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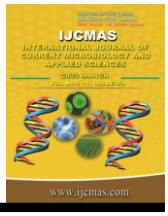

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A Review on Recent Prospectus and Status of Food Based and Ecofriendly Industrial Products from Mushrooms

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A B S T R A C T

Mushrooms are well known and reported to be valuable as nutritional and therapeutic food supplement Worldwide. The present paper aims at reviewing the recent prospectus and status of food based and ecofriendly industrial products from mushrooms. Scenario of consumption of mushrooms as food, its substrates, its production, export avenues in India are discussed. Investigations about the value added products related to food and medicine was discussed. Multiple avenues on creative and innovative, ecofriendly industrial products obtained from mushrooms were listed and its importance were explained for future generation. Research is also continuing for few products for its ecofriendly products from these fascinating fungi.

Introduction

Geologically, mushrooms existed on the earth even before man appeared on it, as evidenced from the fossil records of the lower cretaceous period. Thus anthropologically speaking, there is every possibility that man used the mushrooms as food when he was still a food gatherer and hunter on the chronology of cultural evolution (Feng *et al.,* 2020). Meeting the food demand for the increasing population from the limited land resource is a big challenge for our Indian democracy in this vulnerable climate change era. Due to pandemic, people suffer unemployment, poverty and malnutrition and the present scenario stress the importance of the mushroom cultivation, its products and post harvest techniques and innovative ways to produce more mushroom for food and trade.

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. In India per capita consumption of mushroom is about 90 g, which is very less compared to other countries including USA (1.49 kg) and China (1.16 kg). McCarty *et al.*, 2010. However, mushroom as a vegetable is yet to find regular place among the Indian consumers. From 2010-2017, the mushroom industry in India has registered an average growth

rate of 4.3% per annum. Out of the total mushroom produced, white button mushroom share is 73% followed by oyster mushroom (16%), paddy straw mushroom (7%) and milky mushroom (3%).

India exports fresh and processed mushrooms to other countries mainly for European countries, USA and Hong Kong. Approximately 95 % of total mushroom export is button mushroom. 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 and 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 (Raman *et al.,* 2018). To enhance mushroom research, the National Centre for Mushroom Research at Solan, is famous for carrying out systematic research and extension activities in the field of mushroom. (Karthick and Hamsalakshmi, 2017).

Growth Substrate, Nutritive and Medicinal value of edible mushrooms.

Fungi work as decomposers in the cycling of nutrients by breaking down organic materials to simple molecules. In India as an approximation, the amount of crop residues produced every year exceeds 620 million tons.

Agro-waste 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. 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. (Singh *et al.,* 2017). Rice and wheat straw is the major residues used as substrate for mushroom cultivation followed by the other residues so far.

The edible types of mushrooms include *Volvariella* spp, *Agaricus* spp, *Lentinulla* spp, *Flammulina* spp, *Pholiota* spp, *Coprinus* spp, *Pleurotus* spp, *Ganoderma lucidum*, *Cantharellus cibarius*, *Hydnum repandum*, *Tremella*, and *Auricularia* sp.(URL-1 -2014). Mushrooms had long been used for medicinal and food purposes since decades. Modern pharmacological research confirms large parts of traditional knowledge regarding the medicinal effects of mushrooms due to their antifungal, antibacterial, antioxidant and antiviral properties, besides being used as functional foods. Mushrooms contains less quantity of carbohydrates and less amount of fats, whereas they contains rich amount of proteins, precursor of vitamins A & D, vitamin B5, vitaminB-12, vitamin C and minerals like phosphorous, Potassium, Iron, copper etc. Moreover, it contains all types of amino acids particularly L-lysine and L-tryptophan. Since Mushrooms are rich in all types of essential vitamins, fibres, low fat and proteins, it is preferred for the diabetic and heart patients.

Mushroom powder and its byproducts

The fundamental role in commercialization of Mushrooms are production of versatile food items which may be consumed fresh or cooked wholly. Fresh mushrooms being perishable start deterioration instantly within a day after harvest. Because of the extremely delicate nature of fresh mushrooms, they have to be preserved. Post-harvest procedures can be applied to improve the shelf life, preserve the quality of mushrooms and enhance storage. (Deepalakshmi and Mirunalini, 2014). Freeze dried and canned mushroom is high value low volume products, which may be marketed in domestic as well as international market for a longer duration against the fresh mushroom These procedures will also provide job opportunities for the rural youth, which is the need of the hour.

Mushroom Powder is another form widely used and the polysaccharides present in mushrooms hydrates skin, making it soft and supple. Since it contains vitamin D and when applied topically, they help

shrink breakouts and treat acne. The kojic acid present in mushrooms gently exfoliates the skin and reveals bright complexion. Mushrooms are rich in antioxidants like selenium, vitamin C and choline. These essential nutrients fight free radical damage in your system and keep sign of aging at bay. A study was carried out recently and a composite flour was blended with oyster mushroom powder (OMP) in different proportions for the baking of bread by Majeed *et al.,* (2017). Results showed that OMP increased water absorption capacity of dough. Dough development time increased with the increasing amount of OMP. The capacity of dough to get soft also increased with increasing treatment level. The results shows positive impact to be used as food supplement through bread making.

Various food products have been introduced by using fresh and dried Mushrooms and the products include, Mushroom Pickle, sauce or ketch-up, Mushroom preserve (Murabba), candy, chips, jam, Biscuit, nuggets, papad, bhujia, soup mix, chutney powder, fortified instant noodles, snack bar and Mushroom halwa.

Creative and innovative Ecofriendly Industrial Products from Mushroom

The challenge of global sustainability presents enormous opportunities for product innovation and creative response. Fungi are remarkable and being used for the bioremediation of environments contaminated by pollutants such as oil spills and toxic chemicals (e.g. TNT, sarin nerve gas, pesticides).

Their use for cleaning up sites contaminated by acidic radioactive waste is only just starting to be realized, following the discovery of a fungus (*Rhodotorula taiwanensis*) that not only grows in extremely acidic conditions (pH 2.3) but can also tolerate such high levels of gamma radiation that it is one of the most radiation-resistant organisms on Earth. (D'Mello, 2019). Creative and ecofriendly products available in various markets and Amazon.com

Styrofoam alternative

Expanded polystyrene (EPS) is derived from petroleum, it is a versatile, cushioning, lightweight material, and approximately 95% of the total weight of this material is composed of air used for packaging and building, and it is also the fourth most manufactured thermoplastic in the world. It contains benzene, a widely known carcinogen compound, and styrene, a potentially carcinogenic compound. Due to these facts, EPS for food packaging applications poses a risk to human health. Concerns about the rising volume of packaging wastes particularly request the redefinition and redesign of conventional products in the packaging industry. Fungal mycelium is the vegetative part of fungus which can cement particulate substrate and can be formed into any shape if grown in a mould. Mycelium offers viable, affordable alternatives for polystyrene packaging on a global scale. Mycelium biocomposites (MBs) are rapidly being seen as green alternative for many hydrocarbon-based products, including Expanded Polystyrene (EPS) used for insulation in the construction industry. (Yang *et al.,* 2017).

Bricks from mushrooms mycelium

Energy performance of buildings, insulation materials (such as mineral glass and rock wools, or fossil fuel-based plastic foams) are being used in increasing quantities, which may lead to potential problem with materials depletions and landfill disposal.

One sustainable solution suggested is the use of bio-based, biodegradable materials. A number of attempts have been made to develop biomaterials, such as sheep wood, hemcrete or recycled papers. In this paper, a novel type of bio insulation materials – mycelium is examined. The aim is to produce mycelium materials that could be used as insulations. The bio-based material was required to have properties that matched existing alternatives, such as expanded polystyrene, in terms of physical and mechanical characteristics but with an enhanced

level of biodegradability. The testing data showed mycelium bricks exhibited good thermal performance. Future work is planned to improve growing process and thermal performance of the mycelium bricks.

Building insulation plays an important role in improving thermal comfort, health and wellbeing of occupants and reducing heating and cooling energy consumption, carbon emissions and pollution. However, most of the buildings insulation materials are manufactured using mined and/or fossil fuel based materials. Dual-needle probes are used to measure the thermal conductivity and specific heat capacity. (Xing *et al.*, 2011). In order to improve energy performance of buildings, insulation materials (such as mineral glass and rock wools, or fossil fuel-based plastic foams) are being used in increasing quantities, which may lead to potential problem with material depletions and landfill disposal. One sustainable solution suggested is the use of bio-based, biodegradable materials. A number of attempts have been made to develop biomaterials, such as sheep wool, hemcrete or recycled papers by El-Gharabawy (2016). He preferred a novel type of bio insulation material called mycelium. The bio-based material was expected to have properties such as expanded polystyrene, in terms of physical and mechanical characteristics but with an enhanced level of biodegradability. The testing data showed mycelium bricks exhibited good thermal performance. By improving growing process and thermal performance of the mycelium bricks the product could be attained.

Artificial Leather

Fungi-derived leather substitutes are an emerging class of ethically and environmentally responsible fabrics that are increasingly meeting consumer aesthetic and functional expectations and winning favour as an alternative to bovine and synthetic leathers. While traditional leather and its alternatives are sourced from animals and synthetic polymers, these renewable sustainable leather substitutes are obtained through the upcycling of low-cost agricultural and forestry by-products into chitinous polymers and other polysaccharides using a natural and carbon-neutral biological fungal growth process. (Gac *et al.*, 2014). Mushrooms can be grown on sawdust or agriculture waste, it forms a thick mat that can then be treated to resemble leather. Fungal mycelium is a strong flexible leather and durable just like the traditional leather, made up of natural fibers, water proof and it can breath and feel like leather. This natural biological process can be carried out anywhere. It does not require any sources of light, converts waste into useful material and store carbon by accumulating it in the growing fungus. Mushroom leather are 100% biodegradable, no chemicals are used in colouring and use less water.

Biomedical Innovation: Artificial Lungs

Extracellular matrix (ECM) is composed of several macromolecules, and its role is to provide physical support, communication pathways, and 3D organization to the cells in organs and tissues. In the last decades, several efforts have been made in the field of tissue engineering to mimic this diversity and achieve specific tools to support the regeneration of human tissues. For this reason, various scaffold materials have been designed, and techniques such as electrospinning, freeze-drying and 3D printing have been developed and extensively employed. Biopolymers, such as PCL and PLA, succeeded in matching the requirements for biodegradable materials with prolonged life-time and mechanical resistance inside the body. (Litowczenko *et al.*, 2021). Mycelia, the vegetative part of fungi, are emerging as the avant-garde generation of natural, sustainable, and biodegradable materials for a wide range of applications. They are constituted of a self-growing and interconnected fibrous network of elongated cells, and their chemical and physical properties can be adjusted depending on the conditions of growth and the substrate they are fed upon. So far, only extracts and derivatives from mycelia have been evaluated and tested for biomedical applications. In this study, the entire fibrous structures of mycelia of the edible

fungi *Pleurotus ostreatus* and *Ganoderma lucidum* are presented as self-growing bio-composites that mimic the extracellular matrix of human body tissues, ideal as tissue engineering bio-scafolds. The findings demonstrate the potentiality of mycelia as all-natural and low-cost bio-scafolds, alternative to the tissue engineering systems currently in place (Mondal *et al.*, 2019).

Fungal mycelium and fruiting body has adequate properties and characters to serve as food, medicine, biodegradable innovative ecofriendly materials on a global scale. The present paper clearly helps to understand how mycelium and fruiting body can be used as food, value added products to combat various dreaded disease and also to create ecofriendly products like styrofoam alternative, mycofoam for various innovative products like brick pieces, artificial leather and production of artificial lungs. Every citizen should have the responsibility towards sustainability, renewing the energy source and removing plant biomass waste in an efficient way. Education and continuous research of mushrooms is needed to increase towards percapita consumption and creation of new products.

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