Current prospects of mushroom production and industrial growth in India

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ABSTRACT: The global mushroom industry has grown rapidly in recent years in terms of beneficial effects, market value, and demand. India has a wide range of agro-climatic conditions and is largely an agricultural country with a cultivated area of about 4.37%, generating about 620 million tons of agro waste annually. Mushroom cultivation not only helps recycle agro wastes, but also fills the nutritional gap prevalent among a large population of India. Recently, government industrial policy and creative innovation has promoted research and other endeavors aiming towards the cultivation of mushrooms. Mushroom cultivation in India was initiated in Solan, in the mid-sixties. Mushroom cultivation has been successful in temperate regions of the Himalayas, the Western Ghats, and the hills of northeast India. Recently, many unemployed people have begun to adopt mushroom cultivation as a means of self-employment. It is high time that Indian mushroom cultivators and consumers became aware of the nutritional and medicinal values of cultivated and wild species of mushrooms. The total mushroom production in India between 2010 and 2017 was approximately 0.13 million tons, accounting for a 4.3% increase in the average growth rate of mushrooms per annum. In particular, the total production of white button mushrooms is the highest, with a share of about 73% of total mushroom production. In this review article, we have analyzed the current scenario of the Indian mushroom industry and its contribution to the economic growth of the country.

KEYWORDS: Indian mushroom cultivation, Mushroom industry in India, Mushroom

INTRODUCTION

Mushrooms are long been valued as high medicinal and nutritional food by many societies around the world. Mushrooms are consumed as a medicine in Asian countries and many researcher works have been done on medicinal aspects (Halpern and Miller, 2002). Mushrooms are used in Ayurveda and folk medicine in India (Adhikari, 1981; Jitendra and Vaidya, 2000). India is a largely agricultural country and producing a huge quantity of agro-wastes every year approximately 620 million tons (Singh and Sidhu, 2014). The present agricultural scenario of India has to emerge as an economic power in the world in terms of agricultural productivity by adapting new technologies leading to the economic power of the world. In India, any mushroom is used as a non-traditional cash crop and commonly cultivated species are white button mushroom, oyster, shitake mushrooms and other mushrooms cultivated in small scale are paddy straw, milky and reishi mushrooms. Button mushroom accounts for approximately 95 % of total production and exports. Button mushroom is cultivated in temperate regions of Himachal Pradesh, Jammu and Kashmir, however the oyster, milky, paddy straw mushrooms are cultivated in the tropical and subtropical regions. Mushroom cultivation has become a business and export-oriented. The major export destinations for Indian mushrooms are Canada, US, Israel, and Mexico. Mushrooms are exported in two forms, fresh mushrooms and preserved/processed mushrooms. The demand for processed mushrooms has increased considerably over the past years. They can be canned, dried, packed in frozen forms, including its usage in food industry in mushroom pickle & sauces.
attract investment in technology to development and production of vegetables and mushrooms under controlled conditions (Annual report 2017-2018). Efforts are being made by the Indian government to improve mushroom research and development and to encourage mushroom growers to develop advanced R&D technologies and policies. The R&D and biotechnology laboratories play a vital role in the mushroom breeding process and in the optimization of the cultivation environment for the better yield. Such technological advancements and favorable government initiatives promise ample growth opportunities for the industry participants and the mushroom researchers.

The prospect of mushroom production in India

Mushroom cultivation plays an important role to improve the strengths and livelihood of rural people through economic, nutritional and medicinal contributions. 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 (Prakasam, 2012). During the mid of sixties Dr. E. F. K. Mental from Germany started the work as the FAO consultant at Solan and he constructed the modern spawn laboratory in Himachal Pradesh and also introduced the button mushroom cultivation in India. In 1961, Indian Council of Agricultural Research (ICAR), New Delhi, started first cultivation of the button mushroom (Agaricus bisporus) in Solan. The ICAR funded research scheme was established in Solan, Punjab, Bengaluru and New Delhi in the year 1971. The Solan city is called as “Mushroom City of India”. In 1974 the United National Development Programme introduced the pilot-scale cultivation of button mushroom in Himachal Pradesh. The National Centre for Mushroom Research and Training (NCMRT) was established in 1982 and upgraded to Directorate of Mushroom Research in 2008. The success of early button mushroom cultivators to motivate other enterprising farmers to grow button mushrooms under natural climatic conditions. Mushroom industry in India is mainly focused on button mushroom cultivation and marketing. The recent production data revealed that button mushroom production holds the maximum share of about 73% and followed by oyster mushroom with 16% (Sharma et al., 2017). There are two types of mushroom growers in India, the seasonal growers and round the year growers. Both growers have focused on white button production (Agaricus bisporus) and harvest 2-3 crops in a year. Well qualified professional mycologist/mushroom specialist, educated and unemployed population sector are contribution towards the mushroom cultivation with empowered entrepreneurial skills. This sector of people have established mother compost unit and spawn laboratories in different agro-climatic zones all over India. The techniques required to help for un-educator to start the mushroom cultivation in indoors and their economic status have greatly multiplied. As prior most requisite, the farmers who cultivate the vegetable crops and grains, require plenty of water to meet the needs of the consumers. Now they think alternate ways for producing crops and one among them is cultivating in indoor conditions. Mushroom farming has become a very important cottage industrial activity in the integrated rural development programme. The National Committee on the use of Plastics in Agriculture (NCPA-1982) has recommended greenhouse technology for adoption in various regions of India. The indoor cultivation techniques and greenhouse technology inspired villagers to not only set up mushroom units but also diversify. While many farmers have started growing carnations side by side, others have turned to vegetables cultivation. This technique will not only provide a gainful employment to the rural youths and women, but the cost of production per unit area will be greatly reduced. The mushroom production in India in the year 2020 AD, would touch the magic figure of 6,00,000 tons per annum (Karthick and Hamsalakshmi, 2017). The cultivation of edible mushrooms not only helps in recycling of agro wastes but also filling up the nutritional gap prevalent among large population of India. In addition, spent substrates can be used for biogas production (Bisaria et al., 1990), for fertilizer in agricultural fields and can also upgrade and used as animal feed (Zadrazil et al., 1992).

Bioresource availability for mushroom production in India

India has a wide range of diverse agro-climatic conditions with a cultivated area of about 4.37% and 54.6% of the population where engaged in agriculture and allied activities (India census 2011). The land and
water are two important natural resources, which impacts production of sustainable food resources, in Indian total geographical area of 328.7 million hectares (Council of Agricultural Research -ICAR- 2017-2018). India has lead second rank worldwide in farm output in agriculture and allied sectors showing 13.7% of the GDP (Gross Domestic Production) in 2013. India has about 4% of world’s freshwater resources and soils like alluvial soil occupying 45.6% and black and red soils occupy 16.6 to 10.6 percent of the total geographical area of the country (Vibha, 2017; Siddiqui and Fatima, 2017). Agricultural residues are considered as agro-wastes, in India as an approximation, the amount of crop residues produced every year exceeds 620 million tons (Singh and Sidhu, 2014). Agro-waste in includes crop waste, animal waste (manure) and food processing wastes. A total of 50% of agricultural residues are produced by rice, wheat and oilseed crops (Singh and Prabha, 2017). India produces approximately 130 million tonnes of paddy straw of which only about half is used for fodder and 50 million tonnes of cane trash. During rice and wheat harvesting and milling three types of residues are formed viz., straw, husk, and bran, which are used as a cattle feed, packing material, heating, cooking fuel and cooking oil. Direct incorporation of paddy straw increases methane emission from the irrigated fields and impact global warming (Singh et al., 2008). In the past, the entire paddy and wheat straw was burned by the Indian farmers but nowadays it is being converted as a bio-renewable source. Other predominant agro wastes are maize, cotton, millets, pulse, sunflower and other stalks, bullrushes, groundnut shells, coconut trash, vegetable residue, coir dust, husk, dried leaves, pruning, coffee husk, tea waste. Total of 39 residues from 26 crops, those agro wastes are the valuable substrate for mushroom production and organic manure forming. To initiate the farmers towards bio-organic farming at a commercial scale which could profitable to the rural society (Singh and Prabha, 2017). The agricultural waste towards mushroom production, India can produce 3 million tonnes of mushroom and about 15 million tonnes of bio-compost. The different agro-climate and abundance of farm wastes, different types of temperate, tropical and subtropical climates favors for mushrooms cultivation throughout the country.

**Mushroom consumption in India**

Mushrooms are a good source of soluble protein and fiber which plays an important role in human health. Mushroom protein being easily digestible (70-90%) is considered superior to vegetable proteins. Low protein intake by Indians leads to fatigue, sluggish metabolite, low synthesis of brain hormones and immunity. The prompt way to produce quality protein products will rescue the country from malnutrition. To finding the alternative way to produce cheap and quality food to overcome the malnutrition, microbes and the edible mushrooms are most important. In India, awareness about consumption and health benefits of mushrooms available for cultivation is limited, their demand is also less. The cultivation of *Pleurotus ostreatus* mushroom stands first in followed by *Agaricus bisporus* mushroom in India in terms of popularity and consumption (Khatun et al., 2012). The commonly grown edible mushrooms in India are *Pleurotus sajor-caju*, *Pleurotus ostreatus*, *Pleurotus florida*, *Pleurotus djamor*, *Pleurotus eryngii*, *Auricularia polytricha*, *Hypsizygus tessulatus*, *Lentinula edodes*, *Calocybe indica*, *Volvariella volvacea* (Dhar et al., 2011). Medicinal mushrooms occurring in India are *Ganoderma lucidum*, *Phellinus rimosus*, *Pleurotus spp.* possessed profound medicinal properties (Ajith and Janardhanan, 2007; Jose et al., 2002). The freeze-dried mycelia and dried mushroom in capsules form of *G. lucidum* and *Cordyceps sinensis* (caterpillar mushroom) consumption are very limited in areas of Delhi, Chandigarh, and Kerala (Dhar and Sharma, 2009). Recently the use of mushrooms is seen in Indian diet particularly in vegetable cuisine leading to an increase in per capita consumption of mushroom. Even though the consumption of mushrooms has increased, but there is increasing preference for fresh mushrooms. The consumption of mushroom in India is currently about 30-40 g as compared to 2-3 kg in USA and Europe. In India per capita consumption is about 90 g, which very less compared to other countries including USA 1.49 kg and China 1.16 kg (Directorate of Mushroom Research ICAR, Solan (India) 2011) (Fig. 1). To enhance local consumption there is a need to popularizing the beneficial effects of cultivated and wild collected edible mushrooms.
Only a few of the mushrooms are brought under cultivation on a commercial scale globally. About 80 mushrooms have been grown experimentally, among them, 20 are cultivated commercially, of which, 4-5 species are produced on the industrial scale throughout the world (Chang, 1999). Though mushroom production in Asian countries started before 1000 years, cultivation of mushrooms is a relatively new phenomenon in India (Sharma et al., 2017). The mushroom production has been increased over tenfold between the year 1969 to 2009 and remarkable growth in China, United States, Netherlands, India, and Vietnam, according to FAO. In China cultivation of more than 20 different types of mushrooms are being produced at commercial scale. In India, the commercial market is popularly dominated by Agaricus bisporus (white button mushroom), Pleurotus spp. (oyster mushroom), Volvariella volvacea (paddy-straw mushroom), and Calocybe indica - milky mushroom (Dhar et al., 2011). The most cultivated Pleurotus species are P. sajor-caju, P. flordia, P. flabellatus and P. eous and particularly P. florida and P.sajor-caju are most popular (Directorate of Mushroom Research- ICAR, 2011). Oyster, paddy straw and milky mushrooms are grown seasonally in the tropical/subtropical regions. Even though the temperate button mushrooms are dominant in the tropical and subtropical regions of the country (Fig. 2). ICAR-DMR, Solan the total mushroom production unit estimated at 1, 29,782 metric tons (Sharma et al., 2017).

The button mushroom production is very popular and in global level, it is ranked first. India the button mushroom production share is 73 % and production systems are mixed type i.e. both seasonal farming as well as high-tech industry (Sharma et al., 2017). The Directorate of Mushroom Research (ICAR-DMR) has developed 3 new strains of A. bisporus are NCS-100 (Single spore isolate), NCS-101(Single spore isolate), NCH-102 (hybrid). Two improved strains of summer white Agaricus bitorquis - NCB-6 and NCB-13 were introduced after evaluation trials and cultivation technique standardization. Oyster mushroom production share is 16% and annual production 10,000 tons in India. It is popularly grown in the states of Orissa, Karnataka, Maharashtra, Andhra Pradesh, Madhya Pradesh, West Bengal and in the North-Eastern States of Meghalaya, Tripura Manipur, Mizoram and Assam (Directorate of Mushroom Research (ICAR) Solan, 2011) (Fig. 3). High yield strain of oyster mushroom PL-16-02 (66.07 kg/100 kg straw) was developed by the evolution trails. Paddy straw mushroom Volvariella volvacea high yield strains of Vv-16-02 (17.27 kg/100 kg), Vv-16-03 and Vv-16-06 (17.70 kg/100 kg) were tested in different locations in India. The climatic conditions prevailing in India are best suited for the cultivation of paddy straw mushroom (Thiribhuvanamala et al., 2012). Calocybe indica (Milky mushroom) is the first indigenous mushroom to be commercialized in the country. The maximum yield strains CI-16-03 (104 kg/100 kg) and CI-16-01(79.17 kg/100 kg) on straw dry substrate were developed in Tamil Nadu and Uttarakhand (Annual report 2016-17, ICAR-DMR) Lentinula edodes also known as shiitake mushroom is an edible and culinary medicinal mushroom native to East Asia. Shiitake is second most important edible mushroom and have been used in the East Asia for about 2000 years, but have only been commercially cultivated since 1940. This mushroom has been cultivated in Japan and China for about 2000 years (Silva, 2003; Smith et al., 2002) as well in Thailand, Korea and Brazil. Shiitake mushroom was artificially cultivated in India on wood logs, artificial medium and sawdust and corn cobs supplemented with wheat and rice bran (Suman and Seth, 1982). In India, cultivation of shiitake mushroom is negligible and very limited success, due to the unstandardized cultivation techniques. National Research Centre for Mushroom (NRCM) Solan and Indian Institute of Horticultural Research (IIHR) Bengaluru are trying to develop cultivation technology based on locally available substrates (Sharma et al., 2017).
Current prospects of mushroom production and industrial growth in India (Pandey, 2005). The high yield and maximum biological efficiency strain LE-16-04 (218 kg/100 kg) of the dry substrate was developed at Haryana on sawdust based substrate (Annual report 2016-17, ICAR-DMR). The black ear mushroom (Auricularia spp.) is fourth most popular mushroom in the world. Unfortunately there aren’t any farms that cultivated this mushroom in India even through cultivation technology was standardized in 1986. At present, this mushroom is collected and consumed in many North Eastern states of India and thus demand is already there. Reishi mushroom (Ganoderma lucidum) the commercial units are already in operation located in different regions of our country and producing the quality mushrooms for 2006; Pandey, 2005).

Fig. 2. Types of cultivated edible and medicinal mushrooms in India.

Fig. 3. Relative contribution and domesticated mushroom species.
export. *Ganoderma lucidum* is pharmacologically and commercially potential mushroom the global trade of about two billion dollars; trade in India has crossed Rs.100 crores annually through imports from Malaysia and China (Directorate of Mushroom Research (ICAR) Solan, 2011).

**Trend in global production of mushrooms**

The global mushroom production as per FAO Statistics was estimated at about 2.18 to 3.41 million tons over period of 1997-2007 (Wakchaure, 2011). Mushroom market value is expected to exceed USD 50 billion in the next seven years due to growing mushroom demand in from the recent past. The recent update shows that the market had a value of $35 billion in 2015. Between 2016 and 2021, the market is expected to grow by 9.2 percent. This would bring its size to nearly $60 billion in 2021. China, USA, Netherlands, Poland, Spain, France, Italy, Ireland, Canada and UK are the leading mushroom producers (Table 1). Key mushroom products include shiitake, button, oyster, and others which contain paddy mushroom, Milky mushroom, reishi mushroom, and winter mushrooms, *Morchella* spp. and *Tuber magatum*. The most notable increase in mushroom cultivation and production occurred in China, United States, Netherlands, India and Vietnam, according to the FAO April 2014. The major growth is anticipated in the Asian countries. Europe is the largest market for cultivated mushrooms, accounting for more than 35 percent of the global market. The total mushroom production in India is approximately 0.13 million tons (2010-2017), the growth of mushroom industry an average of 4.3% per annum (Sharma et al., 2017). India exporting 105.4 tons of white button mushrooms in canned and frozen form and button mushroom contribute total 15% of the share in the world production (Singh et al., 2017). According to the German trade association, the production of mushrooms total volume will exceed 70,000 tons, which is an increase of 3,000 tons compared to 2015. Agaricus mushrooms are the most cultivated in the United States, in 2015/2016, their production amounted to 461,000 tons. Two US-owned multinational companies have some ownership in canning operations in China and India. World mushroom production total share 40% mushroom were exported by China in recent years; the majority has been domestic consumption (Fig. 4). In 2015 the total mushroom production of 260 million kg produced by 120 mushroom farms in Netherlands (Jos, 2017). The Brazilian market is growing by about 20 percent per year and the demand is covered by their domestic producers. South Korea produces large quantity and cultivates wide range of mushrooms like oyster, enoki and shimeji mushrooms. South Korea produces about 25,500 tons of mushrooms every year, according to the

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<td>China</td>
<td>4,826,000</td>
<td>5,658,972</td>
<td>6,527,965</td>
<td>7,068,102</td>
<td>7,591,140</td>
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<td>Poland</td>
<td>230,000</td>
<td>220,000</td>
<td>228,300</td>
<td>237,069</td>
<td>245,747</td>
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<td>146,100</td>
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<td>149,700</td>
<td>149,854</td>
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<td>Republic of Korea</td>
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<td>24,787</td>
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<td>26,860</td>
<td>26,292</td>
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<td>All other</td>
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<td>6,227,659</td>
<td>7,094,714</td>
<td>7,665,730</td>
<td>8,216,306</td>
<td>8,659,997</td>
<td>8,480,171</td>
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<td>Total production</td>
<td>12,256,511</td>
<td>14,103,216</td>
<td>16,183,588</td>
<td>18,90,147</td>
<td>18,007,794</td>
<td>18,947,450</td>
<td>18,588,786</td>
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Source: FAO, FAOSTAT Production database.
Note: Data also include truffles which are included for a small share of total production.
United Nations Food and Agriculture Organization (FAO) (Table 1). South Korea has increased exporting mushrooms to 10 different countries and further looking for new markets in Vietnam, Indonesia and India.

Demand for mushroom has risen considerably over the past years in the processing industry. Processed mushroom comes in the commercial market as canned, dried, and frozen. Other than these categories processed mushroom also includes pickled mushroom, powder mushroom, and mushroom sauces. There is increasing the commercial mushroom consumption in restaurants, cafeterias, hotels, marriage receptions and birthday parties is expected to play an important role in mushroom production and marketing in the near future. For the health concern consumers shifting towards vegetarian food and increasing demand for mushroom production. The global market has been segmented on the basis of major regions and its processing category. Transparency Market Research estimates that the revenue generated from the global mushroom market will be rising to a valuation of US$ 69,267.9 from 2016 to 2024 (https://www.transparencymarketresearch.com/mushroom-market.html). The increasing consumer awareness about health and wellness and increasing technologies towards the growth of shelf-life are some of the factors propelling the global market.

**Industrial contribution towards the mushroom production in India**

Contributions towards the mushroom production are made by Indian state and central governments in promoting growers and develop newer Research and Development technologies. New technology development, application, processing techniques, human source skill upgradation and adaptation in the diverse agro-ecological regions will move ahead in R&D. Mushroom industry globally has expanded both horizontally and vertically, meaning that the progress has been in production and adapting all types of human wellness mushrooms. Fresh mushrooms are perishable, so their export/import often has been restricted to transactions mainly between neighboring countries. There were increasing technologies towards the growth of shelf life are some of the factors propelling the global market.

The modern biotechnology laboratories and government research institutes play a vital role in the mushroom breeding process as they optimize the yield, nutritional and medicinal properties. Such technological innovations and favorable government policies promise ample growth opportunities for the industry participants. Emerging economies such as China and India are expected to witness rapid mushroom demand growth due to rising population and growing health awareness. Meanwhile, demand is on the rise in USA is also recording an explosive growth. In 1990s, global mushroom trade started to increase, where North America, Europe Union and Japan being the dominant importers. In United States of America the demand for fresh button mushroom imports was nearly 0.1 million tons, the bulk of which was supplied by China, India and Indonesia. U.S. was the largest importer of China and India canned mushrooms, the principal exporters of canned mushrooms before 2011 (McCarty et al., 2010).

In India mushroom production was increased by approximately 120,000 tons annually, which is 1.8% of the global production, still India is not ranked among the leading mushroom producing countries. The small-scale mushroom farmers mainly producing the button mushrooms and supplying to domestic markets, this will impact on local market development and domesticate the new verities. Indian government supports the entrepreneurs to set the high technology mushroom farms as industrial ventures. The Export Orient Units plan triggered a strong response from investors, and by the early 1990s, several farms based on imported technologies and with a production capacity of over 2,000-100,000 tons per annum, where they established the industries at different locations throughout India. Agro Dutch industry is the largest mushroom producer in India, producing 50,000 TPA (tons per annum) of button mushrooms, with an average daily production of 125 tons. Agro Dutch
industries have an integrated and well-equipped mushroom processing units and are specialists in producing broad range of canned and frozen mushroom. Flex Foods and Dehradun mushroom industry export freeze dried button mushroom in large scale to U.K. The Himalaya International Ltd is a pioneer mushroom industry in India annually producing 10,000 metric tons of canned mushrooms. Zuari Foods And Farms P Ltd (Dr. Kurade's mushrooms) was established in 1994 with a production capacity of 7000 kg/day (Fig. 5). Welkin Overseas is the leading mushroom production industry and well-equipped spawn lab of the country. The laboratory has a rich culture collection of exotic hybrid strains of button, oyster, medicinal and specialty mushrooms. Kulkarni Farm Fresh Private Limited is an established business entity engaged in cultivating, supplying and exporting of Button Mushrooms, the daily production capacity 2 metric tons. The mushroom industry in India has undergone a major transformation due to diversify mushrooms adaptation and domestication. In India, labor intensive industries have advantages in mushroom production and marketing. The FAO has been actively promoting mushroom-forming for rural development and food security in developing countries (Marshall and Nair, 2009).

Research and development towards the mushroom industries

To successfully commercialize edible and medicinal mushrooms in both domestic and exportation market, the need for quality control and research management system is essential. R & D focuses on conserve mushroom diversity, new varieties to enhance mushroom quality, recycling spend compost for making manure and promote secondary agriculture for generating employment. The modern research and development mainly focusing on spawn production, casing materials formulation. Basically, the research has led to improved production technology of edible and medicinal mushroom, cultivation technology of temperature tolerant, and integrated pest management practices for control of economically important diseases, insect pest and nematodes has been worked out and recommended to the mushroom growers (Karthick and Hamsalakshmi, 2017). To enhance mushroom research many research laboratories and organization have contributed, the National Centre for Mushroom Research at Solan, is famous for carrying out systematic research and extension activities in the field of mushroom. ICAR-DMR, Solan has conduct various training programmes on mushrooms, mushroom mela, exhibitions, on farm trials, replies to the queries received on all facets of mushroom cultivation (Directorate of Mushroom Research (ICAR), Solan, India). DMR major contributed on wild germplasm techniques, identified and conserved in a gene bank with cryopreservation facilities. DNA fingerprinting of 43 accessions of A. bisporus, 9 of A. bitorquis, 51 of morels and 61 of different specialty mushrooms was done using RAPD, AFLP and ITS analysis. The Organic mushroom production, bio-control agent for beetles, Storage facility, Ready-to-use mushroom curry in retortable pouches, the mushroom preserve of button mushrooms and sugar-candy of oyster mushrooms were developed as a new product in DMR, Solan. To create awareness and motivate Rural and urban people to take up mushroom cultivation, DMR have put up stalls in the exhibitions, trade fairs, kisanmelas of national, state and regional. The ICAR-DMR has been taken up by Agricultural Universities and Government Departments of the various states in India, they providing consultancy services for establishment of commercial mushroom units. Y S Parmar University of Horticulture & Forestry, Solan, undertaking research work under the coordinated project with DMR, the providing quality spawn to the growers. DMR, Solan has collaborated with different universities regarding conducting research programs with Barkatullah University, Sher-e-Kashmir University of Agricultural Scientists & Technology, Acharya N.G. Ranga Agricultural University and Tamil Nadu Agricultural University (Directorate of Mushroom Research (ICAR), Solan, India).
India. The all India coordinated mushroom improvement project started with six centres in different regions. Hence, the State government based coordinating centre and nine Co-operating centres have contributed towards the research and development. The Indo-Dutch Mushroom Project, Palampur functioning under the state Directorate of Horticulture, they have supplying spawned compost to mushroom growers in different districts in India. Besides, many private spawned compost supplying units in Indian have emerged in last years.

The mushroom research and development play an important role in the flow of market-based innovations through a complex system that influences the combined talents of researcher, scientists, entrepreneurs and industrialists. Sustainable success of mushroom-based industries depends on both research and development. Mushroom science and mushroom biotechnology are two legs of the mushroom industry (Chang, 1996). The large impact on revenue and employment results from innovation impacts not only in high tech enterprises but also new mushroom industries that benefit from increased capabilities and productivity. The technology advancement and modern laboratories are enhancing the acceptability and technologies advancement to increase mushroom shelf-life. Research and development is the key factor in production and quality control in food industries.

Future scenario and opportunity of mushroom production in India

Mushrooms can make a valuable dietary and can play an important role in contributing to the livelihoods of rural and peri-urban dwellers, through food security and income generation. The current scenario of mushroom production in India is quite encouraging with an overall increase in 5 to 6 folds and was estimated to cross 50,000 tons (Verma, 2002). India has rich genetic resources of edible mushrooms its need for conservation and utilization for sustained production. Further, India has diverse climatic conditions in different regions and possible to cultivate many varieties of mushrooms (Sharma, et al., 2017). Successful mushroom cultivation for trade require to working in joint natures or partnership with regional agro-industries, universities or wholesalers can help reduce vulnerability (Thakur, 2014). The development of R&D, infrastructure facilities and distribution network provides the greater scope for marketing of fresh mushrooms. The marketing of fresh mushrooms would determine the future of the mushroom industry in India. The awareness and knowledge about nutritional and medicinal values of mushrooms will increase the production and consumption of mushroom in India. From a dietary perspective, mushrooms are a particular food in vegetarian-predominant in India. With a domestic population of more than one billion, India itself is a large market for mushroom. The quality mushroom spawn, modern cold storage facility and well-equipped processing units are facilitated the mushroom production. The technology can be profitably considered in rural and urban areas where land is a limiting factor and chiefly available of agro-wastes. However, mushroom cultivation also provides opportunities for improving the sustainability of small farming systems through the recycling of organic matter and then returned to the land as fertilizer. Recently, unemployment is increasing rapidly both in developed and developing countries. In this situation, self-employment can be one important way to increase employment. Mushroom processing and storage can be another option of an enterprise as this is labour consuming and skill oriented. Mushroom cultivation not only provides a gainful employment to Indian rural youths, but the cost of mushroom production per unit area will be greatly reduced (Karthick and Hamsalakshmi, 2017). Mushroom cultivation and consumption trend in India, the government of India took several steps for its sustainable development. Also, encourages entrepreneurs and business houses to set up high technology farms as industrial ventures and the plan called 100% export oriented units. The policy initiatives triggered a good response from entrepreneurs/ investors and several firms established integrated units at different locations by imported technologies. However, India lags behind many European and Asian countries in the generation of newer production technologies, their refinement, popularization and adoption by farmers.

Conclusion

From this review, we conclude that India’s potential as a major mushroom producer is its strategic geographical location, making it more convenient to export mushrooms. India produces more than 0.13 million tons of mushroom. In India button, oyster, milky and paddy
The mushroom industry is rapidly growing due to increasing consumer interest and the global demand for mushrooms. The positive relationship between mushroom production and farm-size suggests that larger farms can lead to higher profits. This has encouraged many mushroom growers to expand their operations, resulting in a faster increase in supply compared to the growth in demand. To maintain a competitive edge, mushroom farmers need to adapt to these changes and cater to the international market.

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**Conflict of interest statement**

Authors declare that they do not have any conflict of interests.

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Pandey M. 2005. Mushroom Research and Development of straw mushrooms are commonly grown but button mushroom contributes the highest share of production. The R&D, government schemes, policymakers and entrepreneur are contributing towards the initiation and growth of the mushroom industry. In the current scenario the best crop and high yield production these days are of propelling the mushroom farming as they lead to high-profit margins that can be helpful to both farmers and the economy of the country. There is a positive relationship between mushroom production and farm-size and the income of mushroom growers goes up with the increase in farm size. Also, the consumers have lately shown an extra liking for mushroom eating, which has enhanced the mushroom demand and supply in India. Government and cultivators keeping in view the increasing demand of mushroom due to globalization and compete to the international market.
Current prospects of mushroom production and industrial growth in India...