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Biotechnology of Mushroom

Serial Editors:
Prof. Dr. (Mrs.) Anupama P. Pathak
Prin. Dr. Mukundraj G. Rathod

Bhumi Publishing

First Edition: 2022

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Message

I am happy to know that Prof. Dr. Anupama P. Pathak from the Department of Microbiology, Swami Ramanand Teerth Marathwada University, Nanded and Dr. Mukundraj G. Rathod from Yeshwant College of I.T. Parbhani has written a book on "Biotechnology of Mushroom".

Bio-entrepreneurship is an integration of two different disciplines – science and business. It is the flow of innovation from academia to industry. This book will greatly serve the purpose of bio-entrepreneurship in bio-business of mushroom.

The book has taken detailed account of diversity of edible mushroom. It is noteworthy that introduction to machines invented for mushroom processing is also given in the book. The book includes cultivation technology and post harvesting processing of Mushroom. It is well known that mushrooms have high medicinal and nutritional values. Market of Mushroom is increasing day by day. There is a great opportunity to young generation to start own business of Mushroom cultivation, production and supply. For production of mushroom relatively low cost substrate, Agro-industrial waste is used. Hence this business is economically feasible.

Many references are also quoted in the book, which are helpful to research workers in the field. So I am sure this book will become popular and will be used widely. All the best to both of them.

Yours Sincerely,

Dr. A. M. Deshmukh
President,
Microbiologists Society, India

PREFACE

We are very happy to be publishing this book Biotechnology of Mushroom. This is our first attempt at writing a book on the study of various aspects of edible mushroom and actually we are very delighted to present this book not only for students but also all scientific community. Different species of mushrooms have been known to humans since time immemorial. Some of these species are poisonous and some are edible. In this book we have listed various edible species of mushroom at a glance. Many species of mushrooms have known to exhibit medicinal properties. Many mushroom species contain nutrients that are extremely useful to humans for the growth and nourishment. For vegetarians, mushrooms are a wonderful and invaluable gift of the nature. Currently there are many recipes for edible mushrooms.

Unemployment has drastically increased in recent times with a growing population and people are looking for new businesses. This has attracted a lot of people to the new business of mushroom farming. But most of people have very little knowledge about it and they are in search of more information, that's why this is our small effort to guide students and beginners as well as farmers about mushrooms. Moreover, we hope that this book will be very useful for many undergraduate and post graduate students in life sciences.

In this book we have covered many important things about mushroom biotechnology viz. diversity of cultivable edible species of mushrooms, processing of agro-industrial residues for oyster mushroom cultivation, optimizing substrate dependent growth of oyster mushroom, bioactive potential of different solvent extracts of some mushrooms, post harvesting processing of mushroom, implementing modality of oyster mushroom cultivation technology, mushroom cultivation equipments, trends on value added products of mushrooms and preservation methods of mushrooms.

We hope that this book will be very useful, helpful and instructive for the readers.

ACKNOWLEDGEMENT

With the many collaborative stubborn attempts performed by us on the book, 'Biotechnology of Mushroom', we eager to acknowledge first of all, Hon. Dr. Udhav V. Bhosle, Vice Chancellor of Swami Ramanand Teerth Marathwada University, Nanded for sanctioning a research project to Dr. Mukundraj G. Rathod under Rajiv Gandhi Science and Technology Commission (R.G.S.T.C.) (Government of Maharashtra) scheme for science and technology applications. We are also thankful to Dr. Sarita Yennawar, Asst. Registrar, Academic Planning and Development Section (A.P.D.S.) of Swami Ramanand Teerth Marathwada University, Nanded. Actually this book is one of the parts of the studies peformed under this project.

We would like to show our deepest gratitude to Hon. Dr. Yogesh S. Shouche, Professor, School of Arts & Sciences, Azim Premji University, Bengaluru, and Honorary Scientist, National Centre for Cell Science (Pune). We are grateful to Dr. A.M. Deshmukh, President, Microbiologists society, India, for giving the message and his overall guidance. We are thankful to Prof. Dr. Sankunny Mohan Karuppayil, Former Director of School of Life Sciences and now, Professor and Head, Department of Stem cell and Regenerative medicine at Dept. of Medical Biotechnology, D. Y. Patil Medical College and University, Kolhapur for giving us a good guideline for assignment throughout their numerous consultations.

Special thanks goes to Hon. Dr. Rafik Shaikh, President of M. E. C. H. & W. Society, Parbhani for giving permission and providing necessary infrastructure and facilities to Dr. Mukundraj Govindrao Rathod for performing the research work of the project.

We would also like to mention our gratitude to Prof. Dr. S. P. Chavan, Director of School of life sciences, Swami Ramanand Teerth Marathwada University, Nanded. We are thankful to all the teaching faculty and technical staff of School of Life Sciences, S. R. T. M. University, Nanded and Yeshwant College of Information and Technology, Parbhani, Maharashtra, India.

Authors and serial editors

Dedicated

to

Mother of Universe

Ultimate Source of Energy

Goddess BHAVANI

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Chapter 1 A REVIEW ON DIVERSITY OF CULTIVABLE EDIBLE SPECIES OF MUSHROOMS

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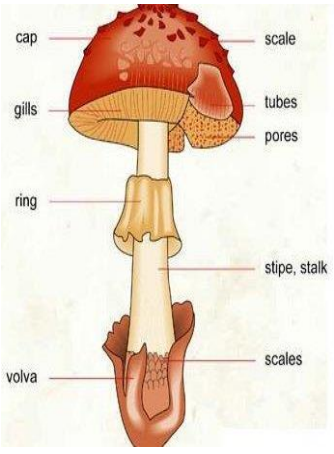
Abstract

This Review paper describes the world wide diversity of cultivable, edible species of mushroom. Mushrooms are fleshy fruiting body of some fungi which have high nutritional values. In early day's edible mushroom related to only white button mushroom (*Agaricus bisporus*) but later on mycologist did find out many species of edible mushrooms and now that finding is still going on. Mushroom belongs to class Basidiomycota of kingdom fungi. According to mycological study, mushroom consumption is probably as long as the history of food gathering. Mushroom has different type of edible as well as non-edible species in nature. Different species of mushroom have been widely distributed and cultivated in different regions of the world. About 651 species representing 185 genera of mushrooms are reported to contain antitumour or immunostimulating polysaccarides that inhibit tumorigenesis.

Keyword: Mushroom, Cultivable, Edible, Distributional diversity.

Introduction



Fungal lineage has organisms which include mainly mushrooms, rusts, puffballs, truffles, smuts, morels and yeast. Amongst that, mushrooms are large, spore bearing, macroscopic, and fruiting bodies of fungi [1]. Mushrooms have high nutritional and medicinal values [2]. That's thereason that fungi have been known as a valuable source of nutrition andmedicines by various communities. As we know mushrooms are fruiting bodies and its major part of life in soil is in the form of microscopic thread like structure which is called mycelium. It is said that one cubic centimeter of soil can have up to 12 to 15 km long Mycelium [3]. We might have seen small or large black spots on old pieces of bread which is nothing but the spore of fungi. More than 2000 mushroom species present in nature and out of them 25 to 30 species are widely accepted as food throughout the world and few of them are commercially cultivated. Mushroom is known as nutraceutical foods having medicinal properties, organoleptic merit and economic significance [6, 7].

Followings are the structural information of mushrooms [5];

1) Attribute Information: (classes: edible and poisonous)
2) Cap-shape: conical, convex, knobbed, bell, flat, sunken.
3) Cap-surface: grooves, smooth, fibrous, scaly.
4) Cap-colour: buff, grey, brown, green, pink, cinnamon, purple, white, red, yellow.
5) Bruises: bruises, no.
6) Odour: anise, creosote, almond, foul, musty, fishy, none, spicy, pungent.
7) Gill-attachment: free, descending, attached, notched.
8) Gill-spacing: crowded, distant, close.
9) Gill-size: narrow, broad.
10) Gill-colour: brown, buff, black, grey, green, purple, orange, red, white, pink, yellow, chocolate. Fig: Mushroom parts [4]
11) Stalk-shape: tapering, enlarging.

History

Mushroom consumption probably started during prehistory, in gathering and hunting period. 4600 year ago, mushrooms were thought to be special and supernatural origin. Egyptians believed to be plants of immortality. Roman thought that mushrooms are food of god. From early days to present days, many people collect mushroom for consumption but still lots of myths and false assumption present. Around 300 to 200 B.C. *Auricularia polytricha*, was first cultivated in ancient china [8]. Around 1650, in western cultures cultivation of mushroom was first recorded in Paris (France). In 1707, Frenchman de tourneforte, wrote and published the description of how to grow mushroom in Paris. Abecrombine wrote a book on Mushroom cultivation [8, 9]. By 1865, the United States started mushroom cultivation. In that time two widely known genetic variants of *Agaricus bisporus* present that is portobella and crimini [9]. In 1886 mushroom cultivation started in India. In 1892 Seren Rasmussen started mushroom cultivation at Westtown. In 1894 – French mycologist, Matrochot and Costantin discovered mushroom disease. Duggar (1905) - Making pure culture spawn from mushroom tissue in America. In 1918 Lambert's pure spore culture bottled spawn was marketed by U. S. During 1980 Ron Ower grew the *Morchella esculenta* in United States [8, 9].

Identification

1) Morphological identification

Morphological identification of some mushroom species has given below [10, 11, 12, 13].

(1). **Name:** Laccaria bicolor **Morphological identification:** 1) cap colour- vary from yellow to buff to orange to lilac 2) waxy & fibrous nature 3) stalk is often twisted **Season of fruiting:** summer-fall **Edibility:** Edible	(2). **Name:** Leccinum aurantiacum **M. identification:** 1) cap-red to brown 2) cap is dry, when it bruised flesh white turning red then grey **Season of fruiting:** Late summer-fall **Edibility:** Edible	(3). **Name:** Calvatia gigantean **M. identification:** 1) softball-soccer ball in size 2) white leathery skin when it young 3) when mature, turning yellow-tan **Season of fruiting:** late summer fall **Edibility:** Edible when young
(4). **Name:** Suillus americanus **M. identification:** 1) cap-yellow with red streaks, smooth 2) yellow flesh 3) tube opening radiate out from stalk in a linear pattern **Season of fruiting:** Late summer-fall **Edibility:** Edible	(5). **Name:** Armillaria solidipes **M. identification:** 1) cap-golden yellow 2) prominent ring on stem 3) black shoe-string cords (rhizomorphs) under black of infected trees or in soil **Season of fruiting:** Late summer-fall **Edibility:** Edible	(6). **Name:** Pleurotus dryinus **M. identification:** 1) cap-offset 2) stipe has a ring, spore print is white 3) gills on hymenium, which is decurrent **Season of fruiting:** summer to autumn **Edibility:** Edible
(7). **Name:** Fomes fomentarius **Morphological identification:** 1) hoof shaped 2) grey, hard conk **Season of fruiting:** Perennial **Edibility:** Non-edible	(8). **Name:** Piptoporus betulinus **Molecular identification:** 1) shape- circular & rounded 2) size- shelf like 3)colour- white to brown **Season of fruiting:** Annual **Edibility:** non-edible unless very young	**(9). Name:** *Amanita virosa* **Morphological identification:** 1) cap white and smooth 2) white gills free from stalk 3)base is bulbous 4) white veil **Season of fruiting:** summer-fall **Edibility:** Non-edible

2) Molecular identification

Total Fungal DNA extraction based molecular identification techniques provide a unique strategy for the identification and determination of different fungal isolates up to a specific level. It includes DNA extraction, PCR amplification, sequencing and analysis.

Fungal DNA extraction is performed from PDA culture by using DNeasy plant mini kit and then primers (ITS1 [5-TCCGTAGGTGAACCTGCGG-3] and ITS4 [5-TCCTCCGCTTATTGATATGC-3] are used for the amplification of ribosomal internal transcribed spacer (ITS).

PCR products are purified and then sent for sequencing. The obtained sequences are then

compared with available related sequences which is get by using Database search engines like BLAST, GenBank (NCBI) [14,15,16].

Classification

Mushrooms belong to kingdom fungi which has different classes. Mushrooms mainly belong to Basidiomycota. For thousands of years especially mushrooms have been explored for their nutritional values and also as therapeutic agents. Mushrooms have anti-inflammatory, anti-oxidant, anti-microbial, anti-diabetic and anti-cancers properties [17, 18, and 19]. Mushrooms classified according to various criteria. Followings are the name of some species, having common name and scientific name with habitat.

Sr. no.	Common name	Scientific name	habitat	References
1	Bay Bolete mushroom	*Boletus badius*	Mexico	[20]
2	Black trumpet mushroom	*Craterullus cornocopioides*	Europe, North America, east Asia	[20][21]
3	Button mushroom	*Agaricus bisporus*	Grasslands in Europe, N. America	[20][22]
4	Caesar's mushroom	*Amanita caesarea*	Southern Europe, Northern Africa, Italy	[20]
5	Charcoal Burner	*Russula cyanoxantha*	Europe	[20]
6	Wood mushroom	*Agaricus silvaticus*	Coniferous forest, Europe, N. America	[20,23,24,25]
7	Common ink cap mushroom	*Coprinopsis atramentaria*	Australia, Sydney, New Zealand, Europe, N. America and Asia	[20,26]
8	Dryad's saddle	*Cerioporus squamosus*	America, Europe, Australia	[20]
9	Enoki mushroom	*Flammulina velutipes*	China , East Asia , Western North America and new Europe	[20,27,28,29]
10	Giant puffball mushroom	*Calvatia giganetea*	Temperate areas throughout the world, meadows, fields and forests.	[20,30,31,32]
11	Gypsy mushroom	*Cortinarius caperatus*	Northern latitude, Finland	[20]

Edible mushroom species

Mushrooms are macro-fungi which exhibit heterotrophic mode of nutrition. There are more than 2600 species present in nature, few of them edible cultivable mushroom species are as

follows [33,34,35,36,37,38,39].

Agaricus bisporus	*Boletus sensibilis*	*Ganoderma tsugae*	*Helvella acetabulum*	*Lepista irina*	*Strobilomyces strobilaceus*
Agaricus brasiliensis	*Boletus subvelutipes*	*Grifola frondosa*	*Lepista nuda*	*Leucoagaricus leucothites*	*Schizophyllum commune*
Agrocybe aegerita	*Boletus edulis*	*Ganoderma applanatum*	*Lactarius piperatus*	*Morchella esculenta*	*Suillus granulatus*
Antrodia	*Boletus badius*	*Geastrum*	*Lycoperdon*	*Macrolepiota*	*Sarcodon*
camphorate		*arenarius*	*perlatum*	*procera*	*imbricatus*
Auricularia auricular	*Clavariadelphus pistillaris*	*Geastrum saccatum*	*Lycoperdon molle*	*Morchella angusticeps*	*Schizophyllum commune*
Agaricus romagnesii	*Cantharellus lutescens*	*Ganoderma atrum*	*Laetiporus sulphureus*	*Morchella conica*	*Tricholoma acerbum*
Agaricus silvaticus	*Cortinarius caperatus*	*Gyroporus castaneus*	*Lactarius piperatus*	*Neoboletus luridiformis*	*Tricholoma equestre*
Agaricus silvicola	*Cerrena unicolor*	*Hericium erinaceus*	*Leucopaxillus giganteus*	*Neolentinus lepideus*	*Tricholoma giganteum*
Auricularia cornea	*Calvatia gigantea*	*Helvella crispa*	*Lentius sajor-caju*	*Pleurotus ostreatus*	*Tricholomopsis rutilans*
Auricularia polytricha	*Cordyceps sinensis*	*Hypholoma fasciculare*	*Lactarius deliciosus*	*Pleurotus dryinus*	*Termitomyces microcarpus*
Auricularia mesenterica	*Cantharellus cibarius*	*Hypsizigus marmoreus*	*Lentinus squarrosulus*	*Piptoporus betulinus*	*Termitomyces schimperi*
Auricularia fuscosuccinea	*Cantharellus clavatus*	*Hygrophorus agathosmus*	*Lactarius sanguifluus*	*Paecilomyces japonica*	*Termitomyces mummiformis*
Agrocybe cylindracea	*Cyanoboletus pulverulentus*	*Hypholoma fasciculare*	*Lentinus edodes*	*Pleurotus pulmonarius*	*Termitomyces tylerance*
Amanita rubescens	*Dictophora indusiata*	*Hypsizigus marmoreus*	*Lactarius pubescens*	*Pleurotus florida*	*Termitomyces heimii*
Agaricus arvensis	*Flammulina velutipes (white)*	*Hydnum repandum*	*Lactarius repraesentaneus*	*Picoa juniperi*	*Termitomyces albuminosus*
Armillariella mellea	*Flammulina velutipes(yellow)*	*Hericium coralloides*	*Lactarius rufus*	*Polyporus squamosus*	*Termitomyces robustus*
Agaricus semotus	*Inonotus obliquus*	*Hericium erinaceus*	*Lactarius uvidus*	*Phellinus merrillii*	*Terfezia claveryi*
Amanita ovoidea	*Ganoderma lucidum*	*Helvella crispa*	*Lactarius zonarius*	*Phellinus rimosus*	*Tremella fuciformis*
Scleroderma flavidum	*Suillus luteus*	*Pluteus salicinus*	*Pleurotus Levis*	*Pleurotus cystidiosus*	*Trametes orientalis*

Suillus bellini	*Sparassis crispa*	*Pulveroboletus ravenelii*	*Pleurotus tuber-regium*	*Pleurotus djamor*	*Trametes (Coriolus) versicolor*
Russula fellea	*Russula delica*	*Russula brevipes*	*Phellinus linteus*	*Pleurotus sajor-caju*	*Verpa conica*
Russula cyanoxantha	*Ramaria botrytis*	*Russula vinosa*	*Pluteus petasatus*	*Pleurotus calyx*	*Volvariella volvacea*
Suillus luteus	*Suillus bellini*	*Sparassis crispa*	*Suillus granulatus*	*Sarcodon imbricatus*	*Volvopluteus gloiocephalus*
Pleurotus subtilis	*Pleurotus floridanus*	*Pleurotus fockei*	*Pleurotus strigosus*	*Pleurotus squarrulosus*	*Pleurotus salignus*
Ganoderma lucidum	*Trametes hirsuta*	*Phaeolus schweinitzii*	*Tirmania nivea*	*Lentinus conatus*	*Lentinus squarrosulus*

Distributional Diversity

Mushroom species are nutraceutically important food source. Distributional diversity of certain edible mushrooms throughout the world has given below.

Sr. no.	Mushroom species	Distributional region	References
1	*Morchella pulchella clowez* *Helvella leucopus pers.*	Eastern Antonia, Turkey	[40]
2	*Volvariella volvacea*	Southeast Asia	[41]
3	*Ramaria botrytis* *Clavulinopsis fusiformis* *Grifola frondosa,* *Laccaria laccata*	Katmandu valley	[42,43]
4	*Ramaria subalpina*	Subalpine forest of Sikkim Himalayas	[44,45]
5	*Lentinus conatus*	Abakaliki, Nigeria	[46]
6	*Lactarius rufus*	Northern temperate zone in Europe &North America	[47]
7	*Lentinus sajor-caju* *L. conatus, L. cladopus* *L. squarrosulus, L. torulosus.*	Northern India	[48]
8	*Auricularia auricular judae*	Global zone of temperate	[49]
9	*Lentinus subnudus* *Psathyrella atroumbonata* *Termitomyces striatus*	Nigeria	[50]
10	*Amanita phalloides*	United states, Canada	[51]

11	*Kuehneromyces mutabilis* *Hypholoma capnoides*	North America, Asia, Japan, Australia	[52,53,54,55]
12	*Pleurotus eryngii*	Turkey, Adiyaman, Malatya, Tunceli, Bingol	[56]
13	*Tirmania nivea*	Tunisia arid zone, Algeria, Spain, Europe	[57,58,59]
14	*Amanita caesarea* *Boletus edulis, Ramaria sp.* *Russula brevipes* *Lactarius indigo*	Tlayacapan (Mexico)	[60]
15	*Agaricus bisporus, A. Silvaticus, Boletus edulis* *Morchella conica*	Azad Kashmir	[61]
16	*Pleurotus comucopiae* *P. dryinus, P. ostreatus*	Punjab	[61]
17	*Phellorina inquinans* *Podaxis pistillaris*	Sindh	[61]
18	*Agaricus rodmani* *Phellorina inquinans* *Podaxis pistillaris* *Lycoperdon sp.*	Baluchistan	[61]
19	*Marasmius heinemannianus*	Benin, West Africa	[62]
20	*Agaricus moelleri* *Clavaria fragilis* *Amanita cokeri* *Amanita fulva* *Coprinus comatus*	Nagaland, India	[63]
21	*Cantharellus cibarius* *Laetiporus sulphureus* *Lentinus sajor-caju*	Northeast India (Assam)	[64]
22	*Ganoderma lucidum* *Phellinus rimosus* *Lentinus tuber-regium*	Southern part of India	[65,66]
23	*Russula integra* *Gomphus floccosus* *Lactarius quiteticolor*	Meghalaya (Northeast India)	[67]
24	*Flammulina velutipes* *Pleurotus ostreatus* *Auricularia polytricha*	China	[68]

25	*Pleurotus highking* *P. ostreatus* *P. geesteranus*	Bangladesh	[68,69]

Mushroom production, its uses and adverse effect:

Due to edibility of mushrooms, they are largely cultivated throughout the world. It‘s production level is different in different country based on their mushroom species diversity and its popularity as edible mushroom.

In Japan about 160,000 metric tons of mushrooms are produced per year. Most of them dried and exported. It represents two billion dollars profit which also makes availability of employments for more than 200,000 peoples. World widely, mushroom production business is worth millions of pounds annually. French and Poland are major exporters of mushrooms. World‘s largest edible mushroom production is done in China [2].

Economically, associations of mushroom growers in Uganda sold 44 tons of mushrooms per year to Japan, 2 tones to the Democratic Republic of Congo and 40 tones to the US [70].

To solve the problem of seasonality in availability, Good storage and value addition by processing and canning should be done. To increase profits, we have to increase the mushroom marketing, constant advertisement to create awareness, good storage of mushrooms and packaging should be done properly [71].

Mushrooms have different types of uses due to its edibility and medicinal properties. Mushrooms indicate possible anti-inflammatory, hepatoprotective, cardiovascular, anticancer, antiviral, antibacterial, antiparasitic and antidiabetic activities [72, 73].

Like effective activities, mushrooms also have adverse effect. It causes many types of different disease. Human activities cause on arable land containing heavy metal, pesticide which cause negative impact on arable land [74]. Mushrooms also used as gun powder [75].

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Chapter 2 A MINI-REVIEW ON PROCESSING OF SELECTED AGRO-INDUSTRIAL RESIDUES/SUBSTRATES AND SOURCES OF SPAWNS FOR OYSTER MUSHROOM CULTIVATION

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Abstract

This chapter reviews processing of selected agro- industrial residues/substrates and sources of spawns for oyster mushroom cultivation. This chapter discusses about the edible oyster mushroom species especially *Pleurotus* sp. which grow on different agro- industrial substrates. *Pleurotus ostreatus* is one of the edible species and popularly known from the group of oyster mushroom. It belongs from kingdom-fungi, division-basidiomycota, order-agaricales and family-pleurotaceae and it is rich in protein having nutritional, medicinal and different pharmacological characteristics. It is the third most cultivated edible mushroom in the worldwide. Some popular species of oyster mushrooms are *Pleurotus florida, Pleurotus pulmonarius, Pleurotus sajor-caju, Pleurotus eryngii, Pleurotus cystidiosus* and *Pleurotus eous* etc.

Keywords: oyster mushroom, agro-industrial, substrates, residues, spawns.

Introduction

Oyster mushroom is an edible mushroom that can be recognized for their high nutritional and different medicinal properties [1]. *Pleurotus* species have a very high nutritional value and are rich sources of proteins, carbohydrates, minerals (calcium, phosphorus, magnesium, potassium, iron and sodium ions), and vitamins especially B, C and D in addition to vitamin (Thiamine, riboflavin, niacinand folic acid) [2]. Furthermore it has some remarkable potential to fight against different ailments. Oyster mushroom has an antitumor, antioxidant and immunological activities [3]. Agro-industrial substrates are abundantly available in worldwide [4]. Oyster mushroom (*Pleurotus* sp.) can be grown on various agro-industrial residues including rice straw, wheat straw, paddy straw, cotton straw, coffee straw, peanut waste, soybean straw, maize residue, sorghum, corncobs, rice husk, paper waste, sawdust, vegetable plant substrates, sugarcane bagasse, plant leaves, tea leaves, banana leaves and date palms. Agro-industrial residues consist of lignocellulosic compounds such as cellulose, hemicellulose and lignin [5]. *Pleurotus* species can utilize these compounds as substrates for their growth by producing lignocellulosic enzymes and thereof very nutritious products can be generated from agro-industrial wastes [6]. In addition, cultivation of oyster mushroom on afore-mentioned agro-industrial waste helps in reduction of environmental pollution caused due to incineration and landfilling methods [5, 7].

Agro-industrial residues/substrates

Agro-industrial residues consist of the waste that is produced during various agricultural activities and different agro-industrial processing. Agro-industrial substrates are the best sources for oyster mushroom cultivation [7, 8]. Agro-industrial substrates include lignocellulosic components which comprise three different polymers such as cellulose, hemicellulose and lignin [5]. Oyster mushrooms are cultivated on a single or in combination of agro-industrial substrates. The lignocellulosic enzymes secreted by the mycelium hydrolyze and decompose lignocellulosic components and produce metabolites for the accretion and development of fruiting bodies [6, 7].

Combination of substrate

Oyster mushrooms can be easily cultivated on different agro-industrial substrates. Various combinations of agro-industrial residues have been reported for the cultivation of oyster mushroom that gives a remarkable yield. Optimal substrate combination with corn cob (cc) and sugarcane bagasse for the cultivation of both *P. ostreatus* and *P. cystidiosus* yielded a high content of protein and ashminerals (calcium, potassium, magnesium, manganese and zinc). In a study, a combination of saw dust and rice husk has reported a good yield of *P. ostreatus* [7].

Soybean straw with addition to wheat straw has reported a good combination for the cultivation of *P. sajor caju.* This combination has given 87.3% biological efficiency. In comparison to this, a low biological efficiency viz. 43.8 % was recorded when the combination of soybean straw and saw dust used for the cultivation of the same species.

To cultivate *P. eryngii*, various combinations of substrates were used for the cultivation of *P. sajor caju* and its protein quality changed by according to the substrate composition. Combination of barley straw and wheat bran and combination of wood chips, soybean powder and rice bran has given 4.64% protein content in fruiting bodies whereas, combination of wheat straw, wheat brawn, and soybean powder has given 13. 66% protein content [7].

Overview of different agro-industrial residues used as substrates for oyster mushroom cultivations:

Sr. no.	Mushroom species	Substrates	References
1	*Pleurotus ostreatus*	Maize residue	[3]
2	*P. ostreatus, P. cystidiosus*	Corncob + saw bagasse	[7]
3	*P. sajor-caju*	Soybean straw + wheat straw, Soybean straw + saw dust	[7]
4	*P. eryngii*	Wheat straw + soybean powder +wheat bran	[7]
5	*P. ostreatus, p. pulmonarius*	Rice Straw	[9],[10],[11],[12], [13]
6	*P. ostreatus,* *p. pulmonarius*	Wheat Straw	[9],[10],[11],[12]
7	*P. ostreatus*	Rice and wheat Straw	[9]
8	*P. ostreatus*	Sugarcane bagasse	[11]

9	*P. ostreatus*	Cotton Straw	[14]
10	*p. pulmonarius*	Soybean straw	[15]
11	*p. pulmonarius*	Corn straw	[15]
12	*p. pulmonarius*	Rape straw	[15]
13	*p. pulmonarius*	Corn cobs	[15]
14	*p. pulmonarius*	Peanut straw	[15], [16]
15	*P. ostreatus*	Cassava peels	[17]
16	*P. ostreatus*	Coconut residues	[17]
17	*P. ostreatus*	Coffee waste	[17]
18	*P. ostreatus*	Water hyacinth	[18]
19	*P. ostreatus*	Corn cob substrate	[18]
20	*P. ostreatus*	Paddy straw	[19]
21	*P. ostreatus*	Cotton seed hull	[12]
22	*P. ostreatus*	Oak sawdust	[20],
23	*P. ostreatus*	Grapevine sawdust	[20]
24	*P. ostreatus*	Blackberry sawdust	[20]
25	*P. ostreatus*	Raspberry sawdust	[20]
26	*P. ostreatus*	Apple sawdust	[20]
27	*P. ostreatus*	Plum sawdust	[20]
28	*P. ostreatus*	Corn stalks	[20],[13]
29	*P. ostreatus, P. eryngii*	Sawdust and rice straw	[10],[21],[2]
30	*P. ostreatus*	Peanut waste	[16]
31	*P. ostreatus*	Waste paper	[22]
32	*P. ostreatus*	Wood chips, wood waste	[22],[23]
33	*P. ostreatus*	Olive pruning residues + spent coffee grounds	[24]
34	*P. ostreatus*	Pineapple rind	[25]
35	*P. ostreatus*	Date-palm leaves	[26]
36	*P. ostreatus*	Grain waste	[27]
37	*P. florida*	Corn husk	[28]

Sources and production of spawns

Commercially spawns are called as mushroom seeds. Furthermore it is described as mycelium mixture of specific strain of mushroom with suitable pre-sterilized grain seeds which provides the nutrients for the growth. Such spawns are inoculated in a specific type of agro-industrial substrate for cultivation of oyster mushroom. Spawn making is a highly deliberative process and hence it is not easy for common mushroom growers, so they need to buy directly from either commercial mushroom growers or mushroom research centers. Some commercial mushroom and spawn suppliers are Sayash Agro (Pune), Indus Mushroom (Pune), Mahaagro India (Mumbai), Pilot mushroom farm and training center (Nagpur), Kamal Farm (Chikhali, Pune), SK oyster mushroom farm (Nashik), Bhutta Agrobiotech (Andheri, Mumbai), Mahadik Mushroom Farm (Ahmednagar), Om Sai Mushroom Company (Sangli), Shubham Agro

(Warangal), Prafull Mushroom (Chandrapur), Smug Town Pvt. Ltd. (Yavatmal), Stan Agro Ventures (Bengaluru), Vin Lab (Mysore), BM Mushrooms and spawn center (west Bengal), Mushroom learning centre (Kolhapur) etc. and mushroom research centers are National Research Centre for Mushroom (NRCM) (Solan, Himachal Pradesh), Mushroom research lab (Kerala), National Research Centre for Mushroom (NRCM), Indian Council of Agriculture Research (ICAR), (Chambaghat) etc. A good quality of spawns have high economic price. Generally available spawns for mushroom cultivations are sawdust spawn, grain spawns (different cereal grains, corn, and wheat), liquid spawns and stick spawns [10].

Spawn preparation

Particularly oyster mushroom's spawns are prepared in a specific volume of polypropylene plastic bottles that are filled with a combination of suitable substrates in an appropriate amount as like first substrate combination- (cotton seed hull-87%, wheat bran-10%, sucrose-1%, plaster stone-1% and calcium superphosphate-1%) and second- (Acacia sawdust-approximately 29%, rice bran-9%, sugar-1%, calcium carbonate-1%, ammonium chloride, magnesium sulphate and monopotassium phosphate each with 0. 03%, 60-65% water) [10]. In a method, spawns are prepared by using bagasse and grains like barley, sorghum etc. for production of oyster mushroom. Grains are carefully washed and immersed in water overnight. After soaking of water by grains they are boiled for moistened purpose then excess water is removed by using cheesecloth [29]. Then (2%) calcium carbonate is added in grains and mixed well. Finally grains are filled in bottles and sterilized by moist heat method at 15 lbs/in^2 for 25 to 30 minutes (The time period may vary as per substrate). After cooling, mycelium discs of specific mushroom culture are inoculated into sterilized bottles aseptically and incubated for few weeks at 26-28^o C and 70% relative humidity [3, 4, and 30].

Substrate preparation

Oyster mushroom has a potential to turn agro-industrial waste into a high value nutritious food. Agro-industrial substrates are abundantly produced in nature on which oyster mushrooms are able to grow, for example rice straw, wheat straw, sugarcane bagasse, sawdust, rice husk, corncob etc. Depending upon nature and size of particular substrates either it may be chopped into 1. 5 – 4 cm lengths (wheat straw, rice straw and sugarcane bagasse) or kept as it is (sawdust and rice husk)[4, 30].

Processing

All substrates were cut into appropriate length (size must be noted), then cleaned, washed and immersed into water for a suitable time duration depending on nature of substrate to achieve moisture. Then,excess water is removed from the substrates. Now such processed agro-industrial substrate with nutrient supplementation and 65% water content are filled in polythene/polyethylene bag for moist heat sterilization at 120^{o}C for 80 minutes to 5 hours depending on substrate used. Each sterilized substrate bag is cooled at room temperature and then 2-5 gm (depending on substrate used) of oyster mushroom spawns are inoculated. Bags are perforated with the help of a sterile-needle. Bags are incubated at the ambient temperature of 25-28^o C and relative humidity about 60-70% for few weeks [4, 29, and 30].

Harvesting

After the finishing incubation period, growth of mycelium on entire surface of substrates

is observed. Then the bags are shifted into a highly facilitated cropping room where fruiting bodies start to appear from the holes of bags. The well grown fruiting bodies of oyster mushrooms are harvested from each of the bag [30]. Generally harvesting period of mushroom ranges 6 to 12 week. It varies and depends upon the type of mushroom strains [29].

Conclusion

The production of Oyster mushroom from different agro-industrial substrates is very beneficial process. Mushroom acts on substrates which is rich in lignocellulosic compounds and produces fruiting bodies. Cultivation of Oyster Mushrooms on agro-industrial residues has a great environmental significance for conversion of low value inedible substrate into a high value nutritional food; furthermore this process is useful for environment waste management and to control environmental problemssuch as air and soil pollution caused by agro-industrial waste. Different types of agro-industrial residues with proper combination act as a suitable substrate for cultivation of oyster mushroom.

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Chapter 3 AN OVERVIEW ON BUTTON MUSHROOM CULTIVATION

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Abstract

Amongst various types of mushrooms, button mushroom is very popular and widely cultivated crop. Edible mushrooms contain full of essential nutrients and minerals. They have an excellent source of vitamin B12. Scientifically it has been proved that the regular consumption of button mushrooms is beneficial for several patients. Button mushroom has a very high market demand and there is a great opportunity lying for new entrepreneurs in button mushroom cultivation. However protection is required to mushroom crops against various kinds of pests and diseases. Commercial cultivation of button mushroom is an indoor process. It can be cultivated throughout the year; however the proper control of temperature, moisture and air flow is necessary. Special compost substrate is required for button mushroom cultivation. The spawns are mixed with compost and the process is called spawning. Different methods are followed for spawning. The next process is casing in which the compost beds after the process of complete spawn run are covered with pasteurized soil and the process is called casing. Under favorable environmental conditions, the fruiting bodies of button mushrooms start to grow. In average 20 kg of fresh button mushrooms are yielded from 100 kg of compost. Hence this is definitely a profitable business for farmers. This chapter is aimed to summarize an overview on button mushroom cultivation.

Keywords: Button mushroom, *Agaricus bisporus*, composting, casing, spawning, harvesting

Introduction

Mushroom is an edible fungus. There are thousands of types of mushrooms exist in nature, but not all types are edible [1, 2]. Umbrella-shaped figures are found around the house or in the fields during the rainy season. These are nothing but the mushrooms. It mainly contains button mushrooms, Dhingri mushrooms and milky mushrooms. Amongst various types of mushrooms, button mushroom is very popular and widely cultivated. The most famous and vastly cultivated variety of button mushroom is *Agaricus bisporus*. However, the button mushroom has several different varieties and strains among it. Broadly two varities are famous which are brown and white in colour. According to different stages of its growth it is known by different names. When they are young or immature they are commonly referred as white or creamy mushroom and when the caps or gills are open up then they are called Portobello mushroom [1-6].

The button mushroom is a superfood. It is not only delicious but also full of essential nutrients and minerals like fibres, proteins, vitamin D, selenium, phosphorous etc. White button

mushrooms contain low calories and sugars. They are an excellent source of vitamin B12. Scientifically it has been proved that the regular consumption of button mushrooms is beneficial for anemia patients. It improves immunity. It is good for bones and heart health. It also helps in weight lossas it contains very low calories per 100 gm of button mushrooms compared to other kinds of fruits and vegetables. Button mushrooms are of soft texture and versatile hence used in wide varieties of dishes and all good restaurants do serve these delicacy. Button mushroom has a very high market demand and value. There is a great opportunity lying for new entrepreneurs in button mushroom cultivation. Cultivation of button mushrooms is very profitable. However protection is required to mushroom crops against various kinds of pests and diseases [1, 7].

Some investment is required to initiate button mushroom farming. Money is to be invested to build farm structure and purchasing various kinds of equipments. Major structures include spawn unit, compost unit, and cropping unit. The post-harvest area is required for processing the crop. Cultivation of mushroom is a skillful task that requires time and patience. Lack of knowledge and training is the biggest contribution towards the failure [8].

Growing conditions and popular methods

Commercial cultivation of button mushroom is an indoor process. It can be cultivated throughout the year; however the proper control of temperature, moisture and air flow is necessary. It is not necessary to invest huge capital on farm construction. Button mushroom can be cultivated in a small and economical way as in the village structures like hut and cottage. The inside racks can be constructed by using the cheap alternative sources like bamboo, woods etc. This type of arrangement is sufficient for seasonal farming but for continuous cropping insulated farm with high-tech sensors are required. Different kinds of ambient temperatures are required for the cultivation of button mushroom in vegetative growth phase and fruiting stage. *Agaricus bisporus,* the most popular and widely cultivated mushroom species requires 21-25^{o}C temperature for its proper mycelium growth. When the spawns of button mushrooms are mixed with substrate viz. compost, the mycelium which is actually the fungus starts spreading out it. This is referred as vegetative growth. When mushroom pin heads starts to appear in fruiting stage, then the ambient temperature requirement is 12 to 18^{o}C. Mushroom pin heads starts to grow rapidly due to sudden favorable change in temperature and moisture. The humidity must be in the range of 80 to 90 %. Arrangement of proper ventilation ducts is required in the mushroom farm. High concentration of CO_2 is required during vegetative growth of mycelia. During fruiting stage there must be proper air circulation. Hence proper growth of button mushrooms occurs [3-7].

Compost preparation

Special compost substrate is required for button mushroom cultivation. Compost quality is dependent on ratio of carbon and nitrogen (17:1) and proper pasteurization and moisture level. Compost is mainly prepared from plant waste like cereal straw, wheat straw, paddy straw etc. The addendums like urea, super phosphate and gypsum are added in composting process. The supplements involved in compost are rice bran, wheat bran etc. Water is added to maintain propermoisture level. Long method of composing is performed at outdoor during season time of winter session. If the rain falls on freshly prepared compost, it may dilute the amount of nutrients required for button mushroom cultivation. So the compost prepared outdoor must be protected in proper built-up structures. According to the different kinds of regions, there are various kinds of

available agricultural residues; hence there is no unique method of composting. In indoor method, compost is prepared in tunnels, a kind of insulated room under moderately high temperature conditions. During the first phase of compost preparation generally paddy straw and wheat straw are placed in layers and sufficient water is added to the stack. Several kinds of fertilizers are added in every alternative day and the mixture is rotated regularly. During composting, microbes and other competitors daily convert ammonia in to microbial protein. Actually the compost preparation in itself is a vast topic [9, 10].

Spawning

Once the compost is ready then the stage of spawning comes. The spawns, seeds of mushrooms, can be prepared by our own or maybe purchased commercially from any reputed laboratory. The process of mixing of spawn with compost is called spawning. Different methods are followed for spawning. In spot spawning method, lumps of spawns are planted 5 cm deep inside the compost. In surface spawning method, the spawns are evenly spread on top of the compost and then mixed in the depth of 3 to 5 cm. In layer spawning method, about 3 to 4 layers of spawns are mixed to the compost. The quantity of spawn required is 1% to the weight of compost. After the process of spawning, nearly about 2 weeks are required for spawn running. During this time the fungal bodies grow out from the spawn and takes about 2 weeks to colonize at 21 to 25 ^{o}C temperature and 90% humidity [11, 12, and 13]. The next stage is of casing.

Casing

The compost beds after the process of complete spawn run are covered with 3 to 4 cm thick layer of soil. This process is known as casing. Casing is an essential to induce fruiting. The casing soil should have high porosity and water holding capacity. pH level of casing soil should be between 7 to 7. 5. The casing soil before application should be pasteurized at 66 to 70 ^{o}C for 7 to 8 hours. 2 % of formaldehyde solution may be used for disinfection of casing soil by chemical method. Approximately 7 days are required to run mycelium in casing soil. Later on, physical parameters of incubation are changed. The temperature is lowered at 13 to 18 ^{o}C and the relative humidity is maintained at 85 %. Air circulation must be started to enter fresh oxygen inside the room. Under favorable environmental conditions, the fruiting bodies of button mushrooms start to grow [14].

Harvest

In average 20 kg of fresh button mushrooms are yielded from 100 kg of compost. In general total mushroom cycle is of 60 days with 2 to 3 profitable flushings. Good harvest is dependent upon many factors viz. proper moisture condition in casing soil, ventilation system, and CO_2 concentration between 0. 08 to 0. 15 % [15].

Conclusion

Cultivation of button mushroom is not at all complicated as it looks. In fact button mushrooms can be grown in small chambers or small boxes. It is quite easy and requires a little care, practices and training for the beginners. It is definitely a profitable business for farmers and has a great opportunity for new entrepreneurs.

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Chapter 4 CULTIVATION BY OPTIMIZING SUBSTRATE DEPENDENT GROWTH OF SELECTED OYSTER MUSHROOM SPECIES UNDER ENVIRONMENTALLY CONTROLLED CONDITIONS: A REVIEW

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Abstract

In this review we are going to study about the cultivation of different oyster mushroom species by optimization of their substrates and environmental conditions. The mushrooms are very sensitive for their growth depending upon the environmental factors such as light, moisture, humidity etc. The different species ofthe oyster mushroom show the different growth rate on different substrate medium and hence here we are going to study about their growth on those different substrates. There are many species of oyster mushrooms amongst that *Pleurotus* sp. is well popular. However the genus Pleurotus includes many edible species such as *Pleurotus ostreatus, Pleurotus sajor-caju, Pleurotus cytidiosus, Pleurotus cornucopiae, Pleurotus pulmonarius, Pleurotus tuber regium, Pleurotus cicitrinopileatus, Pleurotus fabellatus, Pleurotus djamor, Pleurotus eryngii, Pleurotus florida* etc.

Keywords: Cultivation, Pleurotus, substrates, humidity, harvesting, temperature, pH

Introduction

Mushroom is the fungus fruit body having no chlorophyll. It is the source of nutrients, carbohydrates, vitamins, minerals, proteins, dietary fibre, essential amino acids etc. Mushrooms have many medicinal values [2, 6]. The first cultivation of oyster mushroom was initiated in Germany on experimental basis in early sixties, then all the techniques of cultivating mushrooms is perfected in USA. Oyster mushroom imparts the large portion of cultivating the mushrooms all over the world. China, Korea, Japan, Italy, Taiwan, Thailand and Philippines are the major countries producing mushrooms [1]. During production, some environmental factors must be manipulated. The average range of temperature in the shade house is to be 16-30^{o}C and the humidity range is 60-90% for the production of *Pleurotus* sp. [3]. Through the studies mushrooms are advised to grow on organic materials near available. The organic material has high efficiency to cultivate the mushroom. With increase in ventilation and oxygen concentration the corn substrate gives more growth of mushroom mycelia [4]. It has been found that, sawdust and corncob gives the maximum growth of *P. ostreatus.* The optimum temperature criterion for the growth of some species of oyster mushroom is as *P. eryngii* (25^{o}C), *P. ostreatus* (30^{o}C), *P. pulmonarius* (30^{o}C) [5]. The *Pleurotus* species which have the laccase and versatile peroxidase like lignocellulosic enzymes are easily found in terrestrial ecosystem

and tropical forests, like on the logs, decaying matter, fallen trees etc. [6].

Pleurotus ostreatus

The most common lignocellulosic material used for the cultivation of *Pleurotus ostreatus* are cocoa beans, cotton, tea, rice, paper, saw dust etc. Among that cocoa beans are one of the great substrates for the *P. ostreatus*; it has increased remarkable yield of *Pleurotus* species. Among the many substrates sawdust shows minimum contamination. In an optimization approach, mixture of 40% of cocoa shell waste, 40% of sawdust, 19% of oatmeal and distilled water (pH 3.5, humidity 59-73% and Temperature 25^{o}C) has given good yield of *P.* ostreatus in 6 to 8 weeks [7]. The combination of cassava peel, coconut residue and coffee waste can give the high yield of *Pleurotus ostreatus* [8]. The growth of *P. ostreatus* has noted on the pasteurized compost made up of different substrates such as sugar straw, sugar cane bagasse, wheat bran, rice bran etc. [9, 10]. In an experimental study carried out in Saudi Arabia shows that the growth of *P. ostreatus* on grinded date palm leaves along with agricultural waste like wheat straw saw dust etc. imposesthe high carbohydrate and fibre content. The ratio 25:75 of the date palm and agro waste is supposed to be the ideal combination for the best yield and nutritional quality of the mushroom [11].

Along with the substrate the mushroom growth also depends on the light intensities. To prove this, an experiment has been performed on the response of oyster mushroom to the blue light (430 nm – 470 nm) and red light (610 nm – 640 nm). In this experiment, proper substrate was provided to *P. ostreatus* spawns. Humidity was 55%. Ambient temperature was 24^{o}C. The incubation period was of 20 days. After 20 days, the immerged mycelia were kept under different light conditions such as dark, red, and blue for full body growth. In the blue light, there was remarkable increment in the stipe, pileus and gills of *P. ostreatus* [12]. In another study, under 200-lux light intensity high amount of riboflavin, iron and thiamine was recorded in the oyster mushroom [13].

Pleurotus sajor-caju

The *Pleurotus sajor-caju* production has recorded more efficiently on wheat straw bran with less time requirement and high protein content. The enzymes like CMCase and laccase help to degrade the surrounding substrates for the growth of mushroom [14]. A study in 2014 on the effect of temperature and nutritional conditions on mycelium growth of the oyster mushroom shows that brown rice, sugarcane residue, acacia sawdust, corncob are more favorable lignocellulosic media for *P. sajor-caju* mycelia growth at 28^{o}C [15]. The mycelial growth of *P. sajor-caju* is seen more on raw cotton substrate complementedwith humic acid [16].

A comparative study was conducted in 1993 to find a good substrate for the growth of *P. sajor-caju*. The selected substrates were *Lantana camara* and wheat straw. It results into the conclusion that the *P. sajor-caju* shows vigorous growth on sterilized *Lantana camara* lignocellulosic substrate than the sterilized wheat straw [17].

In 1997 cultivation of *P. sajor-caju* was conducted on oak sawdust, wheat bran and corn bran medium. The spawns had taken from China. The spawn incubation was done for 35 days at 60-90% humidity and 17-24^{o}C temperature. After that for the full body growth 94-98% humidity was maintained and temperature was about 15-16^{o}C along with aeration. Then after 5 days harvesting was done and 50-100 gm per bottle yield of mushroom was taken [18].

Some strains of *P. sajor-caju* give different range of growth response over different

pressure, temperature and pH. The range of pressure, temperature and pH varies from 0.5 to 5 Pa, 5 to 40°C and 2 to 12 pH respectively [19].

In India the study had conducted in 2007 on different substrates used for *P. sajor-caju* cultivation by using cotton stalk, ground haulms, soybean straw, pigeon pea stalks and leaves, and wheat straw either in combination or single. Out of these, cotton stalk, pigeon pea stalk and wheat straw were more favorable [20].

Pleurotus cystidiosus

In Indonesia *Pleurotus cystidiosus* is grown on sawdust, rice straw, rice husk, cotton waste, waste tea leaves, corn husk, waste paper etc. The saw dust and cocoa pod waste mixture can really incorporate the nutrient quality to the mushroom as well as it provides high yield. In addition to that the ration of sawdust and cocoa pod waste of 75:25 gives the increased number of fruiting bodies [21]. The different concentrations and ratios of the different agro waste is studied on *P. cystidiosus* with the use of sawdust, corncob, sugarcane bagasse, etc. substrate combining corncob and sugarcane bagasse were favorable for the growth of *P. cystidiosus* [22].

Pleurotus pulmonarius

The growth of *P. pulmonarius* is seen on coffee pulp which took 50 days for complete cultivation. After mycelial growth the bags were incubated at 27°C with 95% humidity and controlling the light about 12 hours. The growth on the coffee pulp helps mushroom in enhancing the disease resistance [23].

A study conducted in Mexico showed that *P. pulmonarius* gives the highest production ondry banana leaves when the substrate is immersed in 2% lime water for one day. This is very cheap and easy method, the harvesting can be done in 61 days. The bags were incubated at 23-29°C temperature with 74-81% humidity [24, 25].

Pleurotus eryngii

In 2003 an experiment was performed in Japan on the cultivation of *P. eryngii* which showed that the wheat bran substrate enriched with the *Cyperus alternifolicus* (umbrella plant) has given more mycelial growth than the sawdust of *Cryptomeria japonica* (sugi). The optimum conditions for mycelial growth were 23° C of ambient temperature for 14 days and for the fruiting body growth the temperature was 17° C with 90% humidity and 25 days of cultivation period [26].

Pleurotus florida

A study performed on *P. florida* showed that it required short time (39 days) to complete its full lifecycle. Rice straw was found the best substrate for it'scultivation. This species is one of the testy edible mushrooms with many medicinal properties [27].

***Pleurotus cornucopia*e**

In cultivation of *Pleurotus cornucopia*e maximum yield is obtained on switch grass followed by cotton seed hull/ wheat straw. Although to get the maximum yield from switch grass it needs to inoculate in winter [28].

Conclusion

Optimum cultivation parameters of various *Pleurotus* sp. have been reviewed in this chapter. Different species have different requirements for their maximum growth. No fixed substrate is available for all species.Hence optimization of every protocol must be performed before shifiting to large scale approach.

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Chapter 5 BIOACTIVE POTENTIAL OF DIFFERENT SOLVENT EXTRACTS OF SOME MUSHROOMS: A REVIEW

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Abstract

Mushrooms have remained an eternal part of traditional cuisines due to their beneficial health potential and have long been recognized as a folk medicine for their broad spectrum of nutraceutical, as well as therapeutic and prophylactic uses. Nowadays, they have been extensively investigated to explain the chemical nature and mechanisms of action of their biomedicine and nutraceutical capacity. Mushrooms are known as a macro fungus. Remarkable health benefits of mushrooms such as antiviral, antibacterial, anti-parasitic, antifungal, wound healing, anticancer, immunomodulating, antioxidant, radical scavenging, detoxification, hepatoprotective cardiovascular, anti- hypercholesterolemia, and anti-diabetic effects, etc., have been reported worldwide and have attracted interests of its further exploration in pharmaceutical and commercial sectors. Mushroom is one of the functional foods that helps in the treatment and therapeutic interventions of sub-optimal health states, and prevent some consequences of life-threatening diseases. Mushrooms mainly contained low and high molecular weight biomolecules such as polysaccharides, fatty acids, lectins, and glucans which are responsible for their therapeutic action. Identification of chemical components and determination of their beneficial actions from mushrooms are the challenging tasks. This chapter highlights bioactive potential of different solvent extracts of some mushrooms.

Keywords: Neuroprotective, immunomodulatory, hepatoprotective, antitumor, antidiabetic, polysaccharide.

Introduction

Mushrooms have been present on earth from a long time and are an important, indispensable part of global cuisine. Mushrooms are exploited for their beneficial health properties.There are about 2000 mushroom species worldwide, but only few of them are edible and nutraceutical. A species of button mushroom *Agaricus bisporus* is the most widely grown mushroom, followed by *Lentinus edodes* and *Flammulina velutipes*. Mushrooms contain various metabolites, such as terpenes, steroids, anthraquinone, phenolic acid, and benzoic acid, while primary metabolites contain proteins, oxalic acid, and peptides. Mushrooms have been reported to have an action against both Gram-positive and Gram-negative bacteria [1].

Nutritionally, they are rich in protein and amino acids [2]. However, they contain a significant amount of vitamins such as B1, B2, B12, C, D, and E

[3,4,5,6,7,8]. Structurally, mushrooms comprise the pileus, lamella, stipe, mycelium, and roots. The roots are mainly responsible for absorbing and gathering nutrients [9]. Earlier, there was a misconception regarding the classification of mushrooms as plants. Later, with advancement in science, they were added under the independent kingdom known as Mycota, mainly characterized by chitin inside the cell walls [10]. Bioactive potential of different solvent extracts of some mushrooms has been discussed below.

Hericium erinaceus

Erinacines (A-I) is very important and well-studied bioactive metabolite. It belongs to a group of cyathin diterpenoids. It was extracted from the mycelium and fruiting body of *Hericium erinaceus* and demonstrtated for its neurotropic and neuroprotective effects. It can induce nerve growth factor (NGF) synthesis, both in vitro and in vivo. However, this medicinal mushroom also has antioxidative, anti-inflammatory, anticancer, immunostimulant, antidiabetic, antimicrobial, hypolipidemic, and antihyperglycemic properties; although it's most frequent use is for the treatment of neurodegenerative diseases and cognitive impairment [11, 12, 13, 14]

Erinacin A, from the erinacine group, has been proven to have an effective protective activity against Parkinson's disease [15]. This metabolite was also found to be effective against ischemic stroke, as reported in a study on rats [16, 35, and 36].

Agaricus bisporus

Agaricus bisporus contains beta-glucans, ergosterol, ergothioneine, vitamin D, and flavonoids, with varying concentrations [11, 17]. Besides, essential amino acids, peptides, glycoproteins, nucleosides, triterpenoids, lectins, fatty acids, and their derivatives make this mushroom of considerable importance for its potential application as an antimicrobial, anticancer, antidiabetic, antihypercholesterolemic, antihypertensive, hepatoprotective, and antioxidant agent [18]. The consumption of *A. bisporus* in the diet is recommended to prevent prostate cancer due to the action of conjugated linoleic acid (CLA) since it inhibits proliferation in prostate cancer cell lines in vivo [19]. The nephroprotective effects of *P. ostreatus* and *A. bisporus* aqueous extracts on hyperoxaluria-induced urolithiasis induced in Wistar rats have been investigated. The mushroom extracts inhibited the progression of nephrolithiasis and showed nephroprotective effects against ethylene glycol-induced kidney dysfunction [20]. The anti-inflammatory and antioxidant properties of *A. bisporus* biomass extracts from in vitro cultures were highlighted by Muszynska et al. [21, 39].

***Pleurotus* sp.**

Several studies have been carried out to assess the biological activities of *Pleurotus* species. *Pleurotus florida* and some other related species were found to have antioxidative, antimicrobial, antidiabetic, anticancer, anti-inflammatory, immunomodulatory, antihypercholesterolemic, antihypertensive, antimicrobial, hepatoprotective, and antiaging properties; although very few mechanisms and specific metabolites responsible for these activities have been elucidated, identified and characterized. For example, the immunomodulatory and antitumor activities of *Pleurotus ostreatus* (Jacq.) P. Kumm. were reported by Sarangi et al. by in vitro and in vivo assay [22]. The effect of water-soluble proteoglycan fractions extracted from *P. ostreatus* on a sarcoma-180-bearing mouse model had been evaluated. Treatment with this extract, it resulted in a quantitative reduction of tumor

cells and their arrest in the pre-G0/G1 phase of the cell cycle. Moreover increased cytotoxicity of NK cells was also recorded. In a study by Jedinak and Sliva comparing the impact of different medicinal mushrooms on the growth of breast and colon cancer cells, *P. ostreatus* proved to be the most effective, suppressing cell proliferation via the p53- dependent and p53-independent pathways. More specifically, the methanolic extract of the mushroom induced the suppression of the proliferation of the human breast cancer cell lines MDA-MB-231 and MCF-7 and colon cancer cell lines HCT-116 and HT-29, and caused cell cycle arrest in the G0/G1 phase in MCF-7 and HT-29 cells [23, 24].

Grifola frondosa (Dicks.) Gray

Grifola frondosa or maitake mushroom is a medical mushroom with numerous medicinal properties. Metabolites from *Grifola frondosa* were extracted and its main bioactive metabolite was named D-fraction or GFP which is a β-glucan proteoglycan compound. Several studies have demonstrated its antitumor effect [25, 26, 27]. Two polysaccharide fractions obtained from GFPs and named as F2 and F3 showed promising hypoglycemic effects in vitro [28].

Similarly many other biologically active compounds have, however, been extracted from maitake mushroom and investigated for their effects [29].

Ganoderma lucidum

Several researchers reported the protective action of this mushrooms on experimentally induced liver injuries. Morel mushrooms have been reported to have beneficial action against the CCl_4 and ethanol-induced hepatotoxicity [30, 31, 32, 33].

Conclusion

The mushrooms are the sources of various biotechnologically important primary and secondary metabolites. They have shown numerous outstanding properties for treating and preventing many life-threatening diseases. Hence they are included in the category of functional food and important nutraceutical. Bioactive compounds extracted from mushrooms by the treatments of different solvents include polysaccharides, proteins, peptides, enzymes, and other compounds. These compounds help to combat against some viruses and thereby enhance immunity. Mushroom has a great diversity and many medicinal varieties, many of them have been remained untouched, and their pharmacological action has not been evaluated up to the date. Thus, there is a need to explore the other side of the coin emphasized with modern and advanced contrivances.

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Chapter 6 A COMPREHENSIVE REVIEW ON POST HARVESTING PROCESSING OF MUSHROOM

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Abstract

Mushroom is defined as a macrofungus with a distinctive fruiting body. Edible mushroom is very nutritious functional food and also contains low fat, calories and good content of vitamin. Mushroom is a rich source of good quality of proteins, essential amino acids, minerals and vitamins. White button mushroom (*Agaricus bisporus*), oyster mushroom (*Pleurotus florida*) and paddy straw mushroom (*Volvariella volvacea*) are popular and edible which are grown commercially in India. Many mushrooms are white to gray in colour while they are growing. Like all fruits and vegetables, mushroom are perishable hence their post harvesting preservation is necessary. Fresh mushroom have a short shelf life. Therefore they are either marketed soon after harvesting or preserved with special care in cold storage room. Harvesting is done by plucking fruiting bodies of mushroom from soil using hands. Sometimes the heads of fruiting body are chopped off using a knife or sharp scalpel. The harvested mushrooms are then subjected to primary processing. At this stage they are very fragile and have a short shelf life, hence they should be consumed fresh. At warm or high temperature they lose their freshness within a day and deteriorate rapidly if not processed or refrigerated. This chapter aimed to review post harvesting processing of mushroom.

Keywords: Mushroom, perishable mushroom, types of mushroom, harvesting, processing

Introduction

In India the first mushroom cultivation was publicized by Thomas in the year 1943 in Agricultural College, Coimbatore, who cultivated paddy straw mushroom, which led to spread the cultivation techniques throughout the India [1]. In 1961, Indian Council of Agricultural Research (ICAR), New Delhi, started first cultivation of the button mushroom (*Agaricus bisporus*) in Solan, which is called the mushroom city of India [1, 2]. Mushrooms are best consumed in their fresh state. Mushroom shows variation in it's original colour and texture under different storage conditions in post harvesting processes. Mushroom has a high rate of respiration and hence proper attention should be given for post harvesting processing. The nicknames of mushroom 'white vegetable' and 'boneless vegetarian meat' are very meaningful since it contains bountiful amount of protein, vitamin and fibre apart from having many medicinal properties. Mushroom contains 20-35% superior quality of protein (dry weight) which is higher than those of vegetables and fruits. The most crucial biotechnological application of mushroom is catabolism of complex lignocellulosic residues from agricultural fields and forests

into simple protein rich biomass. Such type of conversion by biodegradation of agro waste reduces environmental pollution and produces a good kind of manure which may be used as soil conditioner. Mushrooms are easily cultivable in hilly regions due to abundant moisture but can also be grown in artificial environment with proper temperatures and humidity control. Varieties of mushroom must be identified thoroughly before it's cultivation. Some of the major consumed varieties of mushroom in India are button mushroom, shitake mushroom, oyster mushroom and paddy straw mushroom. In India, commonly cultivated species of mushroom are white button mushroom, oyster, Shiitake mushrooms and other mushrooms. Mushrooms are available in local markets of India in 200 gm to 500 gm packs of made up of different materials such as plastic punnets, cardboard chips, plastic tray and expanded polystyrene [3,4, 5, 6, 7, 8, 9 10].

Harvesting

Harvest is carried out at maturation stages of mushroom depending upon the species and upon consumer preferences and market value. Example: in about 3 weeks, small mushroom appearing and then continue to keep their environment. Mushroom harvest is ready when their caps separate fully from their stems. Harvesting is done by plucking the fruiting bodies using hands. Sometimes heads are cut using a sharp knife or scalpel. Nowadays automated machines are also available for the large scale harvesting process. The harvested mushrooms are then subjected to primary processing. Mushroom has a high rate of respiration and hence proper attention need to be given for storage of freshly harvested mushrooms [3,11,12].

Post harvest management and preservation

Mushroom is perishable and after harvest they often change in ways that make them unacceptable for consumption. It is a perishable commodity that requires processing after harvesting to prevent from wilting, ripening, browning, and liquefaction, and loss of texture, aroma and flavor. Hence preservation has very great significance. The preservation process can be accomplished in various ways such as drying, dehydration, freeze drying, pickling, freezing, canning, sterilization, direct packaging etc. After mushroom harvesting, drying is the best option for mushroom farmers who do not have useful facilities. In fact it is the oldest technique known to the mankind. After harvesting the mushrooms have approximately 90% moisture and after drying it should be up to 12%. Drying temperature should be 55 to 60^{o}C for few hours. One of the biggest advantages of drying is that if the mushrooms are not sold immediately, they can be sold later, and the drawing process kills all kinds of insects and contaminating microorganisms, so the mushrooms do not spoil. One of the biggest disadvantages of mushroom drying is loss of texture, flavor, and color along with reduced rehydrability. In general, the drying technique is used for all types of mushrooms except button mushrooms. Traditionally, drying had been carried out under direct sunlight; however nowadays sophisticated instruments are available for large scale mushroom drying such as fluidized bed dryer, dehumidified air dryer, freeze dryer and cabinet dryer [3,13].

After harvesting, the white button mushrooms (*Agaricus bisporus*) are rinsed to remove soil debris and dust. Washing the mushrooms also removes the bacteria that infect them. Many times the mushrooms are taken in a solution of reducing agent so that browning of the mushrooms does not occur by the action of polyphenoloxidases. Mushrooms are washed in an anti-microbial solution, oxine (50 ppm) for 2 minutes at 12^{o}C to extend their shelf life and to prevent bacterial growth and colour deterioration. The use of sodium hypochlorite (100 ppm) and

calcium chloride (0.55%) along with oxine (100 ppm) is more effective. Using these preparations makes the mushrooms firm and easy to store. A final washing of the mushrooms with distilled water is very important to remove all trace of chemicals. Another alternative is to wash the mushrooms in a solution of calcium carbonate. Due to this, the number of bacteria also decreases and the color does not change. But the most useful results so far have been met with a solution containing oxine (50 ppm), sodium erythorbate (0.1%), and calcium chloride (0.5%). The results of an experiment stated that a solution of 0.05% potassium metabisulphite helped the mushrooms to retain their initial white color until the end of storage period. Many farmers are also using this method and then selling mushrooms in the market but the best is to pack fresh mushrooms and then sell since mushrooms are very important for health and should be chemical free. The people's trust in the purity of the mushroom should not be broken, otherwise, if it is misconceived, the sales of the mushroom will not be high, and this will result in economic loss to the mushroom farmers themselves [3,13,14,15].

Modified atmosphere packaging is a unique method for packaging of white button mushrooms. In this method fresh mushrooms are sealed in a container containing modified atmosphere. Actually in this atmosphere equilibrium concentration of O_2 and CO_2 is established. This helps in extending the shelf life and maintenance of mushroom's quality. One method of preserving mushrooms after harvesting is through modified humidity packaging. In this method an attempt is made to maintain maximum humidity in the container in which the mushroom is packed. But in case of high humidity, water droplets accumulate on the top of the container and this leads to high growth of bacteria. So a good alternative to this is to add calcium chloride in the box which is water absorbent. As the calcium chloride absorbs the water, excess water does not pool at the top of the container [3,14,15].

After harvesting of oyster (*Pleurotus* sp.) mushrooms, adhered paddy straw is removed and mushrooms are packed in perforated polythene bags of thickness less than 100 gauge. The vent area of polythene bag should be about 5%. This type of packing helps to retain the freshness and firmness of the oyster mushroom but reduces the weight to a small extent. Rough handling of oyster mushrooms should not be done in any way. If oyster mushrooms are packed in non-perforated polythene bags, water droplets accumulate in those bags, reduce the thickness of the mushroom and also lose their softness and overall texture. For this, cooling with cold air is directed to pack the oyster mushrooms. Fruit bodies oyster mushrooms are collected in trays or baskets. Small pouches containing crushed ice are placed in the trays. The trays are then covered with porous polythene sheets. Such trays are very convenient for transportation [3,15].

Milky mushroom (*Calocybe indica*) is introduced from India to all over the world. It is produced in summers in different parts of India and this is why it is called off season mushroom. Selected mushroom farmers or seasonal growers who do not have access to transportation and storage facilities tend to produce milky mushroom in large quantities. These mushrooms last very well for three to four days without changing color and appearance. It sells very much in highly localized market. It's overall process of washing, packaging, pre-cooling and refrigeration, transports and storage is almost same as button mushroom [3,16].

Paddy straw mushrooms (*Volvariella volvacea*) are also packed in polythene bags. If they are stored at very low (cold) temperatures, there is a possibility of frost injury and deterioration

in quality of fruiting bodies of mushroom. Therefore, such mushrooms need to be stored in porous polythene bags at a temperature of 10 to 15^{o}C. The shelf life period of paddy straw mushroom is very short i.e. one day so it should be sold on the same day of harvest. In Taiwan, bamboo baskets are used for the transportation of milky mushrooms. Pouches containing crushed ice are placed on all sides of this basket and milky mushroom is placed in the center of bamboo basket for transportation. This type of basket has more aeration channels. Wooden boxes are used for mushroom packing in China. These boxes are transported from one place to another by train or boat [3,17,18,19].

Conclusion

Mushrooms are one of the most popular and versatile gift of nature. Mushrooms are packed for proper transportation to the market. If there is a good, attractive and clean packing, the sales of mushrooms are also quick. If there is dirty unhygienic packing, the mushroom is likely to spoil and not even sell. Mushroom can be mixed into any food preparations or can be processed to give a new product. Apart from the mushroom food products many innovative products are emerging such as mushroom based building materials, medicines, mycelium based platforms, biodegradable packaging, mycelium based leather etc.

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Chapter 7 A CRITICAL REVIEW ON IMPLEMENTING MODALITY OF OYSTER MUSHROOM CULTIVATION TECHNOLOGY ESPECIALLY FOR FARMERS AND THE NEW LEARNERS (BEGINNERS)

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Abstract

In all over the world edible mushrooms are eaten and appreciated for their flavor. Mushrooms are edible fungi suitable for all age groups and produces high quantity of quality food. Economic and ecological values and medicinal properties of mushrooms are of great significance. Production of this type of edible fungi can greatly enhance sustainability and economic strength of farmers. The oyster mushrooms have advantages over other mushroom that it grows on a wide range of temperature from 18-30^{o}C and various substrates. Economically oyster mushroom cultivation is easiest and cheaper method as compared to button mushroom. The equipment and processing cost for oyster mushroom cultivation is approximately up to two lakh. In this chapter we have discussed about technical model of oyster mushroom cultivation especially for farmers and the new learners (beginners).

Keywords: Oyster mushroom, equipments, cost, economic importance, cultivation process.

Introduction

Mushrooms are very high in protein and they are cholesterol free hence these macro fungi are considered very beneficial for our health. Many food items can be prepared from edible mushrooms. Actually, they are the fruiting bodies of fungi. Due to this reason mushrooms are also called as fleshy fungi. Simply, mushrooms are described as fleshy, spore bearing and multicellular fungi. Mushrooms are a good source of protein, vitamin and mineral. Mushrooms lack chlorophyll and grow either parasitically or saprophytically. Mushrooms with their flavor, texture, nutritional value and productivity per unit area have been identified as an excellent food source to alleviate malnutrition in developing countries [1-6].

Oyster mushroom (*Pleurotus* sp.) belonging to class basidiomycetes and family agaricaceae is popularly known as Dhingri in India and grows naturally in the temperate and tropical forests on dead and decaying wooden logs or sometimes on dying trunks on deciduous or coniferous woods [7]. The fruit bodies of oyster mushrooms are shell or spatula shaped. They exhibit different shades of colour pigments such as white, creamy, grey, yellow, pink or light brown depending upon the species [8-10]. Edible species of mushrooms are suitable for consumption to children, adults and elder persons. Mushroom can supply high protein diet and lower calorific value, so it is suitable for heart patients as it contains essential amino acids

needed by human body. Nowadays mushroom cultivation has become more popular throughout the world. Production of such edible fungi enhances sustainability and economic strength of the farmers. Inclusion of the edible mushroomsin human diet helps to combat oxidative stress [11, 12].

Cultivation of mushroom requires limited space, low initial investments, and cheap raw materials that are easy to acquire. In India, mushrooms are harvested in every season and cultivated in environment controlled rooms. Mushroom cultivation requires 80 to 90% humidity and adequate ventilation [13]. Before starting a mushroom cultivation unit a new person or entrepreneur needs to undergo training either online or offline. Mushroom cultivation training is given by many companies such as Mushroom learning center, Kolhapur and PFN mushroom and Spirulina cultivation training center, Kodoli (Maharashtra, India). The first thing to do is to choose a proper location for setting up a mushroom unit. Farmers can start the mushroom cultivation business in a small space in their farm. Householders can start mushroom cultivation in a small room in their houses. Cool climate is very useful for mushroom cultivation. Cultivation of mushrooms is very convenient in cold regions of different parts of the world; however mushrooms can be cultivated in climate controlled rooms in regions that do not have such a cold climate. Farmers whose economic conditions are very weak can start mushroom cultivation in simple mud houses. The site chosen for mushroom cultivation should be close to the main road to reduce the cost of transportation. Availability of water is a must. Raw materials such as straw, poultry manure and agricultural wastes should be available around the chosen site at very low cost. Common inputs required for growing mushroom crops in each season include mainly uninterrupted power supply and low-paid labor. Spawn is a basic thing to grow mushrooms. Different agro companies offer different types of mushroom spawns. The Mushroom research centers also provide a good quality of spawns. The spawns should be pure without any pest or disease infestation [14, 15].

General materials and equipments required for mushroom cultivation

For effective mushroom cultivation, the proper technique, tools and equipments are important. The following is the list of tools, equipments and materials required for mushroom cultivation [16, 17].

1. Measuring tape
2. Room for mushroom growing
3. Exhaust fan
4. Desert cooler
5. Thermometer
6. Hygrometer
7. Luxmeter
8. Box for mushroom transportation
9. Straw immersion tank
10. Pump set
11. Sprayer
12. Chaff cutter
13. Trays for mushroom cultivation
14. Bamboo for platform and trays as required
15. Polythene bags
16. Paddy straw and other agricultural waste
17. Spawn bottles, flasks or bags
18. Chemicals for sterilization and processing
19. Weighing balance
20. Refrigerator for storing spawn
21. Food dehydrator
22. Humidifier

The total non-recurring costs in mushroom cultivation is Rs. 1,50,000 (Table 1). The total recurring cost in mushroom farming Rs. 40,000 (Table 2).

Table 1: Expected commercial mushroom cultivation cost for beginners

Sr. No.	Particulars	Approximate cost
1	Cost of construction for rooms	Rs. 1,25000
2	Scrab wooden shelves	Rs. 20,000
3	Miscellaneous cost	Rs. 5000
4	Total cost	Rs. 1,50000

Table 2: Expected recurring cost in mushroom farming

Sr. No.	Particulars	Approximate Cost
1	Paddy straw, chicken manure, rice bran, maize, grain, linseed meal	Rs. 15000
2	Urea, potash, gypsum	Rs. 1500
3	Casing oil	Rs. 5000
4	Polythene bags	Rs 1500
5	Fuel charges + electricity charges	Rs. 4000
6	Labour for 3 months	Rs. 8000
7	Miscellaneous costs	Rs. 5,000
8	Total cost	Rs. 40,000

The above given figures are the approximate and expected costs that an entrepreneur have to invest for setting up a new mushroom farming business in India [18].

Justification about the need of some major equipment

Rack and pipes are required for setting initial start-up for mushroom cultivation and creating proper space and position for holding substrate bags and trays. Humidifier is the most important equipment for maintaining uniform humidity in the mushroom cultivation room [19]. Exhaust fans are required for maintaining fresh atmosphere inside the cultivation room [20]. Temperature is a critical factor which needs to be continuously monitored during cultivation period, otherwise it would adversely affect on growth. Hence digital thermometer is required. Hygrometer is required to measure moisture content in the cultivation room. Light intensity also affects on growth of mushroom hence Luxmeter is required to measure the intensity of light inside the cultivation room. Food dehydrator is required for the post harvesting preservation of mushroom. After dehydration by drying, the mushrooms are preserved for a long period till the selling. Laminar air flow is required for spawn preparation under aseptic condition and to keep them free from the contaminants. Laminar air flow may be used to perform aseptic operations like bag filling, spawn adding, threading and sealing [21].

General steps involved in oyster mushroom cultivation practices [22]

1. Inoculation

Adding spawns (seeds of mushroom) to the sterilized substrate is commonly referred as inoculation in mushroom cultivation practices.

2. Incubation

Incubation is the condition in which the spawn inoculated bags or trays are hold under manually controlled specific temperature and moisture containing atmosphere or any other

specific condition as required in a room or chamber for specific time period.

3. Fruiting

The fruiting stage occurs when the mycelium grows completely inside and outside of the substrate. Contaminated bags should be discarded properly as early as possible because contaminating molds compete with mushroom mycelium for their nutrition, so it may take a long time to appear the fruiting stage. Generally high humidity (75-85%) and low temperature (25-30 ^{o}C) is required during fruiting of mushroom. Frequent spraying of water is necessary for the cropping room depending upon the atmospheric humidity. Fruit bodies formed at 85-90 % relative humidity are bigger with less dry matter while those developed at 65 to 70 % relative humidity are small with the high dry matter. CO_2 concentration during cropping must be less than 800 ppm. Sufficient ventilation has to be provided during mushroom fruiting.

4. Harvest

After the fruiting body has fully grown, it should be harvested within 4 to 8 days and need to be sold at the earliest or stored at proper conditions [22, 23-25].

Conclusion

From this chapter we came to know about the idea of implementing modality of oyster mushroom cultivation techniques for new learners. Mushroom is economically profitable and promising agriculture commodity. Even a person or a farmer who has very little space can do mushroom cultivation practice because it requires very low investment.

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Chapter 8 A DELIBERATIVE REVIEW ON TRENDS ON VALUE ADDED PRODUCTS OF MUSHROOMS AND RECENT PATENTS

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Abstract

Different varieties of mushrooms are popular for their texture, appearance and properties and they have been eaten and used as medicine since thousands of years. Various value added food items of mushrooms are being prepared by many food industries. Biotechnology has played a significant role in providing many commercial products utilizable in the area of society. Lot of mushroom production processes have been patented by the researchers by implementing their own innovative ideas. In this chapter we have summarized some value added products of mushrooms and recent patents.

Keywords: mushroom, intellectual properties, patents, functional food

Introduction

Mushrooms have been eaten and used as medicine since thousands of years. Traditional and folk medicine practitioner were used to exploit mushrooms (bell shaped fungi) for healings and cleansing properties [1]. Different varieties of mushroom viz. white button, crimini, portabella, shiitake, oyster etc. are popular for their texture, appearance and properties. Almost all varieties of mushrooms are very low in calories and fat. They have a moderate amount of fiber content. Mushrooms vary in appearance but generally they exhibit distinguished stem, fleshy rounded cap and gills underneath the cap. Mushroom is a good source of vitamin B, vitamin D and some minerals [2].

Value added products of mushrooms

Nowadays various value added food items are being prepared by many food industries from the edible mushrooms such as mushroom candy, chips, biscuits, soup powder, nuggets, ketchup, curry, papad, noodles and mushroom fortified cakes etc. About 100-200 g mushroom (on dry weight basis) are required to a normal human of 70 kg weight to maintain and coordinate nutritional balance of body. Mushroom puree, mushroom paneer, mushroom rice (pulao), mushroom omelette, mushroom soups etc. are some popular dishes prepared by chefs of high grade hotels. Even many home cooking housewives know the recipes of mushrooms [3, 4].

Patents on mushroom

Biotechnology has played a significant role in providing processing, designing and protection of valuable commercial products utilizable in many area of the society. Patent is one of the ways to protect the intellectual properties (IPR). Other ways of IPR protection are copyrights, trade secrets, trademarks, designs, and geographical indications. Patent is a special

right to the inventor that has been granted by the government through legislation. Actually, a patent is a personal property which can be licensed or sold just like any other property. In India, the Indian Patent Act (1970) allows the 'process patents' but not the 'product patent' and the maximum duration of patent is for 5 years from the date of grant and 7 years from the date of filing the patent application [5].

Wei and Cao published a patent on a method for cultivating mushrooms, comprising mixing culture material with an enzyme for degrading or converting cellulosic material [6]. Tiantian and coworkers published a patent on cultivation substrate of edible mushroom, preparation method of cultivation substrate and cultivation method of edible mushroom [7]. Yongbei et al. published a kind of method of utilization mushroom cultivation improved soil organic matter [8]. Recently, Lapierre and Stefaan published a patent on tilt-able module for mushroom cultivation that can be tilted to an angle from 60° to 85° [9]. Sharma and coworkers developed the technology for growing a distinct strain of shiitake mushroom with a specific combination of substrate. This had reduced the cropping cycle to an extent of 50 % [10]. Jacobus and coworkers invented a device for growing mushrooms, including beds for holding compost and shelving arranged for supporting the beds for holding compost [11]. Amico has patented a system and method for commercially growing button mushrooms. His method is very specific for placing a layer of compost in a bed; laying a polymer sheet over the bed; placing a layer of peat over the sheet and growing a crop of mushrooms in the first layer of peat [12].

Conclusion

Edible species of mushroom can be used as function food. It provides multiple nutrient content which helps in health improvement and known as superfood. Biotechnology has played a significant role in providing processing, designing and implementing various ideas and methods in mushroom cultivation. Such efforts and outcomes of the researchers can be protected by intellectual property rights. The patent can provide great value and an increased return into companies on the investment made in developing new technology.

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Chapter 9 AN INTRODUCTION TO MACHINES INVENTED FOR MUSHROOM PROCESSING (STEM CUTTING AND SIZING, AUTOMATIC MUSHROOM TRIMMING ETC.)

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Abstract

New mushroom varieties and new technologies have drastically increased global mushroom production in last few decades. Mushroom cultivation procedures andits management practices are varied widely based on the type and substrates used. Typical steps in mushroom cultivation processes are substrate preparation, bag filling, sterilization, inoculation, incubation, and harvesting regardless of the types of mushrooms. A lot of efforts have been conducted to mechanize each step of mushroom cultivation. Nowadays many machines have been invented for aligning, feeding, stem-cutting and sizing of mushrooms. This chapter has reviewed the investigation about the mechanized and automated levels of mushroom cultivation practices important for future researches.

Keywords: Automation, Mechanization, Mushrooms, Humidity, Mushroom trimming

Introduction

Automated mushroom growing room containing environmental control systems have been developed to build up suitable climate to the surrounding of mushrooms [1]. Moreover, automated harvesting systems have been developed for more accurate and convenient harvesting [2]. Mushroom farming is becoming a very profitable business for the layman in the recent times. If the cultivation and marketing method is right, this business can generate a lot of income [3]. If you use modern automated techniques, it can definitely make more profit in less time. Machines involved in almost all the steps of mushroom farming are now automated and available in the market [2].

General equipments required

Saw dust is one of the requisite which is used as substrate for mushroom cultivation [4]. Fine powder of saw dust is required for it's quick biodegradation by the mushroom mycellium. Hence the machines are developed for sawdust sieving [5]. Maximum capacity of such machines has recorded as 212 kg/h. Apart from saw dust many other agricultural residues are used for mushroom cultivation. Therefore several mixing machineries have been developed to mix different substrates properly**.** Properly mixed substrates must be bagged and many such bags are required to achieve maximum mushroom production. The more bags, the more produce. However this kind of work takes a lot of time by the manual way. Hence in many countries to save the time, bag filling machines have been developed. Nowadays such machines are available

in commercial level. Suraweera et al. (2021) have reported glow box and oven door methods for inject spawn into sterilized growing media. Some automated machines are developed for automatic adjustment of CO_2 level in the mushroom growing chambers. Humidity is the most essential factor for growing mushrooms. Maintaining humidity in summer is a very challenging task. Therefore, in many places mushroom production is done only in two seasons namely monsoon and winter. For this, humidifier is used to maintain a humid environment (Fig. 1). Oyster is the most popular species of mushroom production in summer. There are different types of humidifier devices and their prices also vary [6].

Fig.1: Centrifog Humidifier

Post harvesting equipments include mushroom drying machines and stem-cutting and sizing machines. Mushroom dryer is another useful machine for the mushroom farmers to avoid breaking of fruiting bodies at the end. This machine maintains the quality of the mushroom and uses optimal temperature for drying. It dries up a huge volume within short time for mushroom drying**.** Operating method of this machine is also very easy. Furthermore, machines for stem-cutting and sizing of mushrooms have been manufactured. Mature fruiting body of mushroom consists of a cap, gills under the cap, a stem and roots at the stem base. In harvesting the mushrooms, the most satisfactory process is to collect undamaged fleshy part of mushroom. Nowadays in novel mushroom processing equipment mushrooms are mechanically fed to the equipment, which positions, cuts the roots from the stems, and sorts the same according to the size of cap diameter. Automating mushroom trimming machines produce slices of mushroom caps of different diameters and thickness [6,7,8].

Conclusion

Different equipments are used in large scale production of mushroom to obtain high yield in short time. This also saves time, energy and labour cost. The yield obtained by using different instruments and equipments leads to higher production than the older traditional methods. A higher quality product of mushroom made using different instruments will definitely help to cater to the growing population.

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Chapter 10

A CONCISE REVIEW ON PRESERVATION METHODS OF MUSHROOM

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Abstract

Mushrooms represent an attractive food for vegetarians due to the high-biological-value proteins and vitamin D content. Mushroom is considered as a functional food rich in both nutrients and medicinal properties. Mushrooms cannot be stored for a long period moreover during processing they show change in colour and texture. There are many traditional and emerging techniques for mushroom preservation. In general, most of the conservation techniques have shown a positive effect on the maintenance of key quality parameters of mushrooms. The development of packaging for the preservation of fresh mushrooms needs to incorporate in sustainable packaging. In this chapter we have reviewed selected preservation methods for mushrooms.

Keywords: Preservation, quality, freezing, drying, storage.

Introduction:

Mushroom is a very delicate and perishable food item. Its shelf life is also very short. They dry quickly as the water vapors evaporate from them [1]. In addition, many bacteria and fungi from air microflora are constantly trying to spoil the mushroom. Therefore, its protein, carbohydrate and soluble components can be reduced [2]. Browning of unpreserved mushrooms starts quickly. The exterior shape of the mushroom begins to change. Actually they lack barriers to prevent water loss and microbial attack. For all these reasons it is very important to preserve mushrooms [3]. Along with the preservation technique, the packaging technique is also very important to ensure the cleanliness and safety of the mushroom. Preservation methods are applied to store cultures of mushroom and their fruiting bodies in stable form for long periods without losing genotypic, phenotypic and physiological traits [4]. Food-grade chemical preservatives such as potassium sorbate, calcium propionate and sorbic acid are used at their maximum permissible limits to enhance the shelf life of foods. Some methods of preservation of mushrooms are given below.

Preservation techniques

Preservation technique of mushroom is a kind of conservation where chemical deterioration and microbial growth of mushroom is slowed or halted and recontamination of the mushroom is strictly avoided. Two types of preservation techniques are available for mushroom culture. First is short term preservation and second is long term preservation [5].

1. **Short term preservation:** Short-term storage of mushroom culture is storing the culture tubes

at room temperature (28- 35ºC) for a period of 1-2 months or in a refrigerator (5-8ºC) for an average period of 3-4 months. This is the most common method of culture preservation.

2. Long term preservation: The major methods for long-term preservation of mushrooms are lyophilization (freeze-drying), thermal power drying, hot air drying, canning, bottling and pickling.

Continuous sub-culturing: This technique has its own limitation since subculturing may induce phenotypic and genetic alterations in the mushroom culture. Moreover chances of contamination also increase. It is time consuming method.

Methods of preservation of fruiting bodies of mushroom-

Refrigeration, freezing, drying, pickling, powdering, making extracts, making tinctures, smoking, salting, and making mushroom jerky and ketchup are some methods of preservation of fruiting bodies of mushroom in intact or processed form [3,4,10].

Methods of post harvest mushroom preservation techniques-

Post harvest mushroom preservation techniques involve three main processes: thermal, chemical and physical [6].

1. Thermal process:

   To preserve the freshness of mushrooms, they need to be cooled immediately after harvesting. If this is not done, there is a chance that the mushrooms will become dry due to evaporation of water in them and their color will turn brown due to this. Vacuum cooling is a technology used commercially for mushrooms. It's important features are high moisture content and porous structure [6,7].

2. Chemical process:

   The use of compost in the cultivation of button mushrooms initially causes high levels of contamination. Other factors can also contaminate button and oyster mushrooms. Therefore to prevent them from spoiling, it is necessary to remove the dirt or micro-organisms stuck to the mushrooms. The use of some chemicals is suggested for this. For example washing of fruiting bodies with sodium metabisulfite gives significant results in maintaining the initial whiteness of mushrooms. But its drawback is that it is not an antimicrobial agent so the microorganisms attached to the mushroom cannot be killed by its use. Sodium metabisulphate has been shown to have severe adverse allergic effects on asthmatic patients, so its use is currently prohibited. Therefore the use of sodium metabislfite has replaced by chlorine dioxide, citric acid, EDTA, hydrogen peroxide (H_2O_2) etc. which have shown the promising effects [6, 8].

3. Physical process:

   Pulsed light is an FDA approved physical sterilization technology used for mushrooms. This technology involves structural changes in the genes of micro-organisms so that the contaminants stuck on mushroom's surface cannot reproduce. Another important system in the physical process is the use of high intensity ultrasound waves. This technology can be used to kill microorganisms stuck on the surface of mushrooms. Next technology in the physical process is the use of gamma radiation approved by the FDA. It is mainly used to preserve the quality and freshness of mushroom slices [6,9].

Conclusion

In conclusion, it is very important to preserve mushrooms from the microbial activity and chemical deterioration. Post harvest mushroom preservation techniques involve thermal, chemical and physical processes. Refrigeration, freezing, drying, pickling, powdering, making extracts, making tinctures, smoking, salting, and making mushroom jerky and ketchup are some popular methods of mushroom preservation in intact or processed form.

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Prof. Dr. (Mrs.) Anupam P. Pathak is the former Director of School of Life sciences and now Head of Microbiology (SLS) in Swami Ramanand Teerth Marathwada University, Nanded. She had published more than 200 research papers including review articles invarious peer reviewed International, National journals and proceedings of conferences in different research areas. Her Google Scholar citations are more than 737 with h index 14 & i10 index 26. Her Scopus citations are 200 and h index in 07. She had attended many conferences, workshops and presented posters & oral papers. She had also worked as a reviewer for various reputed scientific publishers and referee for the many Ph. D. theses. She had deposited many industrially important bacterial cultures at Microbial Culture Collection, National Center for Cell Science, Pune and more than 110 16S rRNA gene sequences in Genebank, Bethesda, United State of America for public use. She had worked as paper setter, assessor, moderator, Ph. D. examiner, SET observer and chief superintendent (C. S.) for the examinations conducted by the university. She had contributed in various extracurricular, co-curricular & social activities. She had worked as member and chairpersons of various departmental and University level committees. She had guided many Undergraduate, post graduate, M. Phil & Ph. D. students of microbiology, biotechnology, botany, zoology and bioinformatics for their projects. She had completed two University Grant Commission, New Delhi funded research projects in Microbiology on extremophiles. From 2013 onwards, she is working as Professor & Head at School of Life Sciences, Swami Ramanand Teerth Marathwada University, Nanded, Maharashtra, India. She is member of Board of Studies (Microbiology) in this university. She is a renounwed scientist and recently she has been ranked at **9th position** amonst the list of top 20 scientists of Swami Ramanand Teerth Marathwada University, Nanded as ranked by AD Scientific Index 2023.

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(Ph. D., SET, Former UGC-PF)

Dr. Mukundraj G. Rathod is now working as in-charge Principal of Yeshwant College of Information Technology, Parbhani, Maharashtra, India. He is also the Head of Biotechnology and Bioinformatics Department of this college. He had published more than 50 research papers including review articles in various peer reviewed International, National journals and proceedings of conferences in different research areas. His Google Scholar citations are 272 with h index & i10 index 9. His Scopus citations are 31 and h index in 04. He had attended many conferences, workshops and presented posters & oral papers. He had also worked as a reviewer for various reputed scientific publishers. He had deposited 7 industrially important cultures at Microbial Culture Collection, National Center for Cell Science, Pune, Maharashtra, India for public use. He had worked as paper setter, assessor, moderator and chief superintendent (C.S.) for the examinations conducted by Swami Ramanand Teerth Marathwada University, Nanded. He had contributed in various extracurricular & social activities. He has guided many undergraduate and post graduate students of biotechnology & bioinformatics for their projects. At present he is the Principal investigator of a research project funded by Swami Ramanand Teerth Marathwada University, Nanded under science and technoloy application scheme of Rajiv Gandhi Science and Technology Commission, Mumbai, India (Government of Maharashtra). Recently he has been ranked at **17th position** amonst the list of top 20 scientists of Swami Ramanand Teerth Marathwada University, Nanded as ranked by AD Scientific Index 2023.

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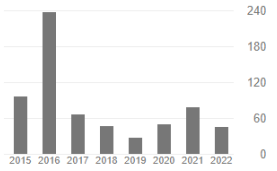

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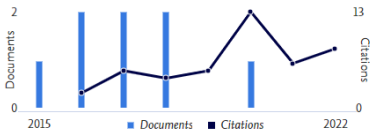

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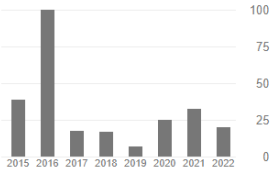

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