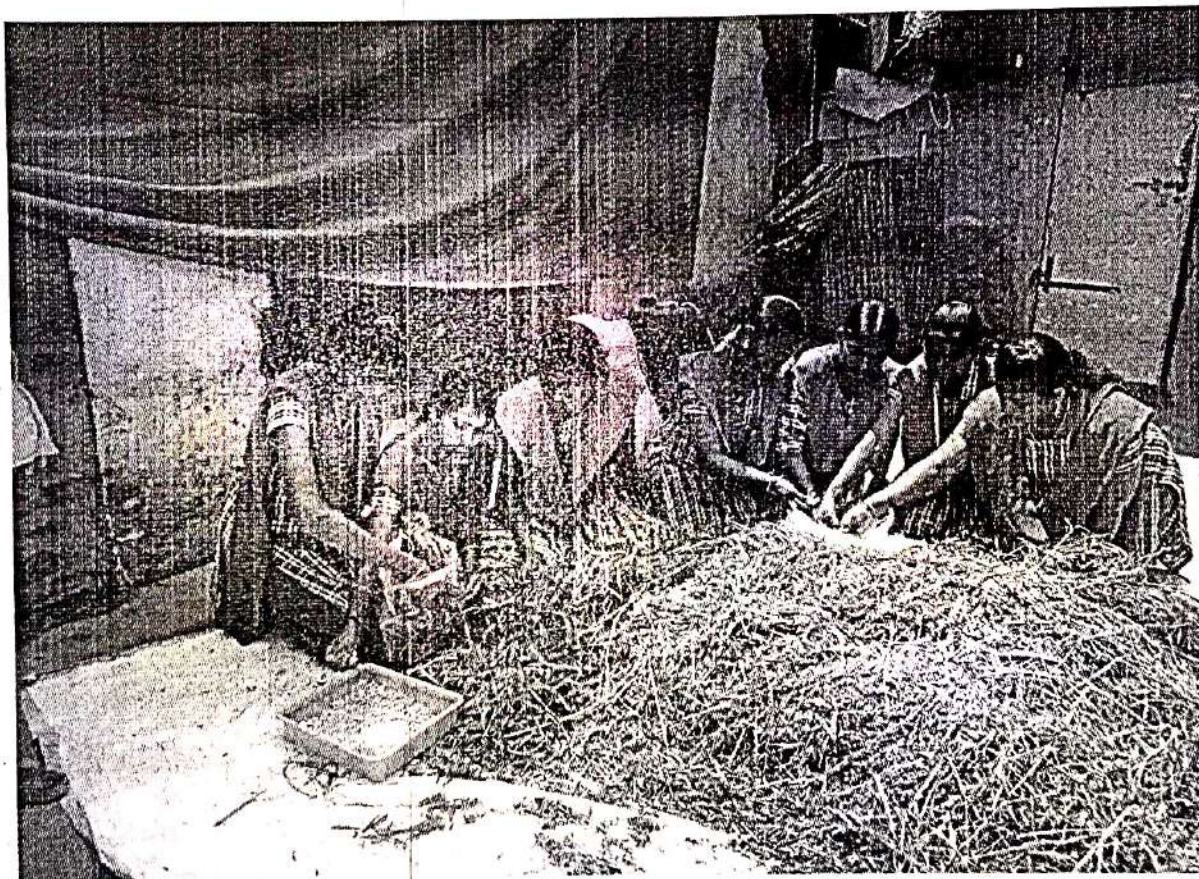
its manufacture.



Spawn makers start the spawn-making process by sterilizing a mixture of millet grain plus water and chalk; rye, wheat, and other small grain may be substituted for millet. Sterilized horse manure formed into blocks was used as the growth medium for spawn up to about 1940, and this was called block or brick spawn, or manure spawn; such spawn is not used today. Once sterilized grain has a bit of mycelium added to it, the grain and mycelium is shaken 3 times at 4-day intervals over a 14-day period of active mycelial growth. Once the grain is colonized by the mycelium, the product is called spawn. Spawn can be refrigerated for a few months, so spawn is made in advance of a farmer's order for spawn.

Spawn is distributed on the compost and then thoroughly mixed into the compost. For years this was done by hand, broadcasting the spawn over the surface

of the compost and ruffling it in with a small rake-like tool. In recent years, however, for the bed system, spawn is mixed into the compost by a special spawning machine that mixes the compost and spawn with tines or small finger-like devices. In a tray or batch system, spawn is mixed into the compost as it moves along a conveyor belt or while falling from a conveyor into a tray. The spawning rate is expressed as a unit or quart per so many square feet of bed surface; 1 unit per 5 ft² is desirable. The rate is sometimes expressed on the basis of spawn weight versus dry compost weight; a 2 percent spawning rate is desirable.



3.1 Supplementation at spawning

In the early 1960s, yield increases were observed when compost was supplemented with protein and/or lipid rich materials at spawning, casing and later. Up to a 10% increase in yield was obtained when small amounts of protein supplements were added to the compost at spawning. Excessive heating and stimulation of competitor molds in the compost substantially limited the amount of supplement and corresponding benefit that could be achieved. It was these limitations that were overcome by the invention of delayed release supplements for mushroom culture (Carroll and Schisler 1976). The disadvantages associated with the supplementation of non-composted nutrients to mushroom compost at spawning were largely overcome by encapsulating micro-droplets of vegetable oil within a protein coat that was denatured with formaldehyde. Increases of as much as 60% were obtained. Today, several commercial supplements are available that can be used at spawning or at casing to stimulate mushroom yield.

Amendment of mushroom substrate with Micromax® is another potential opportunity for growers to improve the yield capacity of their Phase II compost. Micromax® contains a mixture of nine micronutrients including (percentage dry wt basis): Ca (12%), Mg (3%), S (12%), B (0.1%), Cu (1%), Fe (17%), Mn (2.5%), Mo (0.05%), Zn (1%), and inert ingredients (57.35%). Research has shown that approximately 70% of the yield increase observed is due to Mn. Commercial supplement makers have begun to add Mn to their delayed release nutrients for mushroom culture.

Once the spawn and supplement have been mixed throughout the compost and the compost worked so the surface is level, the compost temperature is maintained at 75- 80°F and the relative humidity is kept high to minimize drying of the compost

surface or the spawn. Under these conditions the spawn will grow - producing a thread-like network of mycelium throughout the compost. The mycelium grows in all directions from a spawn grain, and eventually the mycelium from the different spawn grains fuses together, making a spawned bed of compost one biological entity. The spawn appears as a white to blue-white mass throughout the compost after fusion has occurred. As the spawn grows it generates heat, and if the compost temperature increases to above 80° to 85°F, depending on the cultivar, the heat may kill or damage the mycelium and eliminate the possibility of maximum crop productivity and/or mushroom quality. At temperatures below 74°F, spawn growth is slowed and the time interval between spawning and harvesting is extended.

3.2 Phase III and Phase IV compost

Phase III compost is Phase II compost spawn run in bulk in a tunnel, and ready for casing when removed from the tunnel and delivered to the grower. If the Phase III compost then is cased and the spawn allowed to colonize the casing layer before sending to the growing unit or delivering to growers, it is called Phase IV compost. The successes of both Phase III and Phase IV compost depend, to a large extent, on the quality of Phase I and Phase II composts. Use of Phase III compost may also improve mushroom quality, as fragmentation of the colonized compost tends to improve initial color and mushroom shelf life. In recent years, the use of bulk Phase III compost has increased in popularity because it allows an increase in the number of crops a grower can expect from his production rooms. Phase II production on shelves allows an average of about 4.1 crops per year whereas growers using Phase III bulk spawn run compost averages about 7.1 crops per year. An additional gain

can be made in the number of crops (10-12 crops per year) when Phase IV is used (Dewhurst 2002; Lemmers 2003; Chang 2006).

3.3 Mushroom varieties

In the United States, mushroom growers use three major mushroom cultivars: a) Smooth white hybrid - cap smooth, cap and stalk white; b) Off-white hybrid - cap scaly with stalk and cap white; and c) Brown - cap smooth, cap chocolate brown with a white stalk. Within each of the three major groups, there are various isolates, so a grower may have a choice of up to eight strains within each variety. Generally, white and off-white hybrid cultivars are used for processed foods like soups and sauces, but all isolates are good eating as fresh mushrooms. In recent years, the brown varieties have gained market share among consumers. The Crimini variety is similar in appearance to the white mushroom except it is brown and has a richer and earthier flavor. The Portobello variety is a large, open, brown-colored mushroom that can have caps up to 6 inches in diameter. The Portobello offers a rich flavor and meaty texture.

The time needed for spawn to colonize the compost depends on the spawning rate and its distribution, the compost moisture and temperature, compost supplementation, and the nature or quality of the compost. Complete spawn run usually requires 13 to 20 days. Once the compost is fully-grown with spawn, the next step in production is at hand.

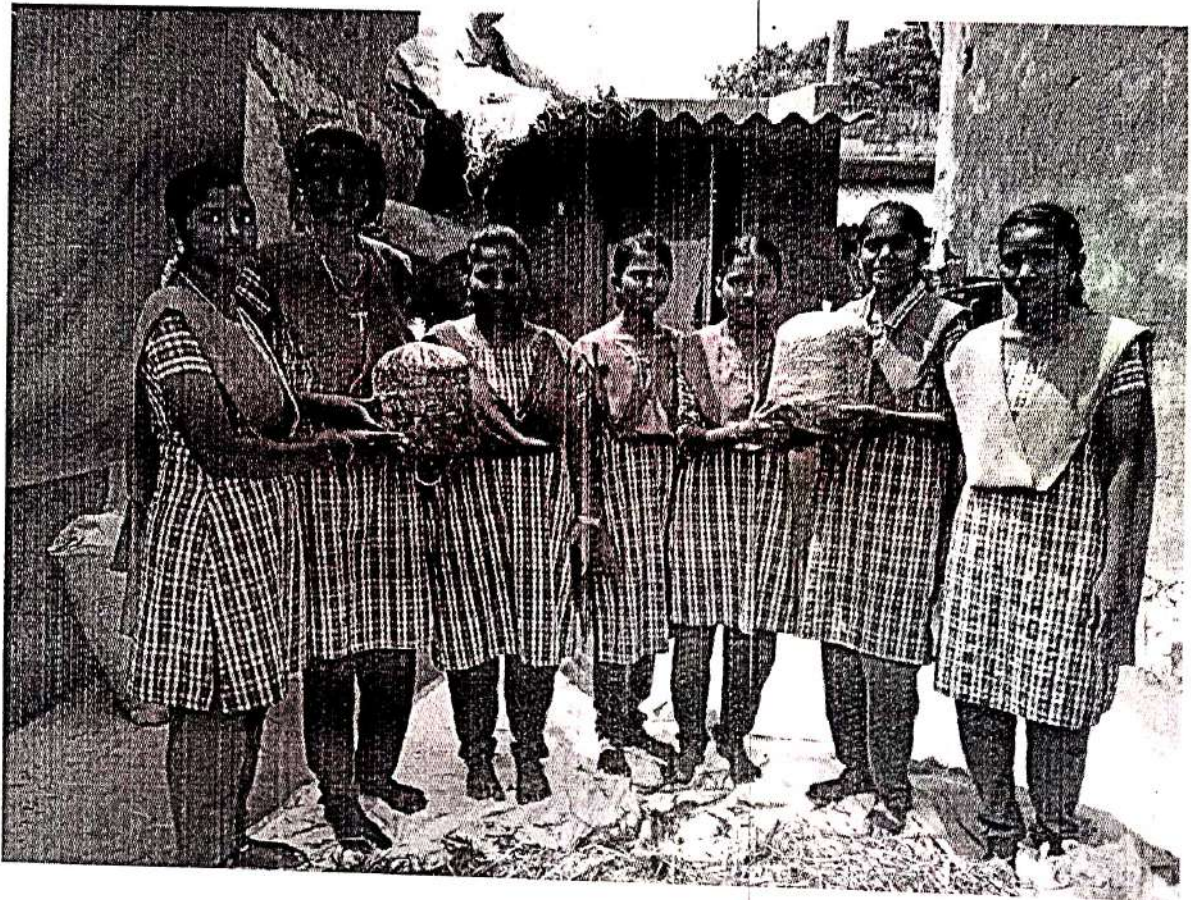
4. Casing

Casing is a top-dressing applied to the spawn-run compost on which the mushrooms eventually form. A mixture of peat moss with ground limestone can be used as casing. Casing does not need nutrients since casing acts as a water reservoir and a place where rhizomorphs form. Rhizomorphs look like thick strings and form when the very fine mycelium fuses together. Mushroom initials, primordia, or pins form on the rhizomorphs, so without rhizomorphs there will be no mushrooms. Casing should be able to hold moisture since moisture is essential for the development of a firm mushroom. The most important functions of the casing layer are supplying water to the mycelium for growth and development, protecting the compost from drying, providing support for the developing mushrooms and resisting structural breakdown following repeated watering. Supplying as much water as possible to the casing as early as possible without leaching into the underlying compost provides the greatest yield potential.

Sphagnum peat moss is the most commonly used material for casing. Sphagnum can range from brown (young, less decomposed, loose textured, surface peat) to black (compact, more decomposed, deep dug) and may be processed differently at the harvest site. Milled peat is partially dried before packaging and transport while wet-dug peat is transported in a saturated form. Some growers prefer wet-dug peat because of the higher water holding capacity compared to milled peat.

Peat moss-based casing does not require pasteurization because the material is free from pathogens, weed molds and nematodes that may reduce mushroom

yield. One 6-ft³ compressed bale when mixed with water and 40 lb of limestone will cover about 125 ft² of compost surface at about 2 inches depth.



4.1 Casing inoculum (CI)

Casing inoculum is a sterilized mixture of peat, vermiculite and wheat bran that has been colonized by mushroom mycelium. It is mixed with casing to decrease cropping cycle time, improve uniformity of mushroom distribution over the bed and improve mushroom cleanliness. Mycelium from the CI colonizes the casing layer while it fuses with the underlying mycelium of the compost. This allows more breaks per crop or more crops per year.

4.2 Supplementation at casing

The addition of nutrients at casing was first tried in the early 1960s.

Results showed that much greater amounts of nutrients could be added at casing than at spawning and that yield increases were almost proportional to the amount added.

Although yield increases as high as 100% may be realized, certain potential problems and limitations exist for supplementation at casing. Weed molds, nematodes and pathogens must not be present in the compost when supplementing at casing. These organisms will be dispersed throughout the compost when it is fragmented prior to supplementation and can multiply very rapidly before the mushroom mycelium recovers its growth.

Managing the crop after casing requires that the compost temperature be kept at around 75°F for up to 5 days after casing, and the relative humidity should be high. Thereafter, the compost temperature should be lowered about 2°F each day until small mushroom initials (pins) have formed. Throughout the period following casing, water must be applied intermittently to raise the moisture level to field capacity before the mushroom pins form. Knowing when, how, and how much water to apply to casing is an "art form" which readily separates experienced growers from beginners.

5. Pinning

Mushroom initials develop after rhizomorphs have formed in the casing. The initials are extremely small but can be seen as outgrowths on a rhizomorph. Once an initial quadruples in size, the structure is a pin. Pins continue to expand and grow larger through the button stage, and ultimately a button enlarges to a mushroom.

Harvestable mushrooms appear 18 to 21 days after casing. Pins develop when the carbon dioxide content of room air is lowered to 0.08 percent or lower, depending on the cultivar, by introducing fresh air into the growing room. Outside air has a carbon dioxide content of about 0.04 percentage.

The timing of fresh air introduction is very important and is something learned only through experience. Generally, it is best to ventilate as little as possible until the mycelium has begun to show at the surface of the casing, and to stop watering at the time when pin initials are forming. If the carbon dioxide is lowered too early by airing too soon, the mycelium will stop growing through the casing and mushroom initials form below the surface of the casing. As such mushrooms continue to grow, they push through the casing and are dirty at harvest time. Too little moisture can also result in mushrooms forming below the surface of the casing. Pinning affects both the potential yield and quality of a crop and is a significant step in the production cycle.

6. Cropping

The terms flush, break, or bloom are names given to the repeating 3- to 5-day harvest periods during the cropping cycle; these are followed by a few days when no mushrooms are available to harvest. This cycle repeats itself in a rhythmic fashion, and harvesting can go on as long as mushrooms continue to mature. Most mushroom farmers harvest for 35 to 42 days, although some harvest a crop for 60 days, and harvest can go on for as long as 150 days.

Air temperature during cropping should be held between 57° to 62°F for good results. This temperature range not only favors mushroom growth, but

cooler temperatures can lengthen the life cycles of both disease pathogens and insects pests. It may seem odd that there are pests that can damage mushrooms, but no crop is grown that does not have to compete with other organisms. Mushroom pests can cause total crop failures, and often the deciding factor on how long to harvest a crop is based on the level of pest infestation. These pathogens and insects can be controlled by cultural practices coupled with the use of pesticides, but it is most desirable to exclude these organisms from the growing rooms.



The relative humidity in the growing rooms should be high enough to minimize the drying of casing but not so high as to cause the cap surfaces of developing mushrooms to be clammy or sticky. Water is applied to the casing so water stress does not hinder the developing mushrooms; in commercial practice this means watering 2 to 3 times each week. Each watering may consist of more or

fewer gallons, depending on the dryness of the casing, the cultivar being grown, and the stage of development of the pins, buttons, or mushrooms. Most first-time growers apply too much water and the surface of the casing seals; this is seen as a loss of texture at the surface of the casing. Sealed casing prevents the exchange of gases essential for mushroom pin formation. One can estimate how much water to add after first break has been harvested by realizing that 90 percent of the mushroom is water and a gallon of water weighs 8.3 lb. If 100 lb of mushrooms were harvested, 90 lb of water (11 gal.) were removed from the casing; and this is what must be replaced before second break mushrooms develop.

Outside air is used to control both the air and compost temperatures during the harvest period. Outside air also displaces the carbon dioxide given off by the growing mycelium. The more mycelial growth, the more carbon dioxide produced, and since more growth occurs early in the crop, more fresh air is needed during the first two breaks. The amount of fresh air also depends on the growing mushrooms, the area of the producing surface, the amount of compost in the growing room, and the condition or composition of the fresh air being introduced. Experience seems to be the best guide regarding the volume of air required, but there is a rule of thumb: $0.3 \text{ ft}^3/\text{ft}^2/\text{hr}$ when the compost is 8 inches deep, and of this volume 50 to 100 percent must be outside air.

Ventilation is essential for mushroom growing, and it is also necessary to control humidity and temperature. Moisture can be added to the air by a cold mist or by live steam, or simply by wetting the walls and floors. Moisture can be removed from the growing room by: 1) admitting a greater volume of outside air; 2) introducing drier air; 3) moving the same amount of outside air and heating it to a higher

temperature since warmer air holds more moisture and thus lowers the relative humidity. Temperature control in a mushroom growing room is no different from temperature control in your home. Heat can originate from hot water circulated through pipes mounted on the walls. Hot, forced air can be blown through a ventilation duct, which is rather common at more recently built mushroom farms. There are a few mushroom farms located in limestone caves where the rock acts as both a heating and cooling surface depending on the time of year. Caves of any sort are not necessarily suited for mushroom growing, and abandoned coalmines have too many intrinsic problems to be considered as viable sites for a mushroom farm. Even limestone caves require extensive renovation and improvement before they are suitable for mushroom growing, and only the growing occurs in the cave with composting taking place above ground on a wharf.

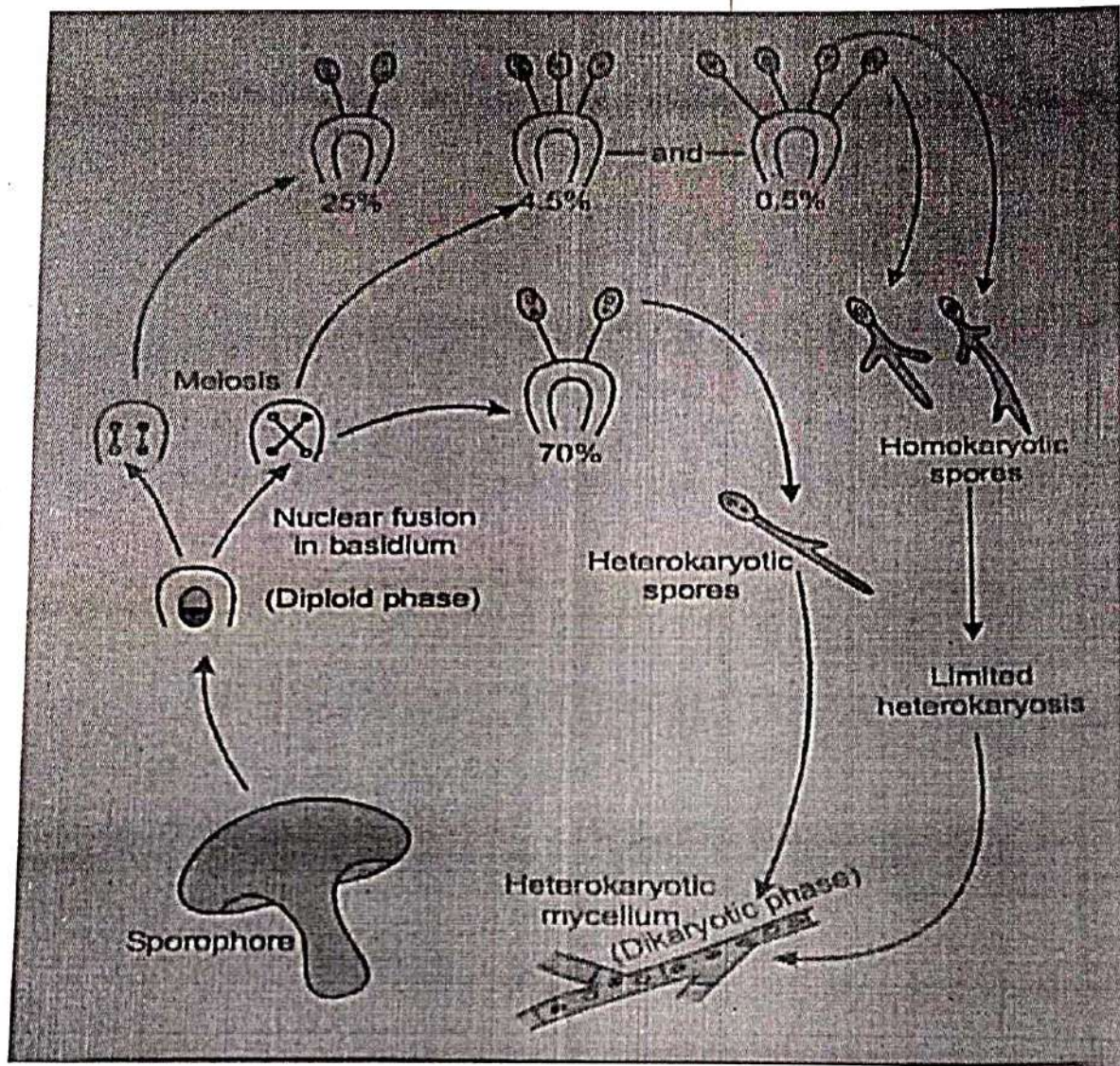


Mushrooms are harvested in a 7- to 10-day cycle, but this may be longer or shorter depending on the temperature, humidity, cultivar, and the stage when they are picked (Fig. 6). When mature mushrooms are picked, an inhibitor to mushroom development is removed and the next flush moves toward maturity. Mushrooms are normally picked at a time when the veil is not too far extended. Consumers in North America want closed, tight, and white or brown (Crimini) mushrooms while open browns (Portobello) are preferred by some consumers. The maturity of a mushroom is assessed by how far the veil is stretched, and not by how large the mushroom is. Consequently, mature mushrooms are both large and small, although farmers and consumers alike prefer medium- to large-size mushrooms.

Picking and packaging methods often vary from farm to farm. Freshly harvested mushrooms must be kept refrigerated at 35° to 45°F. To prolong the shelf life of mushrooms, it is important that mushrooms "breathe" after harvest, so storage in a non-waxed paper bag is preferred to a plastic bag.

A question frequently arises concerning the need for illumination while the mushrooms grow. Mushrooms do not require light to grow; only green plants require light for photosynthesis. However, growing rooms can be illuminated to facilitate harvesting or cropping practices.

LIFE CYCLE OF AGARICUS BISPORUS



UNIT-IV
Cultivation of Agaricus bisporus

UNIT-IV
Cultivation of Agaricus bisporus

Agaricus bitorquis a sister species of *A. bisporus* requires 4-6°C higher temperature than *A. bisporus* for its growth and fructification. It has longer shelf life. Its fruit bodies are large and hence ideal for canning. It is resistant to all known mushroom viruses. It can tolerate higher carbon dioxide concentration in the cropping room compared to *A. bisporus*.

It is a 4 spored fungus as compared to 2 spored *A. bisporus*. Its sexual behaviour is unifactorial heterothallic (Raper, 1976). *A. bisporus* on the other hand has secondary homothallic sexual behaviour. First attempt for its cultivation was made by Calleux (1969) and later by Hasselback and Musters (1971), but the successful cultivation could be done by Poppe (1972) after isolating and selecting the pure culture of *A. bitorquis* (Poppe 1971). He observed that the fungus required higher temperature for its growth and cultivation and had superior shelf life as compared to *A. bisporus*. Fritsche and Pomper (1975) reported the availability of new commercially available strain; of *A. bitorquis* namely Horst K-26 and Horst K-32, both giving very white fruitbodies with higher shelf life. Fritsche (1976) reported great variability among the tissue cultures prepared from fruit bodies from different origins. He further reported that only two strains gave high yield with better quality mushrooms. In India cultivation of *bitorquis* was first attempted by Tewari and Sohi (1976) at Bangalore. Raper (1976) reported that in *A. bitorquis* normal fruit bodies developed at conditions comparable to growth of *A. bisporus* but for temperature which was higher in case of *A. bitorquis*. Raper (1978) further reported that this mushroom had life cycle which allowed that false truffle (*Diehlomyces microsporus*) could reduce of strains K26 and K32 under varied growing conditions and observed fl traits. Van Zaayen and Pol-Luiten (1977) recorded higher productivity facilitating the controlled mating for making crosses combine genetic visible distinct sexual interactions in compatible mating type, thus great advantage in breeding because of its heterothallic nature. In strain Somycell 2017 more than in any other strain. Guleria (1985) reported that 30 °C was best temperature for spawn growth and vegetative growth in compost. He also

spawning and Spawn Run:

As the temperature of the compost comes down to about 25-30 °C, the that spawn is mixed in the compost. The optimum rate of spawn is 0.5- 0.75% of fresh weight of compost. Any method of spawning like surface spawning, layer spawning or through spawning can be practiced, however, through spawning gave the best results. After thoroughly mixing the spawn into compost, it is then filled in bags/beds and slightly pressed with hands and covered. Pressing too hard particularly when moisture level of compost is high, can result in anaerobic conditions and harmful for the mycelial run. The temperature of the spawned compost is maintained at 28-30 °C. If the temperature is properly maintained with high carbondioxide concentration in the rooms, spawn run will be completed in 2 weeks it time. If the bed/compost surface has been covered with newspaper sheets, sheets are periodically sprayed with water to keep these moist and RH is maintained at 85-90%. However, if the cover is of 3 polythene there is no need to spray water on bed surface. In controlled environment growing rooms temperature and humidity can be maintained through air handling unit. During the spawn run very little of fresh air is required that too for maintenance of temperature. Good spawn run is considered when the entire compost is impregnated by spawn and turns white.

Casing and Case Run:

Casing is a practice of applying a layer of casing mixture on the surface of the spawned compost. In button mushrooms no fruiting can be obtained if a layer of casing soil is not applied. In western countries peat is largely used as casing for button mushroom. This material is not available in our country and Farm Yard Manure (Fym) and spent compost are used as substitute peat. Both these should be atleast 2 years old and completely decomposed. Leaching of these materials in water for 4-6 hours improves the quality of both these materials by removing toxic salts. Casing material is prepared by mixing FYM with loam soil in the ratio of

4: 1 (v/v), spent compost can be used as such the pH of the casing should be 7-7.5. Moist casing soil should be pasteurized in pasteurization chamber at a temperature of 65-70 °C for 6-8 hours. After removing covers from the beds/bags the surface is leveled by slightly pressing with hands and a uniform layer or casing, 4-5 cm in thickness is applied. No water is applied on bed surface before casing, as this will not only make the process of casing very cumbersome but will kill the mycelium on the surface and hence delay the case run. After the casing has been applied water needs to be applied regularly to keep the casing moist by spraying water as must. Formaldehyde @ 0.5% can be added to water during the first spray immediately after casing to kill the contaminants that might have come during spawning, casing, spawn run and case run. Casing should be moist at the time of application and should

besprayed with water immediately after application.



During spawn run a temperature of 28-30 °C, high RH (85-90%) and high carbondioxide concentration are maintained. Minimal fresh air is required during case run. Higher carbondioxide concentration during case run results in quick case run. The moisture available in the casing soil is very important hence casing should be kept wet by spraying water periodically. If these conditions are provided, case run takes about one weeks time to complete. During this stage mycelium completely colonies the casing soil and forms thick strands compared to silky strands in the compost.

Various agronomic practices that can improve the prospects of a crop are as follows:

Supplementation with N-Rich substances:

Supplements are nitrogen rich substances that are added to completely colonized compost before application of casing layer to causing layer to improve the nutritive level of compost. The most frequent used supplements are soybean seed meal and cotton seed meal. These are coarsely ground and treated with 5000 ppm formaldehyde solution and then thoroughly mixed in fully colonized compost at the rate of 1 per cent on fresh weight basis. The supplementation results in an increase in bed temperature by 2-3 °C which though does not cause any perceptive damage to the crop but needs to be managed properly to get a food crop. Supplementation can result in 20-25% increase in yield with good quality mushrooms.

CAC'ing (Spawned casing):

Completely colonized composed is mixed in the casing soil at the rate of 1-1.5 kg per m² bed area to be covered at the time of casing application. This practice gives a quicker case run followed by early crop with evenly disturbed fruit bodies in initial heavy flushes this practice also gives early finish of crop.

Ruffling of Spawn Run Compost :

The compost showing complete colonization is broken to disturb the mycelium. It is completely ruffled and 'caned' in bags/beds followed by application of casing soil. This ruffling is believed to trigger the fructification in button mushrooms and thus results in early crop with heavy initial flushes and early finish of crop, thus entire yield potential can be obtained in 3-4 weeks of cropping.

Certain other practices like spraying of veradix (Indole butyric acid) @ 0.1% at pinhead initiation stage during the first three flushes have been reported to improve yield in *A. bitorquis*.

Cropping:

After the case run is complete, air is introduced in cropping rooms by opening ventilation and the temperature is brought down to 24 °C. The casing soil is kept moist by periodically spraying water periodically on the surface of casing soil. After these changes have been brought about, it takes about 10-12 days for fruit body initials appear. Frequent air changes are given and temperature of rooms is maintained at 24-26 °C. After the pinheads have been formed, direct spray of water on pinheads is avoided but relative humidity in the rooms is maintained at 85%. Spraying is resumed on bed surface once the pinheads have attained the size of pea sometimes there is a problem of mass pinning in *A. bitorquis* than can be avoided by restricting the entry of fresh air through regulation of ventilation opening. The requirement of air as a general rule is 20-25 m³ air per tonne of compost. The air is forced into room through air handling units which has an in built centrifugal fan than can create an air pressure supporting 50 mm of water level. This will result in moderate pinning with majority developing into mature fruit bodies. Harvesting is done when the fruit body size is about 3-4 cm, and the cap is still not open. For harvesting fruit body is held lightly between thumb and fore finger and rotated slightly and lifted. Soil ridden lower end which has some root like rhizoids is removed with a sharp knife. The debris attract large number of insect pest and disease propagules and

therefore should be disposed off in such a way that it does not serve as an inoculum for the crop.



During the first and second flush, the production is heaviest with very active mycelium and therefore requirement of fresh air is maximum during this stage carbon dioxide concentration at this stage should be below 1500 ppm. Precise temperature humidity and fresh air levels can only be maintained in controlled environment cropping rooms which are insulated and where conditioned air is forced into room via a circulating ducts which has holes for directing the air downwards to floor and redistributing these between the tiers through maintenance of positive pressure. Exhausted air is removed through vents near the II floor. All entry points and exhausts are covered with fly mesh/fliers to prevent the entry of insect-pests and disease propagules. Clean tap water should be used for spraying.

Mushrooms are packed in polythene bags with small pin holes to prevent anaerobic rotting and chilled for 2-4 hours at 5-6 °C and marketed. Under refrigeration, these mushrooms have a shelf life 3-4 days. Compared to *A. bisporus*, this mushroom can stay in

good condition for 2-3 days even at 15 °C without any adverse effect on its quality. In absence of ready market for the fresh mushroom, this mushroom can be canned or pickled. The mushrooms are harder compared to *A. bisporus* and this can retain their texture in cans for pickles. Its outer surface is smooth and silky compared to *A. bisporus* where fruit bodies are not so smooth.

UNIT- V

PROCESSING AND PRESERVATION

As far as processing technologies are concerned, sun drying of the mushroom is one of the simplest and oldest methods followed by growers from the time immemorial. Due

to the difficulties in drying of some of the mushrooms, new preservation technologies like cabinet drying, canning, picking freeze-drying and irradiation treatment mushrooms have developed to improve the self life and consumption of mushrooms.

A.Short Term Storage :

White Button Mushroom: (Agaricus bisporus)

White button mushroom still dominates the Indian and international market and a lot of work has been done minimize the loss in quality of these mushrooms.

Washing :

Because of the unavailability of peat as casing material in India, washing becomes necessary to remove soil particles. The washed mushrooms generally deteriorate rapidly than mushroom packed dry, due to the increased water content that results in greater growth rate of spoilage by bacteria. Small growers wash in solution of reducing agent to retard browning cause by polyphenol oxidase. Hence, various anti, microbial as well as reductant compounds are used in washing mushrooms to extend the shelf life. Fresh white mushrooms are white or light buff with out dark marks on either cap (pileus) or stem (stipe), the veil is closed and the gills (lamellal) are not visible. To maintain whiteness, dipping of mushroom in dilute solution of hydrogen peroxide (1:3) for half an hour and then steeping in 0.25% citric acid solution containing 500ppm sulphur dioxide has significant effect. However, the common practice to maintain whiteness of the produce and to remove any adhering casing soil, compost or other substrates is to wash the produce in 0.025 to 0.05% potassium metabisulphite solution.

Beelman (1987) reported that oxine, a stabilized form of chloride dioxide, was very effective in controlling bacterial growth and colour deterioration when used at a level of 50 ppm or higher with a two minute or longer wash period at 12°C the use of sodium hypochlorite (100 ppm) and calcium chloride (0.55%) with oxine (100 ppm) resulted in increased antibacterial effectiveness. use of calcium chloride and oxine also resulted in lower cap opening and firmer mushrooms during storage. saxena and rai (1988) observed that washing of mushroom in 0.05% potassium metabisulphite improved the initial whiteness, which lasted longer during the storage. Guthrie and Beelman (1989) studied the effect of different methods of washing mushrooms on bacterial population and quality of fresh mushrooms during the storage. They found that washing fresh mushroom in water containing sodium sulphite solutions results in lower bacterial numbers and an improved initial appearance, but more rapid bacterial growth and browning occurred during subsequent storage compared to unwashed controls. Mushroom washed in hard water (150 ppm calcium carbonate) reduced bacterial growth and there was less colour deterioration during storage. Washing mushrooms in a solution consisting of oxine (50ppm), sodium erythorbate (0.1%) and calcium chloride (0.5%) resulted in significant lower bacterial populations and less colour deterioration during the storage later.

Modified Atmospheric packaging (MAP):

Modified Atmospheric Packaging is a method by which a modified atmosphere is created in a sealed package of fresh product by respiratory gas exchange, namely oxygen (O₂) intake and carbon dioxide (CO₂) evolution. When the rate of gas exchange, equilibrium concentrations of O₂ and CO₂ are consequently established. The equilibrium depends on: temperature, respiration, rate of specific product, product weight, O₂ and CO₂ permeabilities of packaging and film area.

Modification Atmospheric Packaging (MAP) of mushrooms has been shown successfully to delay senescence and maintain quality after harvest. It has been found that the

shelf life of mushrooms increased by over wrapping them with PVC films. Chopra et al, (1985) recommended low gauge polythene bags with 0.5% venting area for packaging mushroom in case of refrigerated storage. Saxena and Rai (1988) studied the usage of non-perforated polythene bags for the storage of button mushrooms for 4 days at 5 °C. For transporting mushrooms to long distance, polystyrene or pulp-board should be used instead of using polythene bags. The punnets are over-wrapped with differentially permeable Poly Vinyl Chloride (PVC) or poly acetate films. They create modified atmosphere in punnets producing an atmosphere of about 10% CO₂ and 2% O₂.

Halachmy and Mannhein (1991) reported that there is no chilling injury to mushroom at temperatures as low as 1.5 °C. the respiration rates were found to decrease with temperature and reduction in temperature resulted in the best appearance of mushroom. The critical O₂ and CO₂ concentration were found to be 1.5-2% and 12% respectively. Lopez-Briones et al., (1992) found that CO₂ concentration below (<2.5%) reduces brown discoloration. Roy et al., (1995) found an optimum oxygen concentration of 6% minimized the cap opening in conventionally grown mushrooms.

Modified Humidity Packaging (MHP)

Most polymeric films are used in conventional packings have lower water vapour transmission rates relative to transpiration rates of fresh produce. This leads to a nearly saturated conditions within packages. The high in package relative humidity (IPRH) can cause condensation of water vapour within a package and allow microbial growth. This may either increase or decrease the spoilage depending on the product depending on their transpiration coefficients and water potentials.

Shirazi and Cameron (1992) found that the IPRH can be controlled at the predetermined RH level using adsorption isotherm. To obtain the desired IPRH, there are two compounds that exhibit type-II possible approaches: perforation of the package, which

precludes the possibility of achieving modified atmosphere conditions within the package, and use of in-package water absorbing compounds like calcium chloride can maintain the required RH. Roy et al., (1996) found that MAP in combination with MHP further improved the shelf life of fresh mushrooms during storage.

Controlled Atmospheric Storage

This method is based on the principle of environmental control where mushrooms are stored. In this method, the oxygen and carbon dioxide concentrations are altered inside the package and respiration rate gets altered. Controlled atmospheric package reduces brown discoloration (enzymatic browning) and the shelf life is extended.

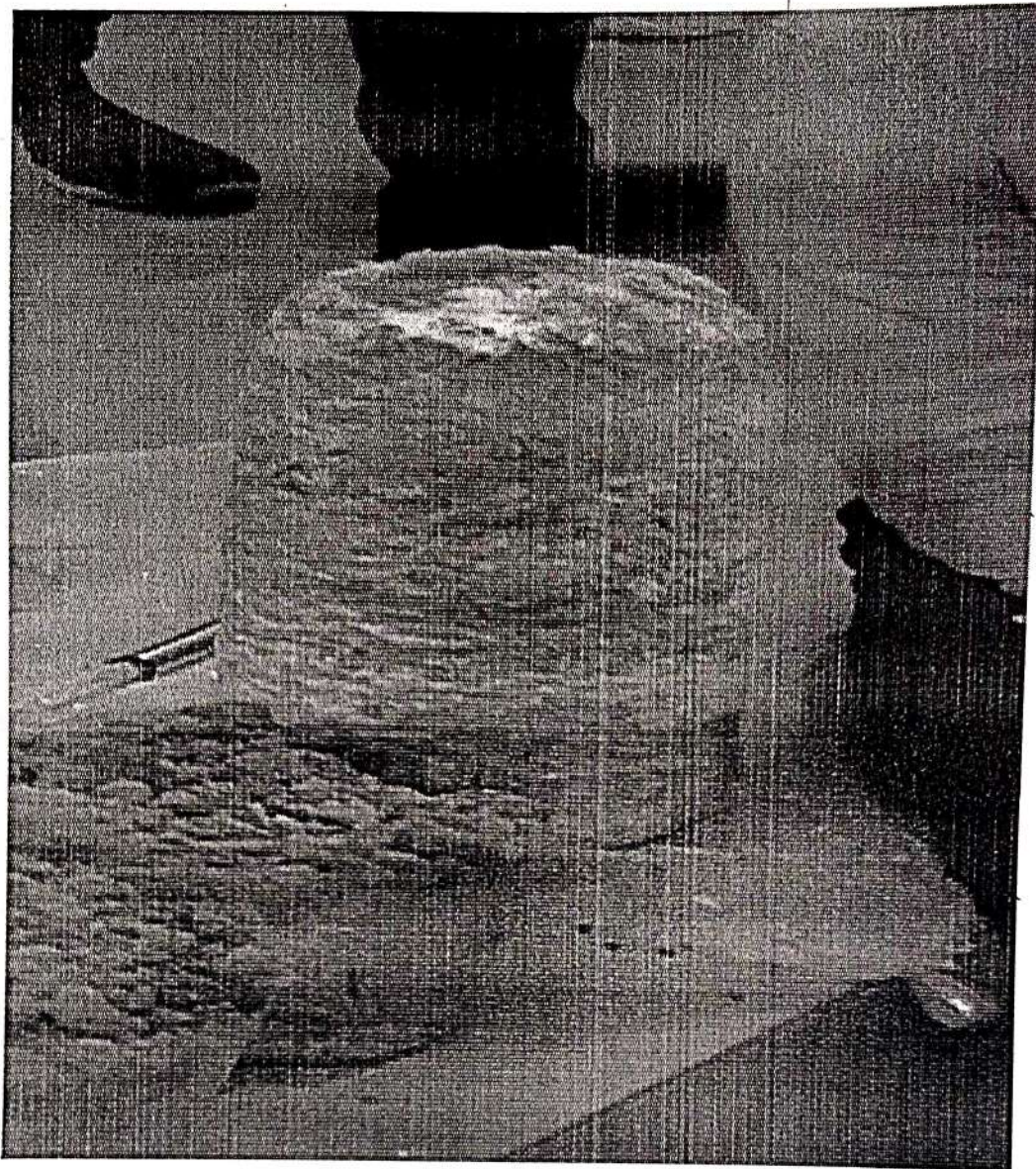


The calcium chloride added to the irrigation water improved yield and colour of the canned mushroom product. Mushrooms exposed to lower airflow rates in the growing room remain whiter than those exposed to higher airflow rates. Addition of proprietary form of stabilized carbon dioxide (Oxine, 200 ppm) to preharvest watering applications on mushrooms had lower incidence of blotch and retained whiter colour during storage. (Beelman et al., 1989), Chopra et al., (1985) reported a successful combination treatment of honey + citric acid + latex (0.5% + 0.5% + 0.5%) for short-term storage.

Packing and packaging

Properly washed/treated with chemical solution, the mushrooms are packed in suitable containers with the main objective of proper protection and preservation of produce. While a good package sells a product, a mediocre package can interfere with sale of an otherwise excellent product. For the local markets in India, mushrooms are packed in retail packs of 200 g or 400 g in simple polythene packs of less than loo gauze thickness. Large quantity packing of mushrooms is done using polythene or pulp-board punnets, which will withstand long distance transport. These punnets are over-wrapped with differentially permeable PVC or poly acetate films. These over-wrapping help in creating modified atmosphere in punnets with 10% CO₂ and 2% O₂ and mushrooms maintain their fresh look for 3 days at 18 °C. In loo gauze polythene bags 0.5 per cent ventilation is generally recommended for refrigerated storage

whereas, for the local market non-perforated bags should be used.



Precooling or Refrigeration

The temperature of the button mushroom after picking varies between 15 °C and 18 °C, and it rises steadily during the storage due to respiration and atmospheric temperature. This heat causes deterioration in quality. Hence, the heat should be removed immediately after the harvest and the temperature of mushrooms should be brought down to 4-5 °C as quickly as possible. The choice of the cooling system depends upon the quantity to be handled, which

may be a refrigerator for a small grower to a cold room with all facilities for a commercial grower. Using forced chill air, ice bank or vacuum cooling systems, mushrooms can be cooled up to 2-4 °C.

The size and shape of the packs also play an important role in cooling room. Packs with more than 10 kg mushrooms or with 15 cm thick layers of mushroom cause problems. Vertical flowing of air is more suitable for cooling. The mushrooms should not be stored in the same cooler along with fruits as the gases produced by fruits i.e. ethylene cause discoloration and vacuum cooling is becoming more popular.

Vacuum Cooling

In vacuum cooling, the water in cell walls and interhytal spaces of mushrooms is evaporated under low pressure and the evaporative cooling lowers the temperature from ambient to 2 °C in 15 to 20 minutes. Vacuum cooling is an uniform and faster process, where mushrooms are subjected to very low Pressure and water evaporates giving of the latent heat of vaporization, thus cooling itself. The 319 vacuum Cooled Mushrooms have superior colour than conventional cooled mushrooms. The major drawback of the system is the high capital cost, and an inevitable loss of fresh weight during the process of cooling. Filling and emptying the cooling chamber introduces another operation and expenses into the marketing chain.

Ice-Bank Cooling

In order to reduce the weight loss during the conventional vacuum cooling, ice bank cooling of mushrooms is flow in vogue, wherein a stack of mushrooms is passed through forced draft of chilled but humidified air from the ice-bank.

Steeping Preservation

The simplest and most economical method to preserve for short periods is by steeping them in solution of salt or acids. The common practice is that cleaned mushrooms are washed in water or chemical added water and filled in large plastic containers. Blanching in brine solution is generally done before filling them into the cans. Brine solution is then added into the cans or containers. Pruthy et al., (1978) reported that steeping of water, blanched mushrooms in 1% potassium meta bisulphate (KMS) along with 2% citric acid (over night), before drying improved colour, texture and reconstitution properties. Solution consisting of 2% sodium chloride, 2% citric acid, 2% sodium bicarbonate and 0.15% KMS was used for steeping preservation of blanched mushrooms for 8-10 days at 21-28 °C (Kapoor, 1989). Chemical solution of 2% salt, 2% sugar, 0.3% citric acid, 0.1% KMS and 1% ascorbic acid was also used for steeping preservation of mushrooms. Steeping preservation of mushrooms helps to extend shelf life of mushrooms.

Radiation Preservation

Application of gamma radiation retards the deteriorative process and helps in extending the shelf life of mushroom. An enhancement in shelf life of *Agaricus bisporus* up to a period of 10 days can be achieved by application of gamma ray close to 2 KGy and storage at 10 °C. Irradiation reduces the incidence of fungal and bacterial infection and retards the breakdown of mannitol trehalose. The loss of flavour components is noticed in irradiated mushrooms. The cap opening is also delayed by irradiation. Amino acids in fresh mushrooms preserved by γ irradiation showed that irradiation at low levels proved better than irradiation levels of 1 and 2 KGy.

Transport:

A lot of care is to exercise for transportation of mushroom, because the effect of pre-cooling and packing will be partially negated if the product is later stored and transported in a hot environment. Mushroom therefore, need refrigerated transport. To keep the mushrooms cool during transport to short distances, the polypacks of the mushrooms can be stacked in small wooden cases or boxes with sufficient crushed ice in polypacks (over-wrapped in paper). For long distance, transport of large quantities in refrigerated van is essential though it is costlier.

Long Term Storage

White Button mushrooms:

Freshly harvested mushrooms are highly perishable and require immediate processing for stable preservation. Picking and sun drying are economically viable methods of preserving mushrooms during the glut period. However, freezing, freeze drying and canning gives a product of excellent quality and can be exposed commercially for export market. The following methods have potential for processing mushroom into different products for long

Preservation by low Temperature (freezing)

Individual quick freezing technology is employed to yield a product of excellent longer shelf life. Quick freezing is a process where temperature of the mushrooms passes through the zone of maximum crystal (0-3°C) in 30 min. or less. Enzyme activity is only restarted at freezing

temperature. To control their activity mushrooms prior to freezing are required to be blanched. For best results, the storage temperature should be 35 to 40°C

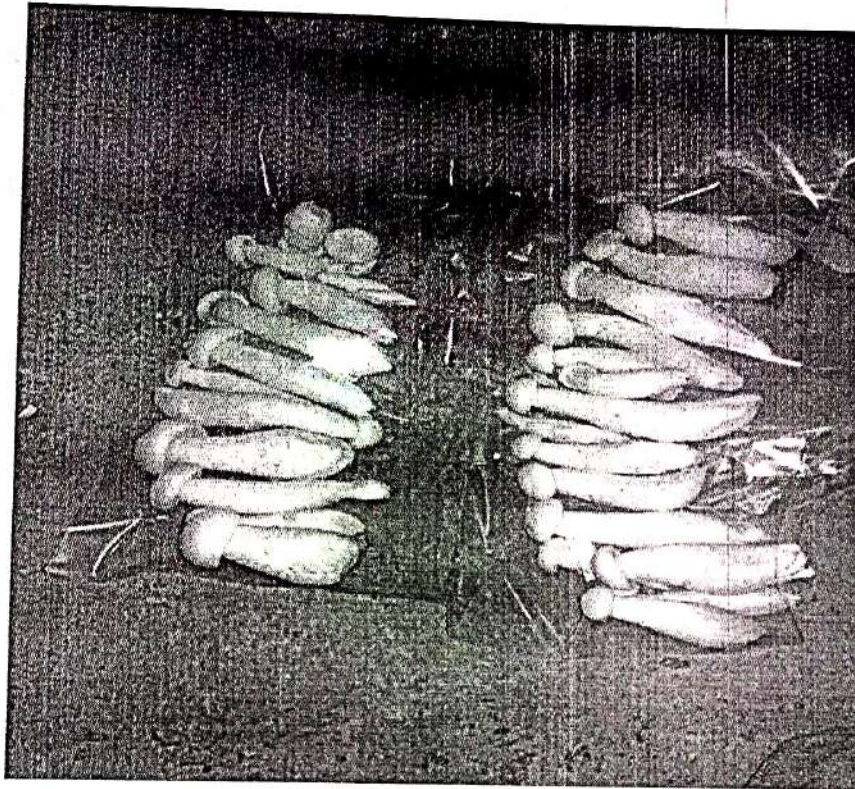
Preservation by High Temperature (canning)

The main principle of preservation by the use of high temperature is to destroy the micro organism and to prevent recontamination by hermetic sealing. During recent years, retortable glass bottles and flexible pouches are also being used due to high cost of cans. Generally, for canning purpose, small size buttons are required without stem attached. Ascorbic acid, ethylene diamine tetra acetic acid (EDTA) and citric acid recommended as useful adjunct for improvement of colouring canning of mushrooms. The canning process can be divided into six unit operations namely, cleaning, blanching, filling, sterilization, cooling, labeling and packaging. The storage before canning is done at 4-5°C. The mushrooms without stem or stem length of 0.5 to 1 cm are preferable for canning and these are canned whole or sliced.

Good quality mushroom are selected and diseased and damaged /bruised shriveled and browned reject. Grading on the basis of cap diameter is also done (Azad et al., 1987). Then the mushrooms are washed 3-4 times in cold running water to remove air, soil etc. without disturbing them. To prevent dark discolouration of skin, the mushrooms are washed in iron free with 0.1 % citric acid. Blanching is done to inhibit enzymatic activity, To inactivate micro organisms and to remove from raw material and uniform pack the mushrooms are blanched in stainless steel kettles filled with a boiling solution of 0.1% citric acid and 1% common salt. The blanching time ranges from 5 to 7 minutes at 95-100° (Tanga 1974; Saxena and Rai, 1990). The foam developed during blanching should be removed constantly. The loss of weight during blanching is 20-25% of the fresh weight of products (Saxena and Rai, 1990). Mushrooms are filled in tin cans of the sizes i.e A -I tall and A-2 ½ for the domestic market and A -10 for export. The solution at 90°C is added to the filled cans up to brim. Food additives like

agar(0.125%) and pectin (0.5%) improves the flavor of canned products (lal and Sharma,1997). After brining , the cans are exhausted to remove entrapped air gasses to ensure a longer shelf life for which can filled brine are fed to the exhaust fox for a specified period depending up on the length of tunnel and size of can. Exhausting can also the done by placing the filled cans in boiling water till the temperature in the center of the can reaches 85-90° c for 1-2 min. then the can is sealed hermetically with double seamer and kept in a up side down position (Rai et al., 2003).

Cans are now sterilized at 15 lbs pressure for 25-35 minutes to avoid spoilage by microorganisms. The sterilization is done at 118°C to avoid discoloration and burnt taste. Sterilized canned are cooled rapidly in cold running water, to bring them to room temperature. It gives a sudden shock to the microorganisms to get rid of their adverse effect. To avoid rusting, the outer surfaces of the cans are dried immediately. Then these are labeled and placed in wooden or corrugated cardboard boxes. Cans are checked for any swell, leakage, puffing and other disorders before labeling by keeping them at room temperature at 8-10days(Raietal.,2003).



Preservation by Drying (Freeze Drying)

The main objective of drying is removal of free water to such a level ($a_w < 0.7$) that the bio-chemical and microbial activity is checked due to reduced water activity. The removal of water from substance by direct sublimation from frozen state to the vapour state is known as freeze-drying. Freeze drying yields a product of excellent quality, but the cost of removal of water is ten times higher than conventional air-drying. First the water present in the product is removed by sublimation. After removal of all the ice, the food may contain little quantity of water that may be removed by evaporation in the freeze dryer. In a freeze-drying system, the size and shape of original product can be retained and the shrinkage, which is a problem with

other drying methods, is negligible. Mushroom becomes brittle, but have a superior flavour and appearance (Kapoor, 1989).

Sun drying is the appropriate technology for our country, because of free source of energy and minimum investment in capital cost. Blanching and sulphuring/sulphiting are important treatment given before drying. Pre-drying soaking of blanched slices in potassium metabisulphite (1A) + citric acid (0.2%) + sugar (6%) + salt (3%) for 16 hours followed by drying at 60±2 °C for 8.5 hours yields best product with longer shelf life (Lal and Sharma, 1997). Sun drying followed by oven drying is the best method of preservation for *Pleurotus* and *Volvariella* spp for long period of time.

Preservation by Chemicals

There are several chemicals additives, which are non-nutritive and are added in small quantities in food to improve its appearance, flavour, texture and storage properties. Mainly used additives are salt, sugar, acetic acid, vinegar, spices and essential oils etc. On the other hand chemical preservatives maintain nutritional quality and enhance the keeping quality. Potassium metabisulphite is commonly used preservative in mushroom processing.

Preservation by Lactic Acid Fermentation

Fermentation is a process of anaerobic or partial anaerobic oxidation of carbohydrates. During the process of fermentation, sufficient quantity of lactic acid is produced to prevent the product from further spoilage during storage.

Pickling

One of the most economically viable methods of preserving mushrooms for longer period is by way of pickling. It is most simple or easiest method. Mushrooms are washed, sliced and blanched for 5 minutes in 2% brine + 0.05% metabisulphite solution. The blanched mushrooms are washed in cold water for 2-3 times and the excess water is drained off. To these mushroom 1.0% sodium chloride is added and kept over-night. The excess water is drained off on the next day and appropriate preservatives and spices are mixed to get organoleptically acceptable pickle. Acetic acid or sodium benzoate is added as preservatives. Turmeric, raje, red chillies, cumin aniseed, black pepper powder, jaggari, ajwain, kalonji along with mustard oil are added to the processed mushrooms. The pickle, thus, prepared can be stored in plastic jar for more than one year (Saxena and Rai, 1990).

According to Singh et al., (1995) cleaned mushrooms are blanched in hot water at 80 °C for 5 minutes. After cooling down, 60% brine solution is added to mushrooms to get a ratio of 7: 3 by volume. Fermentation is carried out at 15-20 °C, for 15 days and then kept at 0-4 °C to obtain a pH of 3.9. Sugar is added to the preparation at the rate of 3.3% by weight to the brine and salt concentrated at 6.6% by weight.

Preservation by minimal processing

By the judicious combination different processes/chemical preparation, product with better retention of original colour, flavor and nutrition can be obtained.

Unit-VI
Nutritional and Medicinal
Values of Mushrooms

Meeting the food demand for the increasing population from the limited land resource is a big challenge for our Indian democracy in this vulnerable climate change era. In addition to this, wide spread malnutrition and associated diseases are more common among the economically poor population. This compels us to search for cheap alternative quality nutritional sources for our huge population. Non green revolution otherwise referred as mushroom farming is one among the apt ways to meet this challenge because mushroom grow on wastes without requiring additional land besides its exceptional nutritional and medicinal properties.

A. Nutritional values of Mushrooms

Indian diet is primarily based on cereals (wheat, rice and maize), which is deficient in protein. Supplementation of mushroom recipe in Indian diet will bridge protein gap and improve the general health of socio-economically backward communities. Earlier mushrooms were considered as an expensive vegetable and were preferred by affluent peoples for culinary purposes. Currently common populace also considers mushroom as a quality food due to its health benefits. Mushroom is considered to be a complete, health food and suitable for all age groups, child to aged people. The nutritional value of mushroom is affected by numerous factors such as species, stage of development and environmental conditions. Mushrooms are rich in protein, dietary fiber, vitamins and minerals. The digestible carbohydrate profile of mushroom includes starches, pentoses, hexoses, disaccharides, amino sugars, sugar alcohols and sugar acids. The total carbohydrate content in mushroom varied from 26-82% on dry weight basis in different mushrooms. The crude fibre composition of the mushroom consists of partially digestible polysaccharides and chitin. Edible mushrooms commonly have insignificant lipid level with higher proportion of polyunsaturated fatty acids. All these resulted in low calorific yield from mushroom foods. Mushrooms do not have cholesterol. Instead, they have ergosterol that acts as a precursor for Vit-D synthesis in human body. The

protein content of edible mushrooms is usually high, but varies greatly. The crude protein content of mushrooms varied from 12 – 35% depending upon the species. The free amino acids composition differs widely but in general they are rich in threonine and valine but deficient in sulphur containing aminoacids (ethionine and cysteine). Nutritive values of different mushroom are given in Table 1.

Table 1: Nutritive values of different mushrooms (dry weight basis g/100g)

Mushroom	Carbohydrate	Fiber	Protein	Fat	Ash	Energy k cal
Agaricus bisporous	46.17	20.90	33.48	3.10	5.70	499
Pleurotus sajor-caju	63.40	48.60	19.23	2.70	6.32	412
Lentinula edodes	47.60	28.80	32.93	3.73	5.20	387
Pleurotus ostreatus	57.60	8.70	30.40	2.20	9.80	265
Vovarella volvaceae	54.80	5.50	37.50	2.60	1.10	305
Calocybe indica	64.26	3.40	17.69	4.10	7.43	391
Flammulina velutipes	73.10	3.70	17.60	1.90	7.40	378
Auricularia auricular	82.80	19.80	4.20	8.30	4.70	351

Mushrooms comprise about eighty to ninety per cent of water, and eight to ten per cent of fiber. In addition to these, mushroom is an excellent source of vitamins especially C and B (Folic acid, Thiamine, Riboflavine and Niacin). Minerals viz., potassium, sodium and phosphorous are higher in fruit bodies of the mushroom. It also contains other essential minerals (Cu, Zn, Mg) in traces but deficient in iron and calcium.

B. Medicinal values

Since thousands of years, edible fungi have been revered for their immense health benefits and extensively used in folk medicine. Specific biochemical compounds in mushrooms are responsible for improving human health in many ways. These bioactive compounds include polysaccharides, tri-terpenoids, low molecular weight proteins, glycoproteins and immunomodulating compounds. Hence mushrooms have been shown to promote immune function; boost health; lower the risk of cancer; inhibit tumor growth; help balancing blood sugar; ward off viruses, bacteria, and fungi; reduce inflammation; and support the body's detoxification mechanisms. Increasing recognition of mushrooms in complementing conventional medicines is also well known for fighting many diseases. Medicinal values of the some important mushroom are given in Table 2.

1. Good for heart

The edible mushrooms have little fat with higher proportion of unsaturated fatty acids and absence of cholesterol and consequently it is the relevant choice for heart patients and treating cardiovascular diseases. Minimal sodium with rich potassium in mushroom enhances salt balance and maintaining blood circulation in human. Hence, mushrooms are suitable for people suffering from high blood pressure. Regular consumption of mushrooms like *Lentinula*, *Pleurotus* spp were stern to decrease cholesterol.

Table : Medicinal values of some important mushrooms

Mushroom	Compounds	Medicinal properties	Courtesy
<i>Ganoderma lucidum</i>	Ganoderic acid	Augments immune system	Lin and Zhang, 2004
		Liver protection	Wang et al., 2007
	Beta-glucan	Antibiotic properties	Moradali et al., 2006
		Inhibits cholesterol synthesis	Komoda et al., 1989
<i>Lentinula edodes</i>	Eritadenine	Lower cholesterol	Enman et al., 2007
	Lentinan	Anti-cancer agent	
<i>A. bisporous</i>	Lectins	Enhance insulin secretion	Ahmad, 1984
<i>P. sajor-caju</i>	Lovastatin	Lower cholesterol	Gunde and Cimerman, 1995
<i>G. frondosa</i>	Polysaccharide	Increases insulin secretion	Horio and Ohtsuru, 2001
	Lectins	Decrease blood glucose	
<i>Auricularia auricula</i>	Acidic polysaccharides	Decrease blood glucose	Yuan et al., 1998
<i>Flammulina velutipes</i>	Ergothioneine	Antioxidant	Bao (2008)
	Proflamin	Anti cancer activity	Ikekawa et al., 1985
<i>Trametes versicolor</i>	Polysaccharide-K (Kresin)	Decrease immune system depression	Coles and Toth, 2005
<i>Cordyceps sinensis</i>	Cordycepin	Cure lung infections	Li et al., 2006
		Hypoglycemic activity	Ko et al., 2009
		Cellular health properties	Nishizawa et al., 2007

2. Low calorie food

The diabetic patients choose mushroom as an ideal food due to its low calorific value, no starch, and little fat and sugars. The lean proteins present in mushrooms help to burn cholesterol in the body. Thus it is most preferable food for people striving to shed their extra weight.

3. Prevent cancer

Compounds restricting tumor activity are found in some mushrooms but only a limited number have undergone clinical trials. All forms of edible mushrooms, and white button mushrooms in particular, can prevent prostate and breast cancer. Fresh mushrooms are capable of arresting the action of 5-alpha-reductase and aromatase, chemicals responsible for growth of cancerous tumors. The drug known as Polysaccharide-K (Kresin), is isolated from *Trametes versicolor* (*Coriolus versicolor*), which is used as a leading cancer drug. Some mushroom-derived polysaccharides have ability to reduce the side effects of radiotherapy and chemotherapy too. Such effects have been clinically validated in mushrooms like *Lentinula edodes*, *Trametes versicolor*, *Agaricus bisporous* and others

4. Anti-aging property

The polysaccharides from mushrooms are potent scavengers of super oxide free radicals. These antioxidants prevent the action of free radicals in the body, consequently reducing the aging process. Ergothioneine is a specific antioxidant found in *Flammulina velutipes* and *Agaricus bisporus* which is necessary for healthy eyes, kidney, bone marrow, liver and skin.

5. Regulates digestive system

The fermentable fiber as well as oligosaccharide from mushrooms acts as a prebiotics in intestine and therefore they anchor useful bacteria in the colon. This dietary fibre assists the digestion process and healthy functioning of bowel system.

6. Strengthens immunity

Mushrooms are capable of strengthening the immune system. A diverse collection of polysaccharides (beta-glucans) and minerals, isolated from mushroom is responsible for up-

regulating the immune system. These compounds potentiate the host's innate (non-specific) and acquired (specific) immune responses and activate all kinds of immune cells.

Mushrooms, akin to plants, have a great potential for the production quality food. These are the source of bioactive metabolites and are a prolific resource for drugs. Knowledge advancement in biochemistry, biotechnology and molecular biology boosts application of mushrooms in medical sciences. From a holistic consideration, the edible mushrooms and its by-products may offer highly palatable, nutritious and healthy food besides its pharmacological benefits. Still there are enough challenges ahead. Until now, how these products work is elusive and vast number of potential wild mushrooms are not explored. The utility of mycelia is paid little attention but it has tremendous potential, as it can be produced year around with defined standard. Knowledge on dose requirement, route and timing of administration, mechanism of action and site of activity is also lacking. Work is under progress in various laboratories across the world to validate these medicinal properties and isolation of new compounds. If these challenges are met out in the coming days, mushroom industries will play a lead role in nutraceutical and pharmaceutical industries. The increasing awareness about high nutritional value accompanied by medicinal properties means that mushrooms are going to be important food item in coming days and at places may emerge as an alternate to non-vegetarian foods. Growing mushroom is economically and ecologically beneficial. Consuming mushroom is beneficial in every respect.

UNIT-VII

RESULT AND DISCUSSION

Silica gel chromatography of the dichloromethane extract of *A. bisporus* afforded ergosterol (1), brassicasterol (2), trilinolein (3) and linoleic acid (4). The NMR spectra of 1 are in accordance with data reported in the literature for ergosterol¹⁴ ; 2 for brassicasterol¹⁵ ; 3 for trilinolein¹⁴ ; and 4 for linoleic acid¹⁶ . The fatty acid attached to the glycerol was deduced as linoleic acid based on the double allylic methylene protons at δ 2.75 (t, J = 6.6 Hz) and the terminal methyl protons at δ 0.87 (t, J = 6.6 Hz)¹⁶ . A study reported that ergosterol (1) provides significant protection against the promotion of bladder tumor induced by many types of promoters in the environment¹⁷. Moreover, the ergosterol content of brown and white button mushrooms correlated with their antioxidant activities¹⁰. In another study, ergosterol was reported to have the capability to inhibit lipid peroxidation¹⁸ . On the other hand, brassicasterol (2) was reported to exhibit anti-aging property¹⁹ . Trilinolein (3) exhibits protective effects against cardiovascular disorders²⁰. It also inhibits ischemia-induced ventricular arrhythmias and it exhibits antioxidant effect²¹ . It was also reported to inhibit the growth of human non-small cell lung carcinoma A549 and induce apoptosis in a dose- and time- dependent manner²² . Another study reported that triglycerides showed a direct relationship between toxicity and increasing unsaturation, which in turn correlated with increasing susceptibility to oxidation. Linoleic acid (4) belongs to the omega-6 fatty acids. It was reported to be a strong anticarcinogen in a number of animal models. It reduces risk of colon and breast cancer¹⁹ and lowers cardiovascular disease risk and inflammations²³ .

UNIT -VIII.
CONCLUSION

Mushroom yeast and algal food are frequently mentioned as alternative source of protein/food. Of these mushroom Mushroom hn ee dhost as eanreti Mushroom yeast and algal food are frequently nms preferred, since they offer greater potential (16 are kg /m² production annually from 5-6 crops of white buttons). contain 20-35% protein (about 3% on fresh weight basis), which is higher than most of the vegetables. Quality of mushroom protein is superior to vegetable protein and as good as animal protein. Digestibility of mushroom protein is also high. Due to low calories, low fat (rich in linoleic acid and lacking in cholesterol and high K/Na r those with obesity, ratio), mushrooms are dietician choice of hypertension and heart diseases. With low calories, no sugar and starch and high protein content, they are said to be the 'the delight of diabetic'. Alkaline ash content coupled with high fibre content present in mushroom is suited to those with hyperacidity and constipation. To correct the irregularities of carbohydrate metabolism, cardiac discomfort and Beri-Beri disease, mushroom are highly recommended due to their high contents of thiamine. Scurby disease can also be cured to some extent by eating mushroom. Due to high price of button mushrooms, a mis-conception has crept in to the minds of people, that they are more nutritious than other mushrooms. Pleurotus and Volvariella are also as nutritious as button mushroom. Rather their cultivation should be encouraged in our country, because of the existing agro-climatic condition and their utilization of varieties of agricultural and forestry waste and easy method of cultivation. Small farmers and landless workers should be motivated to cultivate/produce and consume more mushrooms.

UNIT-IX

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