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Postharvest Technology of Button Mushroom: A Socio-Economic Feasibility

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Abstract

Fresh mushroom is highly perishable and deteriorates immediately after harvest. It develops brown colour on the surface of the cap due to the lyses of cell and enzymatic action of polyphenol oxidase that results in shorter shelf life. Being highly perishable in nature, the fresh mushrooms need to be processed to extend the off-season availability by adopting appropriate postharvest technology and processing into value-added products. The value-added products are the need of the hour for the mushroom growers not only to reduce the losses but also to enhance the income by value-addition to boost the consumption of mushroom. The possible value-added products can be developed either by converting freshly harvested mushrooms into ketch-up, murabba, candy, chipsand pickles or by dehydrating freshly harvesting mushrooms into dehydrated form and then making soup powder, biscuit, nuggets and Ready–to–eat mushroom curry (RTE). This review article summarizes the information regarding postharvest technologies and value addition of fresh mushroom generally followed worldwide.

INTRODUCTION

Mushroom is a rich source of good quality protein, containing most of the essential amino acids, minerals and vitamins. Fresh mushroom is highly perishable in nature and in case of forest mushroom, which is available in a particular season only, processing is the only option in order to utilize excess production in the season and to make it available during off season. This is applicable in all types of cultivated species (Tseng and Mau, 1999 and Czapski, 2000). More than 2000 mushroom species exist in nature, but only about 22 species are cultivated (Manzi, *et al*, 2001). Around 20 genera of mushrooms are being cultivated throughout the world, only four types, *viz*., white button mushroom (*Agaricus bisporus*), oyster mushroom (*Pleurotus* spp.), paddy straw mushroom (*Volvariella volvacea*) and milky mushroom (*Calocybe indica)* are grown commercially in India. Button mushroom is the most popular mushroom grown in India contributing about 90 per cent of total country's production (Mehta *et al*, 2011). It is capable of fetching highest price in Indian and International market. The method of cultivation of mushroom was recorded as early as 300 BC and commercial cultivation was started near about 600 AD in China. In India, production of white button mushroom

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started in the hilly regions of Himachal Pradesh (Chail), Kashmir and Tamil Nadu (Ooty).

Realizing the importance of mushrooms for ensuring nutritional and social security of the underprivileged small farmers and landless labourers, the Indian Council of Agricultural Research established the National Research Centre for Mushroom (NRCM) in 1983 at Solan (Himachal Pradesh) to conduct research programmes and transfer of technologies on various aspects of mushrooms production. Himachal Pradesh is a leading state in commercial production of mushroom also called as land of mushroom and Solan where NRCM is located is known as mushroom city of India.. Initially, AICRP-Mushroom was started with six centres one each at Tamil Nadu Agricultural University (Tamil Nadu), Punjab Agricultural University (Punjab), G.B. Pant University of Agriculture and Technology (Uttarkand), C.S. Azad University of Agriculture and Technology (Kanpur), Bidhan Chandra Krishi Vishwa Vidyalaya (West Bengal) and Mahatma Phule Agricultural University (Maharashtra). After establishing the All India Coordinated Research Projects on Mushroom (AICRP-Mushroom) at Solan, the research on mushroom was intensified (Ahlawat *et al*., 2008).

Production and consumption of mushrooms have tremendously increased in India mainly due to increase in awareness of the commercial value and nutritional significance of this commodity. At present production of mushrooms has crossed lakh tone with annual growth rate of above 15% (Sharma and Dhar, 2010). In India, white button mushroom still contributes more than 85 % of the total mushroom production, though its share is below 40% in the global trade (Prakasam, 2012). India contributes about 3% of the total world button mushroom production. Even if we use 1% of the residues for mushroom production, we can produce 3.0 million tons of mushrooms, which will be almost equal to current global button mushroom production (current world production 3.4 million tons) (Prakasam, 2012). Introduction and cultivation of the tropical mushrooms like oyster, paddy straw and milky mushrooms have brought in much-needed diversification in the mushroom portfolio of the country. Among the states, Punjab, Uttarakhand, Haryana, Uttar Pradesh Tamil Nadu, and are being major contributors of mushroom production in the country (Table 1). Composition of mushroom is given in Table 2.

Table 1. Leading states in Mushroom cultivation

State/ Union Territory	Annual Production (Tonnes)
Punjab	60000
Uttarakhand	8000
Haryana	7178
Uttar Pradesh	7000
Tamil Nadu	6500
Himachal Pradesh	5993
Orissa	5846
Andhra Pradesh	3022
Delhi	3070
Maharashtra	2975
Kerala	800

(Source: Singh *et al*., 2011)

Table 2. Composition of button mushrooms

Constituents	Quantity
Moisture	90 to 93%
Crude protein	28 to 42.5 %
crude fibre	8.3 to 16.2%
Ash	9.4 to 14.5 %
Carbohydrates and	59.4 %
Fat	3.1%
Calcium	71 mg
Phosphorous	912 mg
Sodium	106 mg
Potassium	2850 mg
Riboflavin(B2)	3.7 mg
Ascorbic acid (C)	26.5 mg
Niacin (B3)	42.5 mg

CULTIVATION OF MUSHROOM

Mushroom cultivation requires cereal straws for substrate preparation and there is cereal straw available in India for recycling to edible biomass of highly nutritional and medicinal value. India produces nearly 140 million tonnes of cereals and equal amount of straw is generated by the farmers, which can partly be utilized by the farmers for mushroom cultivation. Land requirement is a minimum and any spare room of the house can be converted into a mushroom growing room, or a hut built on a piece of land can also be used for the purpose. The raw materials required for crop rising or generated by the farmers on their own fields (paddy/wheat/or any other cereal straw).

The family labour is used for different operations and the only input required from outside is the seed/spawn of mushrooms. This makes the farmer self confident in raising the crop with great remuneration. A farmer grows one crop or two in the season and his income subsisted largely. The raw materials requirement for raising a crop of mushroom is recyclable cereal straw/organic waste/organic by-products. The main agro by-products used for substrate preparation for mushroom farming includes wheat/paddy straw, sugarcane baggage, saw dust, cotton seed meal/soybean meal and other locally available agro byproducts and agro waste materials like stalk of maize, bajra and jowar/banana pseudo stem/ groundnut hull/ corn cobs etc.

POSTHARVEST PHYSIOLOGICAL AND BIOCHEMICAL CHANGES

Understanding of the postharvest physiological processes which affect the quality and shelf life and how these could be managed to ameliorate the situation is required.

Colour

Whiteness is the most important quality attribute in the button mushroom, besides, of course, shape and size. In a survey conducted in UK on the preference of the consumers about quality in the button mushroom, whiteness got the greatest score. Whiteness categories for mushrooms have been quantified by Gormley (1975) based on Hunter L* (Lightness values); (1) Higher than 93, excellent (100 is the theoretical maximum); (2) 90-93, very good; (3) 86- 89, good; (4) 80-85, reasonable; (5) 69- 79, poor; (6) below 69, very poor. Mushrooms with values below 80 were considered unacceptable at wholesale and below 69 at retail. Lower storage temperature retarded the changes.

Hyphae of white strains are virtually colourless and translucent but they contain enzymes, which under certain conditions react with the substrates in the cell content to form pigmented compounds, the reason for postharvest mushroom browning (Burton, 1986). Tyrosinase, commonly known as Phenol Oxidase is responsible for post harvest browning. Mishandling during harvesting, enzymes and substrates, which are perhaps in separate cell compartments, get mixed up and the reaction is activated. Colourless phenols, after initial reaction form quinones, which transform and polymerise into pink, purple to brown compounds. Button mushroom is highly prone to enzymatic browning when the surface of the mushroom is exposed to air. Enzymes *viz*., Tyrosinase and Poly Phenol Oxidase released at the surface act on the polyphenols present in the mushroom and oxidize them to quinones (Swaminathan, 1988 and Jolivet *et al*., 1995). Like any enzymatic reaction, the rate of reaction will depend upon quantity and activity of enzyme protein, amount of substrate available and favourable conditions for the reaction (pH, temperature etc) high moisture content. But no doubt, brown mushrooms represent mishandled and aged mushrooms after the harvest (Nichols, 1985 and Swaminathan, 1988). Increased browning of mushrooms stored at high temperature was observed and

was correlated with increased activity of polyphenol oxidase (Goodenough, 1976; Goodenough and Ricketts, 1977).

Post harvest metabolism

Harvesting results in severing the supply of substrates by the mycelium for growth and respiration despite the fact that mushrooms after harvest continue to grow (expand) with development of gills and formation of basidiospores. Expectedly, metabolic shift takes place resulting in compositional changes. The shorter shelf life of mushrooms is due to its very high respiration rate-of about 28.2-43.6 mg CO_2 per kg fresh weight per hour at 0°C (Hammond and Nichols, 1975). The respiratory heat in mushrooms is reported to be 14 kcal / kg / 24 h at 20°C (Nichols and Hammond, 1975) and manifold acts as the preferred post harvest respiratory substrate. Storage of mushrooms at higher temperature (18 to 20°C) resulted in reduction in protein with accumulation of free amino acids due to activated protease enzyme activity (Rai and Saxena, 1988). At higher temperature urea accumulation (Hammond, 1979) and breakdown of nucleic acids and other nitrogenous substances may occur. Button mushroom stored at 10 and 20^0C shows a sigmoid pattern of growth, but at 00C growth is retarded substantially. Mushrooms with high dry matter content had an increased firmness, better shelf life and decreased shrinking during canning (Van Loon *et al*., 2000). Eby *et al*. (1977) reported a change in electrophoresis protein patterns during storage at 12°C, and an increase in free amino acids. Reduction in temperature to 0°C prevented the increase in protease activity, but caused a greater accumulation of free amino acids (Murr and Morris, 1975).

MUSHROOM PROCESSING AND PRESERVATION

Washing

Washing is normally done to remove adhering soil particles, however, it is not necessary if harvested mushroom is free from any soil adhering. Washing also decreases shelf life in oyster mushroom. Washing in a solution of potassium metabisulphite (KMS) is recommended as a post harvest treatment to retard browning reaction facilitates by poly phenol oxidase. Also, other anti-microbial compounds are used in wash water to extend the shelf life of mushroom. Oxine, a stabilized form of chlorine dioxide, was found very effective in controlling bacterial growth and colour deterioration when used at a level of 50 ppm or higher with a two minute or longer wash period at 12ºC. The use of sodium hypochlorite (100 ppm) and calcium chloride (0.55%) with oxine (100 ppm) resulted in increased antibacterial effectiveness.

Drying

It is the process of removal of moisture from the product up to a certain level. At this level or below it, microbial and biochemical activities are considerably reduced. Dried products can be stored safely if sealed container is moisture proof. Mushroom contains about 90% moisture at the time of harvesting and are dried to a moisture level below 10- 12 per cent. Drying temperature itself destroys most of the microbes present on the mushrooms and in the absence of moisture, all dried products including mushroom are free from microbial growth. However, insect and their larvae can easily multiply and grow if not packed properly. Dried mushrooms can be easily powdered and used in many different types of preparations such as soups, bakery products, culinary items etc. Drying temperature also influences quality of final dried products. Mushroom dried at higher temperature may

lose texture, flavour and even colour along with reduced rehydration quality. Recent times, a number of drying and dehydration technologies are used such as solar drying, fluidized bed drying, dehumidified air-cabinet drying, osmo-air drying, freeze-drying, cabinet drying and microwave drying are few examples used for almost all types of mushrooms.

Storage Conditions

The ideal temperature and relative humidity for mushroom storage is 0 to 1° C (32 to 33.8° F) and 95% respectively. At this condition, it can be stored for 7 to 9 days without much quality deterioration. Storage at higher temperature reduces quality and shelf life reported by many workers. According to Umiecka (1986), Storage at 2° C (35.6 °F) reduces storage-life to 3 to 5 days by accelerating surface browning, stripe elongation, and veil opening. High RH is also essential to prevent desiccation and loss of glossiness. It is because absence of moisture accelerates stripe blackening and veil opening. Mushrooms should be packed in polyethylene pouches of suitable thickness and perforation. The CFB cartoons are also used with a perforated over-wrap of polyethylene film to reduce moisture loss. It is important to avoid water condensation inside packages or pouches as condensation attracts microbial spoilage.

Controlled Atmosphere Condition (CAC)

Many workers that reduced O_2 report it and elevated CO_2 concentration has beneficial effects on quality during storage of mushroom**.** A combination of 3% O_2 and 10% CO_2 is reported to extend storage-life of mushroom up to 12 to 15 days at 0° C (Suslow and Cantwell, 1998). Another report says that 10 to 15% CO_2 concentration reduces cap opening, browning and stripe elongation. Zheng and Xi, (1994) also reported that mushroom quality was maintained in 8% O_2 and 10% CO_2 concentration. However, ultra low level of O2 and very high level of CO_2 in the storage atmosphere may cause development of off-flavours, cap opening and stripe elongation.

Chilling and Freezing injury

Mushrooms are not low temperature sensitive, but freezing take place if temperature goes below -0.6° C (31 °F). This temperature causes freezing injury characterised as water-soaked and extremely soft caps (Suslow and Cantwell, 1998).

Quality Characteristics

A good quality mushroom should be free from open veils, disease, spots, insect injury and decay. A uniform, well-rounded cap with smooth glossy surface and fully intact veil are signs of high quality product. Mushroom cap colour should be white or dark brown.

Harvesting, Sorting, Grading and Packing

Mushrooms like other fruits and vegetables are harvested at proper maturity stage. This stage is reached when the caps are well formed, round in shape and veil is completely intact. The stripe should have a small length to thickness ratio and should be sufficiently long enough to permit some trimming without cutting the caps. All opened veil, diseased, discoloured and decayed should be removed. Mushrooms are graded according to size and cap diameter. U.S. grades are No. 1 and No. 2. Sizes range from small (button), 1.9 to 3.2 cm (0.75 to 1.25 in) to medium, 3.2 to 4.5 cm (1.25 to 1.0 in); and Large, > 4.5 cm (1 in), measured as cap diameter. Mushrooms are packed in punnets, polyethylene pouch and box with trays or cartons with a perforated polyethylene film over-wrap (Suslow and Cantwell, 1998). In the recent years controlled atmosphere packaging (CAP) and modified atmosphere packaging (MAP) are found beneficial in terms of improved shelf

life. If simple polythene bags are used for packing, it is important to make desired number of holes for proper humidity control.

Pre-cooling

Mushrooms should be pre-cooled to 2 to 4° C (32 to 39° F) immediately after harvest. Hydro-cooling, forced-air cooling and vacuum cooling systems are often used to reduce temperature of mushrooms. The quality of fresh mushrooms is maintained for extended period if immediately packed and vacuum-cooled and then transported at a low temperature.

Preservation

Solution consisting of 2% sodium chloride, 2% citric acid, 2% sodium bicarbonate and 0.15% KMS is used for steeping preservation of blanched mushrooms for 8-10 days at 21-28º C. Chemical solution of 2% salt, 2% sugar, 0.3% citric acid, 0.1% KMS and 1% ascorbic acid is also found suitable for steeping preservation of mushrooms. It helps to extend shelf life of mushrooms. Low doses of gamma radiation can be used to reduce the contamination and extend the shelf life of mushrooms. Irradiation should be given immediately after harvest for optimum benefits.

Disease and Disorders

Both disease and disorders are noticed in postharvest life of mushroom. Common disorders include upward bending of caps and opening of the veil. This occurs due to continuous growth after harvesting. Storage at recommended temperature and relative humidity is needed to reduce continued development leading to opening of caps. Not many disease affects mushroom after harvesting but bacterial blotch or *Pseudomonas spp*. could be a possible threat during extended storage at high temperatures (Suslow and Cantwell, 1998).

VALUE-ADDED PRODUCTS

Fresh mushrooms cannot be stored for more than two to three days due to its perishable nature. This is a limiting factor for mushroom marketing. Quality deterioration starts just after harvesting. Therefore, Producers are not able to hold it as fresh for more days to market. Processing into value added products is one option producer can adopt to save the product from spoilage as well as to earn more money.

There are a number of value-added products can be prepared such as ketch-up, murabba, candy, chips, pickles, canned mushroom, mushroom soup, powder, biscuit, nuggets etc.

Mushroom Ketch-up

Ketchup is prepared from freshly harvested mushroom. After harvesting, it is washed in 0.05 per cent KMS Solution and cooked in 50 per cent of water for 20 minutes. Mushroom paste is prepared by using a mixer grinder with 0.2 per cent Arrowroot powder. After adding all other ingredients, it is cooked to a TSS of 35^0 Brix. At the end of cooking acetic acid @ 1.5 per cent is added, stirred for 2-3 minutes and then filled in washed, sterilized and dried bottled or jars. Ingredients for mushroom ketchup preparation may vary according to regional taste. Mehta et al. (2011) observed the followings ingredients listed in the Table- 3.

Mushroom Candy

Mushroom candy is prepared more or less similar to fruit candy. After harvesting, it is washed and halved into two pieces. The pieces are blanched for 5 minutes in 0.05 per cent of Potassium Meta Bisulphite (KMS) solution. After draining excess water, pieces are treated with sugar. Sugar treatment is given at the rate of 1.5 kg sugar per kg of blanched mushroom. Initially sugar has to be divided into three equal parts. On the 1st day, pieces are covered with one part of

sugar and kept it for 24 hours. Next day, the same mushrooms are covered with 2nd part of sugar and again kept for overnight and on the third day it is removed from the sugar syrup. This sugar syrup is boiled with 3rd part of sugar and citric acid @ 0.1 per cent is also added in the boiling syrup. Stirring and boiling continued till its concentration reaches up to 70^0Brix. Now mushroom pieces are again added and boiled for 5 minutes to bring its final concentration up to 72^0 Brix. After cooling, the pieces are removed from the syrup and drained for half an hour. The drained mushrooms are placed on the sorting tables to separate out all defective and unwanted and only best quality are kept in a mechanical or cabinet drier at about 60^0 C for about 10 hours. After dehydration, packed in polypropylene bags. The candy can be stored up to 8 months with excellent acceptability and good taste.

Table 3. Ingredients of mushroom Ketch-up

Ingradients	Quantity
Salt	10 %
Sugar	25 %
Acetic acid,	1.5%
Sodium benzoate	0.065 %
Onion	10 %
Garlic	0.5 %
Ginger	3.0 %
Red chilli powder	1.0%
Ajinomoto	0.2 %
Arrarote	0.2 %
Cumin	1.0%
Black pepper	0.1%

Mushroom Murabba

Mushroom murabba is another value added product prepared by cooking it whole or in the form of pieces in heavy sugar syrup, till it becomes tender and transparent. In preparation of 1kg mushroom murabba 1.250kg of sugar is required and cooking is continued till a concentration of at least 68 per cent of soluble solid is reached. Preparation procedure may vary from author to author but in general, freshly harvested button mushrooms are graded, washed, pricked and blanched in 0.05 per cent Potassium Meta Bisulphite (KMS) for 10 minutes. After blanching, it is treated with 40 per cent of its weight of sugar daily for 3 days. At the last day, mushrooms are taken out from the syrup and 0.1 per cent citric acid and remaining 40 per cent of sugar is added in the sugar syrup and boiled with continuous stirring till its concentration reaches to 68^0 Brix. At this strength, mushrooms are again added in the syrup and the good quality murabba is prepared.

Mushroom chips

Chips can also be prepared from mushroom mainly from button mushroom. After harvesting, it is washed, sliced and blanched in 2% brine solution and the kept overnight in a solution containing 0.1 per cent citric acid +1.5 per cent of NaCl + 0.3 per cent chilli powder. After draining off the solution, pieces are dried in a suitable dryer at 60^0C for 6-8 hours. Now dried pieces are fried in good quality refined oil. Fried chips are seasoned with garam masala and other spices to enhance the taste. After seasoning, the chips are packed in polypropylene or polyethylene packets and sealed.

Mushroom nuggets

Nuggets are gaining importance for preparation of vegetables curry along with vegetable or alone in North India and is prepared from pulses powder such as black gram powder, soybean powder, green gram powder etc. It adds taste as well as nutrients to the meal. For preparation of mushroom nuggets, mushroom powder is mixed with the pulses powder and a paste is prepared by adding water. The other ingredients like salt, spices etc. are added to this prepared paste and round balls of 2 to 4 cm diameter are made out of the paste. Now theses ball are sun dried. Mehta et al. (2011) standardised the ingredients for preparation of mushroom nuggets (Table-04).

Table-4. Ingredients for preparation of mushroom nuggets

Ingradients	Quantity
Urad dhal powder	80%
Mushroom powder	10%
Salt	02%
Red chilli powder	01%
Sodium bicarbonate	0.01%
water	07%

CONCLUSIONS

This review of literature shows that edible mushroom are highly perishable, hence in periods when supply exceeds demand, processing could be a feasible approach. The basic aim of processing is to increase the quality and shelf life without changing their nutritive and sensory quality. Effective processing techniques will not only reduce the postharvest losses but also result in greater remuneration to the growers as well as processors. Value added products such as Mushroom Ketch-up, Mushroom candy, mushroom murabba, mushroom chips and Mushroom nuggets etc can be added to the mushrooms at the various levels and to varied extent, right from grading to the readymade snacks or the main-course item.

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