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Mushroom cultivation: A sustainable approach to future agriculture to ensure quality food and nutritional security of current population in India

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Abstract

Mushroom cultivation has a rich history, with humans transitioning from foraging to cultivating these versatile fungi. Mushrooms are valued for their unique flavors and nutritional benefits, being low in calories and rich in essential nutrients. Cultivating mushrooms involves careful environmental control and specific techniques, leading to the formation of fruiting bodies ready for harvest. Mushroom cultivation has gained attention as a sustainable approach to agriculture due to minimal waste and carbon emissions. They can be cultivated using agricultural waste and contribute to waste management and soil regeneration. Integrating mushroom cultivation into agriculture promotes resource efficiency, soil health, and biodiversity conservation, aligning with sustainable farming practices.

Keywords: agriculture, quality food, nutritional, Mushroom

1. Introduction

Mushrooms are not only loved for their exotic taste but also for the numerous benefits they offer. They can be enjoyed in various forms such as fresh, pickled, dried, powdered, or canned. The cultivation of mushrooms has gained significant momentum among modern entrepreneurs due to their nutritional and medicinal advantages, as well as their cost-effectiveness and high yield. Mushrooms are classified as fleshy fungi belonging to the Basidiomycota and Agaricomycetes groups. They typically consist of a stem, cap, and gills beneath the cap [TNAU Agritech Portal Nutrition]. These fungi are renowned for their unique flavor and health benefits. They are rich in essential nutrients and are known to contain vitamins, minerals, and low levels of fat. Some varieties of mushrooms contain Vitamin B, copper, selenium, and less than 1% fat [TNAU Agritech Portal Nutrition]. One remarkable characteristic of mushrooms is their natural ability to produce Vitamin D, which is typically obtained from animal sources such as poultry. This is due to the presence of ergosterol, a compound that can be converted into Vitamin D when exposed to sunlight or artificial lighting. Agaricus bisporus, a type of mushroom, exhibits nutritional value as shown in Table 1 [TNAU Agritech Portal Nutrition]. Mushrooms are not only versatile but also highly nutritious. They thrive well in decomposed substances and offer a good yield. In addition to their natural Vitamin D content, they come in various wild and edible variations. Some popular types of mushrooms include Agaricus bisporus, Shiitake, Oyster, and Paddy Straw mushrooms. The cultivation of mushrooms requires specific conditions, such as 80-90% humidity and temperatures ranging from 16 to 23°C.

The cultivation process involves compost preparation, spawning, casing, harvesting, and subsequent processing. After harvesting, mushrooms are fragile and require careful processing. Various methods can be employed, including drying, dehydration, freeze-drying, pickling, freezing, canning, sterilizing, direct packing, and more.

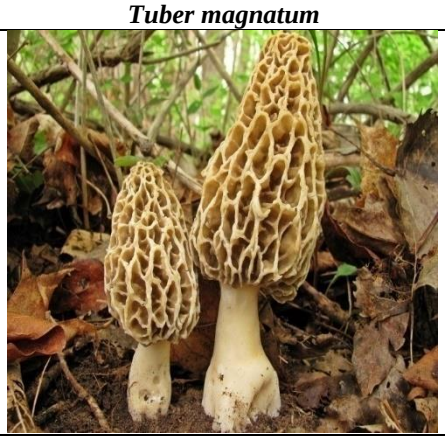
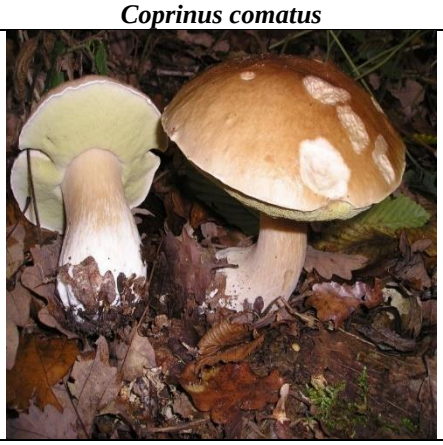
A mushroom is a macrofungus, characterized by its distinctive fruiting body, which plays a crucial role in the breakdown of organic materials for food production. Typically, mushrooms refer to fungi with a stem (stipe), a cap (pileus), and gills (lamellae) or pores on the underside of the cap. In different regions and languages, mushrooms are known by various names such as Kushumpa in Sanskrit, Khumbi or chatrak in Hindi, Khumbi or Kukurmutta in Punjab and Haryana, Umbrella of frog in Bengal, Kukurmutta or Khumbi in Uttar Pradesh and Bihar, and Umbrella of snake in South India. India, a vast subcontinent spanning over 3 million square kilometers, has a population of over 1.3 billion people, with approximately 68 percent residing in villages and depending on agriculture. Malnutrition is a significant issue in the country, primarily due to its large population, and India has one of the lowest protein consumption rates among affluent nations. The typical Indian diet is heavily grain-based, providing ample calories but lacking in essential proteins. This leads to a prominent nutritional deficiency in high-quality protein intake. Low-income individuals often suffer from chronic malnutrition, resulting in low birth weight, increased preschool mortality, and symptoms of "Kwashiorkor." Additionally, deficiencies in iron and vitamin A are prevalent, causing anemia and xerophthalmia, respectively. Mushrooms are commonly perceived as an alternative dietary source to address these nutritional challenges (Okuda, 2022) [6]. They are rich in protein, carbohydrates, minerals, and vitamins, making them a valuable addition to one's diet. The Food and Agriculture Organization (FAO) has recommended mushrooms as a food source that can assist developing nations heavily reliant on cereals in meeting their protein requirements. Research suggests that an average human weighing 70 kg would need between 100 and 200 g of mushrooms (dry weight) to maintain nutritional balance.

2. Histirical Background of Mushroom

- **Theophrastus (372-287B.C.)** - The great Greek Philosopher wrote about the food value of mushrooms during middle ages when mushrooms composed Royal dishes for the Greek and Roman emperors.
- The earliest cultivated edible fungi were *Auricularia auricula* in 600AD and *Flammulina velutipes* in 800-900 AD.
- Cultivation of other mushrooms such as *Lentinula edodes*, *Volvariella volvacea* and *Tremella fuciformis* were first recorded in China in the year 1000, 1700 and 1800 AD, respectively.
- First time artificial cultivation of white button mushroom in France around the year 1650 AD.
- In 1940, spawn production and cultivation of paddy straw mushroom by Su and Seth.
- In 1939-45, first attempted on experimental cultivation of paddy straw was undertaken by Department of Agriculture at Chennai (Madras).
- In 1961, a scheme entitled “Development of Mushroom Cultivation in Himachal Pradesh” was started at Solan by the Himachal Pradesh Government in collaboration with ICAR. This was first serious attempt on cultivation of *Agaricus bisporus* in the country.
- The National Centre for Mushroom Research and Training started at Chambaghat, Solan (H.P.) during year 1983 in VIth five year plan.
- **NCMRT (later NRCM)** was formerly inaugurated on **21 June, 1987 by Dr. Gurdial Singh Dhillon** (then Union Minister of Agriculture and President of ICAR Society).
- In 1983, Initially All India Coordinated Mushroom Improvement Project (AICMIP) started with six centers were
- Punjab Agriculture University, Ludhiana
- Govind ballabh Pant University of Agriculture & Technology, Pantnagar, U.K.
- Chandra Sekhar Azad Agriculture University & technology, Kanpur
- Bidhan Chandra Krishi Viswavidyalaya, Kallyani, W.B.
- Tamil Nadu Agriculture University, Coimbatore, T.N.
- Mahatma Phule Agriculture University, Pune **A**t the later stage during VIIth FivE Year Plan, one new centre at IGKVV, Raipur was added and two new existing centers at Kanpur and Kallyani were dropped.
- Solan is widely popular for its mushroom cultivation and bearing the title “Mushroom City of India” for their contribution on 10th September, 1997.
- The NRCM centre was upgraded to “Directorate of Mushroom Research” on 26th December, 2008.
- At present 23 coordinating centers and 9 cooperating centers in 27 states of the country.

Common Edible Mushrooms

		
Agaricus bitorquis	***Pleurotus djamor***	***Pleurotus ostreatus***

		
Lentinula edodes	***Tuber aestivum***	***Tuber magnatum***
		
Flammulina velutipes	***Coprinus comatus***	***Morchella esculenta***
		
Calocybe indica	***Boletus edulis***	***Tuber macrospermum***

Poisonous Mushrooms

		
Amanita phalloides	***Amanita smithiana***	***Cortinarius rubellus***

		
Paxillus involutus	***Amanita muscaria***	***Lactarius torminosus***
		
Russula emetica	***Lepiota subincarnata***	***Amanita virosa***

Medicinal Mushrooms

		
Grifola frondosa	***Ganoderma lucidum***	***Calvatia gigantea***
		
Cordyceps sinensis	***Polyporus umbellatus***	***Agaricus blazei***

		
Hericium erinaceus	***Trametes versicolor***	

3. Uses of Mushroom

1. Mushroom used as food material for health, and also known as vegetarian meat.
2. Mushroom used in cosmetics and costume decoration.
3. Mushroom used as bottle corks formation, e.g. *Polyporus squamosus*
4. For dyeing formation, e.g.
   a. ***Polyporus bispidus***- gives a brown dye is used for coloring silk, cotton and wool.
   b. ***P. sulphureus***- gives yellow colour
   c. ***Fomes igniarius***- gives brown dye
5. For writing material, e.g.
   a. ***Coprinus comatus***- used for black ink formation
6. **Medicinal use:** Medicinal mushrooms are used as possible treatments for diseases. Research indicated that mushrooms have possible cardiovascular, anticancer, antiviral, antibacterial, antiparasitic, antiinflammotory activities. Thus, many mushrooms have medicinal properties. These are following.

i. ***Ganoderma lucidum*** (ganoderic acid Beta-glucan compounds)-
- Augments immune system
- Liver protection
- Antibiotic properties
- Inhibits cholesterol synthesis

ii. ***Lentinula edodes*** (eritadenine and lentinan compounds)-
- Lower down the cholesterol level
- Anti-cancer agent

iii. ***Agaricus bisporus*** (lectins compound)-
- Enhance insulin secretions

iv. ***Pleurotus sajor-caju*** (lovastatin)-
- Lower the cholesterol level

v. ***Grifola frondosa*** (polysaccharide lectins)-
- Increase insulin secretion
- Decrease blood glucose

vi. ***Auricularia auricula*** (acidic polysaccharides)-
- Decrease blood glucose

vii. ***Flammulina velutipes*** (ergothioneine proflamin)-
- Antioxidant
- Anti-cancer activity

viii. ***Agaricus blazaei***-
- It has remarkable anticancer properties
- It also provide protection against radiation

ix. ***Trametes versicolor*** (polysaccharide-Kresin)-
- Treatment of much infection caused by *A. niger*, Escherichia coli, Candida albicans, Herpes, HIV and Streptomyces pneumonia
- It is help in chronic fatigue
- It improves immune function in women

x. ***Clavatia gigantea*** (calvacin compound)-
- Used for anaesthesia
- Antitumor properties

xi. ***Polyporus officinalis***-
- For bleeding inhibition
- It is also used against Tuberculosis, Jaundice and

xii. ***Lycoperdon giganteum***-
- It is used as soft and comfortable surgical, dressings.

Xiii. ***Cordyceps sinensis*** (Caterpillar mushroom)- Polysaccharide components and cordycepin]
- Increase the strength
- Anti-aging properties
- Anti-tumor effects
- Anti-cancerous properties

5. Nutritional value of mushroom

Mushrooms are an incredibly valuable source of nourishment and have earned the nickname "vegetable meat" due to their nutritional profile. They provide a significant amount of essential nutrients and offer protective benefits, making them a valuable addition to a balanced diet. The nutritional data presented in Table 1 supports the notion that mushrooms are a complete and healthy food suitable for individuals of all age groups. The nutritional composition of mushrooms can vary depending on factors such as the species, variety, stage of development, and environmental conditions. However, mushrooms are generally known to be rich in protein, dietary fiber, vitamins, and minerals. They contain proteins that are abundant in threonine and valine, although they may be deficient in sulfur-containing amino acids such as methionine and cysteine. One advantage of mushrooms is their low lipid content, which means they contain minimal levels of fat and cholesterol. Additionally, mushrooms tend to have a higher proportion of polyunsaturated fatty acids, which are beneficial for overall health. Furthermore, mushrooms contain ergosterol, a compound that serves as a precursor for Vitamin D synthesis in the human body. This natural source of Vitamin D adds to the nutritional value of mushrooms and can contribute to maintaining optimal health.

Table 1: Composition of common edible mushrooms (g/100 g fresh weight)

S. No.	Mushrooms	Carbohydrates	Fiber	Protein	Fat	Ash	Energy
1	*Agaricus bisporus*	46.17	20.9	33.48	3.10	5.70	499
2	*Pleurotus sajor caju*	63.40	48.6	19.23	2.70	6.32	412
3	*Lentinula edodes*	47.60	28.8	32.93	3.73	5.20	387
4	*Pleurotus osreatus*	57.60	8.70	30.40	2.20	9.80	265
5	*Volvariell volvacea*	54.80	5.50	37.50	2.60	1.10	305
6	*Calocybe indica*	64.26	3.40	17.69	4.10	7.43	391
7	*Flammulina velutipes*	73.10	3.70	17.60	1.90	7.40	378
8	*Auricularia auricula*	82.80	19.8	4.20	8.30	4.70	351

Courtesy: A. *bisporous, P. sajor-caju, Lentinula edodes* (Stamets, 2005), *Pleurotus ostreatus, V. volvaceae Calocybe indica Flammulina velutipes and Auricularia spp*.

Mushrooms are renowned as a valuable health food due to their impressive nutritional profile. They are low in calories while being rich in essential nutrients such as vegetable proteins, chitin, iron, zinc, fiber, vitamins, minerals, phosphorus, and potassium. In fact, mushrooms contain a comprehensive range of necessary elements for optimal health. Compared to cereals, mushrooms have relatively low calorie content. However, they make up for it with their high protein content. The digestibility of mushroom protein typically ranges from 71 to 90%, indicating that it can be efficiently utilized by the body. The protein in mushrooms consists of various amino acids, including all the essential amino acids required by adults. A detailed breakdown of the amino acid composition can be found in Table 2.

Table 2: Amino acids composition of *Agaricus bisporus*

S. No.	Amino acids	g/100 g dry matter	S. No.	Amino acids	g/100 g dry matter
1	Alanine	2.40	10	Lysine*	1.62
2	Arginine	1.90	11	Methionine	0.39
3	Aspartic acid	3.14	12	Phenyl alanine	1.55
4	Cysteine	0.18	13	Proline	2.50
5	Glutamic acid	7.06	14	Serine	1.89
6	Glycine	1.20	15	Threonine	1.48
7	Histidine	0.64	16	Tryptophan*	3.94
8	Isoleucine	1.28	17	Tyrosine	0.78
9	Leucine	2.16	18	Valine	1.63
***low in cereals**					

Carbohydrate: The carbohydrate content of mushroom is low (4-5% fresh mushroom). Carbohydrate is present in the form of Chitin, Glycogen and Mannose, while starch is absent. So, it can be prescribed as excellent diet for diabetes patients.

Fat: The fat content of mushroom is also very low (0.3%) in form of linoleic acid. Cholesterol is absent. So, it is good food for heart patients.

Vitamins: Mushrooms are rich in vitamins particularly riboflavin, nicotinic and folic acid but do not contain many vitamins like A, D, E, and K. (Table 3).

Minerals: The presence of different minerals elements in mushroom increases the food value. Hundred gram fresh mushrooms contain 3-20 mg of calcium, 1-5 mg of Iron, 0.1-1.2 mg of Copper, 0.1-0.5 mg Zinc, 18-70 mg of Phosphorus and 20-30 mg of Sulphur.

Table 3: Vitamins content of some of the edible mushroom (mg/100g. dry weight)

S. No.	Mushrooms	Thiamin	Riboflavin	Nicotinic acid (Niacin)	Ascorbic acid
1	*Agaricus bisporus*	1.1	5.0	55.7	81.9
2	*Pleurotus ostreatus*	4.8	4.7	108.7	00.0
3	*Volvariella volvacea*	1.2	3.3	91.9	20.2
4	*Lentinula edodes*	7.8	4.9	54.9	00.0

6. Major types of cultivated mushrooms

Mushrooms are easily cultivable in hilly regions due to abundant moisture but can also be grown in artificial environment with proper temperature and humidity control. Varieties must be identified thoroughly as some of them might cause food poisoning or allergy upon consumption. Some of the major varieties consumed in India are as follows:

6.1. Button Mushroom

Button mushroom (*Agaricus bisporus*) belongs to Class Basidiomycetes and Family Agaricaceae and is native to Europe and North America (Sharma, 2018) [8]. This is the most widely cultivated mushroom and includes two main varieties: white button mushrooms (immature stage) and cremini/baby bella/brown mushrooms (slightly mature stage), out of which white button mushroom is commonly grown in India. According to ICAR-Directorate of Mushroom Research, this variety contributes more than 85% to mushroom production. It is the most relished variety used in eateries and households.

6.2. Shiitake Mushroom

Shiitake Mushrooms (*Lentinula edodes*) are native to East Asia are highly consumed in Asian countries and have been cultivated for centuries. They readily grow on wood of deciduous and hard wood trees such as Oak, Chestnut, and Maple etc. and require moist and warm climate. In rare cases they may cause allergic reaction like itching but can be

eliminated by thorough cooking. They have a savory and rich flavor. They have a meaty texture and are often used in stir-fries, soups, and other Asian dishes. These are used in Asian cuisines and traditional medicines.

6.3. Oyster Mushroom

Oyster Mushrooms (*Pleurotus ostreatus*) belong to Pleurotus species. It is known as "Dhingri" in India. They grow easily on decaying wood or straw (Denis *et al*., 2022) [2]. They are a popular cultivated mushroom with a distinctive shape resembling oyster shells. They have a fan or oyster-shaped cap that can vary in color from white to gray, brown, or blue. The gills are typically white and run directly from the cap's edge to the stem Oyster mushrooms are known for their mild, slightly nutty flavor and tender texture. They are versatile in cooking and are used in various dishes such as stir-fries, soups, pasta dishes, and risottos. They are also a popular meat substitute in vegetarian and vegan recipes. Oyster mushrooms are commercially cultivated worldwide due to their culinary appeal and nutritional content. They are a good source of protein, dietary fiber, vitamins, and minerals.

6.4. Paddy Straw Mushroom

Paddy straw mushroom (Roy & Kaur, 2016) [7], scientifically known as *Volvariella volvacea*, is a popular cultivated mushroom in many Asian countries, particularly in China, India, and Southeast Asia. It is also known by other names such as straw mushroom, straw hat mushroom, or rice straw mushroom. They belong to division Basidiomycota. They are primarily grown on agricultural byproducts, such as rice straw or sugarcane bagasse. They have a distinct appearance with a small to medium-sized cap, which is initially egg-shaped but expands as it matures. The cap color varies from light gray to light brown, and the gills are white, turning pink as the mushroom matures. These mushrooms have a delicate and mild flavor, making them a versatile ingredient in various Asian dishes. They are commonly used in stir-fries, soups, curries, and salads. Cultivating paddy straw mushrooms typically involves growing them in warm and humid conditions, often indoors or in controlled environments. The growing substrate, usually rice straw, is sterilized, moistened, and inoculated with mushroom spawn. The mushrooms grow rapidly, typically within a few days to a week, and are harvested when the caps are still firm and before the gills turn pink. Paddy straw mushrooms are not as widely cultivated or consumed as some other mushroom varieties, but they hold cultural and culinary significance in many Asian cuisines, particularly in dishes from China, Thailand, Vietnam, and India.

7. Steps of Mushroom Cultivation

Mushroom cultivation requires certain essential elements such as manure or compost, spawns, as well as appropriate temperature and humidity levels. Creating favorable growing conditions is crucial, including maintaining relative humidity between 80% and 90%, ensuring ample ventilation, and controlling temperature within specific ranges. During the spawn run, a temperature range of 20-28 ºC is ideal, while for reproductive growth, it should be lowered to 12-18 ºC. Initially, the temperature should be maintained at around 23 ± 20 ºC for the first week and then gradually reduced to 16 ± 20 ºC in subsequent weeks. It is also important to regulate the CO_2 concentration, aiming for a range of 0.08-0.15% [National Horticulture Board]. With appropriate environmental conditions, pin heads, which are small mushroom primordia, will start appearing within a few days and gradually develop into the button stage. In addition to the environmental factors, certain inputs such as insecticides, as well as nutritional supplements like nitrogen, vermiculite, and water, are necessary for a successful mushroom harvest. These elements help ensure the health and growth of the mushrooms throughout the cultivation process. To summarize, successful mushroom cultivation involves maintaining the proper environment and providing essential inputs to support their growth and development. By following these steps and guidelines, cultivators can optimize their chances of achieving a healthy and abundant mushroom harvest (Manoharachary, 2022) [4].

7.1 Compost Preparation

The first step in mushroom cultivation is preparing the compost. This typically involves a mixture of wheat straws, horse manure, poultry manure, rice bran, and gypsum. The compost is carefully prepared by mixing these ingredients, allowing fermentation to break down chemical compounds. It is important to protect the raw compost from rain or external moisture. Frequent turnings and watering are performed to maintain optimal moisture levels. After 15 to 20 days, the compost is ready to be used as a bed and is spread onto wooden trays, where spawns will be added.

7.2. Spawning

Spawns refer to mycelium that has been propagated on agars or grains. Spawning is the process of sowing or mixing spawns into the compost. While mushrooms produce spores that could be used for propagation, they are not commonly used due to uncertain germination and growth. The spawns are thoroughly mixed with the compost, covered with newspaper, and sufficiently watered to maintain moisture. Throughout the cultivation period, high humidity is maintained to prevent moisture loss. The spawns gradually grow into white, cottony mycelium growth.

7.3. Casing

Casing is the application of sterilized soil or dressing, often containing cow manure, onto the compost mixed with spawns. This is done when the mycelium growth starts appearing on the compost surface. After 15 to 20 days of casing application, mushroom heads or pins become visible on the surface. They are allowed to mature for a specific period and harvested before the cap opens. Mushrooms with an opened cap (resembling an umbrella) are considered of lower quality.

7.4. Harvesting

Harvesting is done by either plucking the mushrooms from the soil using hands or chopping off the heads with a knife. The harvested mushrooms are then ready for primary processing.

7.5 Processing

Mushrooms are delicate and have a short shelf life unless consumed fresh. At room temperature, they lose freshness within a day and rapidly deteriorate if not processed or refrigerated. Mushrooms also tend to undergo browning due to the presence of the enzyme tyrosinase, which converts monophenols to diphenols and then oxidizes them to form insoluble brown pigment called melanin. The initial

processing involves washing mushrooms to remove soil or compost adhering to them and blanching them for a few minutes to inactivate enzymes. To prevent discoloration, they may be treated with brine, salt, or citric acid prior to canning or packaging. The following are common processing and preservation methods used:

7.6. Drying

Drying or dehydration is the oldest and basic processing method for various food products. Removing moisture inhibits microbial growth, as moisture is the most suitable medium for their propagation. Mushrooms can be dried using sun drying or mechanical drying methods. Sun drying is the cheapest and popular method, but it may produce a darker product. Mechanical drying methods include tray drying, freeze drying, vacuum drying, microwave oven drying, and air drying. Dried mushrooms can be rehydrated and used in soups, stews, pickles, and other dishes.

7.7. Freezing

With over 90% water content, mushrooms are well-suited for freezing as a preservation method. Prior to freezing, mushrooms may undergo various pretreatments to minimize adverse effects. Blast freezing at temperatures of -25°C to -30°C is commonly employed. Cryogenic freezing at extremely low temperatures of -80°C to -100°C for 5-6 minutes can extend the shelf life of mushrooms up to one year.

7.8. Sterilization

Sterilization of mushrooms can be done using chemicals, steam, or irradiation. Applying a radiation dose of 1-3 kGy, for example, can extend the shelf life of mushrooms.

7.9. Canning

Canning involves preserving mushrooms in brine, vinegar, oil, or marinades. Freshly harvested mushrooms are cleaned, graded, blanched, and filled into cans along with brine or vinegar before sealing. The cans are then heat sterilized, cooled, labeled, and packaged for storage or consumption.

7.10. Pickling

Pickling is an age-old preservation method that uses spices, salt, vinegar, and oil. Pickled mushrooms are made by combining mushrooms with spices such as turmeric, red chili, garlic, and cloves, along with salt and oil. The pickling process induces fermentation, resulting in a distinct flavor.

8. The suggestions to solve the marketing problems of mushrooms

1. Expand the market area and strengthen the demand

a) Popularize mushrooms using ICT as delicacy with nutritive and medicinal value, on mass media like Doordarshan, radio also ads and posters.
b) Break consumer resistance by creating awareness in new areas. Demonstration of recipes and free samples in new areas. Free recipe booklet.

2. Form cooperatives for sale

a) Create cold storage facility
b) Create refrigerated transport facility
c) Create processing facility
d) Create distributor function for big cities.

3. Decrease the cost of production and bring down the sale price to boost the demand.
4. Good pre packs for eye appeal.
5. Train retailers about handling, storage, food value and recipes.
6. Approach supermarkets, chain vegetable stores, mother dairy retail counters for retail sale.
7. States should fix minimum support price.
8. Public sector marketing, processing and export organisations should come forward.
9. Assured supply throughout the year at a reasonable constant price is key to good marketing. Efforts should be made to diversify and cultivate different mushrooms throughout the year along with cultivating some of the important mushroom during off-season under controlled condition.
10. In a limited area, say a village or a cooperative, the crops should be time-scheduled to get a daily reasonably uniform production to avoid glut on a day, this is required to meet the commensurate demand.
11. Star hotels can be invited to popularise the different recipes made out of mushrooms among the customers.
12. Dietacians of different nursing home or medicals can be invited and make them understand about the mushroom which provide a rich addition to the diet in the form of protein ,carbohydrate, valuable salt, vitamins &minerals, amino acid and energy.

9. Future Prospects

India has tremendous potential for mushroom production and all commercial edible and medicinal mushrooms can be grown (Sharma *et al*., 2017) [9]. There is increasing demand for quality products at competitive rate both in domestic and export market. Though growth of mushroom will depend on increasing and widening domestic market in coming years, export market will be equally attractive. To be successful in both domestic and export market it is essential to produce quality fresh mushrooms and processed products devoid of pesticide residues and at competitive rate. It is also important to commercially utilize the compost left after cultivation for making manure, vermin-compost, briquettes, etc. for additional income and total recycling of agro wastes. Mushroom cultivation offers sustainable approaches to future agriculture (Kumar *et al*., 2020). It enhances food security, utilizes resources efficiently, manages waste effectively, promotes soil regeneration and biodiversity conservation, reduces carbon footprint, and supports sustainable farming practices. Mushroom cultivation provides economic opportunities and contributes to building resilient food systems for the future.

Conclusion

Mushrooms are a remarkable gift from nature, prized for their versatility and wide range of uses. They can be seamlessly incorporated into various food preparations or processed to create innovative products. The market today offers an array of mushroom-based products, including mushroom pickles, seasonings, beverages, extracts, dried and canned mushrooms, mushroom supplements, and even cosmetics. The versatility of mushrooms extends beyond the food industry, as they are increasingly being utilized in other sectors. Innovative applications include mushroom-based building materials, medicinal products, mycelium-based

platforms, biodegradable packaging, and even mycelium-based leather alternatives. Cultivating mushrooms is relatively straightforward, and they exhibit rapid growth with minimal carbon emissions and waste generation. This makes mushroom cultivation an environmentally friendly practice. Moreover, mushroom farming offers a sustainable source of income for growers, providing economic benefits in addition to their inherent nutritional and medicinal value. As research and development in the mushroom industry continue to progress, new possibilities for utilizing mushrooms in various sectors are constantly emerging. The future of mushrooms looks promising in every aspect due to their diverse properties and numerous applications. From food products to innovative materials and solutions, mushrooms hold great potential. Their ease of cultivation, quick growth, and environmental sustainability make them a valuable resource. As more industries explore the unique attributes of mushrooms, we can expect continued growth and innovation, creating a bright future for these fascinating fungi.

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