# SHELF-LIFE OF OYSTER MUSHROOM

## [*Pleurotus florida* Eger and *Pleurotus sajor-caju* (Fr.) Singer]

By

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**THESIS**

Submitted in partial fulfilment of the
requirement for the degree of

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DEPARTMENT OF PROCESSING TECHNOLOGY
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**1998**

# DECLARATION

I hereby declare that the thesis entitled **'Shelf-life of oyster mushroom [*Pleurotus florida* Eger and *Pleurotus sajor-caju* (Fr.) Singer]'** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title of any other University or Society.

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## CERTIFICATE

Certified that the thesis entitled **'Shelf-life of oyster mushroom [*Pleurotus florida* Eger and *Pleurotus sajor-caju* (Fr.) Singer]'** is a bonafide work done independently by **Miss.V.Rama** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

**(P. Jacob John)**
Chairman, Advisory Committee

# CERTIFICATE

We, the undersigned members of the Advisory Committee of **Miss.V.Rama,** a candidate for the degree of **Master of Science in Horticulture** with major in **Processing Technology,** agree that the thesis entitled **'Shelf-life of oyster mushroom [*Pleurotus florida* Eger and *Pleurotus sájor-caju* (Fr.) Singer]'** may be submitted by Miss.V.Rama in partial fulfilment of the requirement for the degree.

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EXTERNAL EXAMINER

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**V. Rama**

*In memory of*
*my*
*beloved father*

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# ABBREVIATIONS

| | |
|---|---|
| CRD | - Completely Randomised Design |
| CA | - Controlled atmosphere |
| DR | - Dehydration ratio |
| g | - gram |
| Hz | - Hertz |
| kg | - kilogram |
| KMS | - potassium metabisulphite |
| Kw | - Kilo watt |
| MAP | - Modified Atmospheric Packaging |
| MD | - mechanical drying |
| MW | - microwave oven drying |
| PE | - Polyethylene |
| PLW | - Physiological loss in weight |
| PP | - Polypropylene |
| ppm | - Parts per million |
| PVC | - Polyvinyl chloride |
| RH | - relative humidity |
| SD | - sun-drying |
| viz. | - namely |

# Introduction

# INTRODUCTION

Nature alone is antique, and the oldest art, a mushroom. The use of mushroom as food goes back to the farthest antiquity, considered as a delicacy from the early days of civilization, for its aroma and flavour. The world demand for mushrooms is increasing at very fast rate, thanks to the greater appreciation and awareness of their unique nutritional and medicinal values. Though the consumption of mushroom is very limited, India is now witnessing a virtual revolution in promoting exports, with a large number of units mushrooming up; the country with a meagre production of 4000 tonnes in 1985-86 has crossed 30,000 tonnes in 1996-97 (Ganeshkumar *et al.*, 1997). The production of mushrooms does not demand land and sunlight and also helps in the bioconversion of potential pollutants like agrowaste to protein rich foods for human consumption.

No food is so wrapped in mystery as mushroom so amazing to see tiny pin heads on a tray of dung and straw growing into buttons rich in proteins, vitamins and minerals, being called as 'Queen of vegetables'. Mushroom, a protein rich wonder food is ideal to bridge the gap of protein malnutrition, than any other vegetable. The mushroom protein is easily digestible and also contain essential amino acids, tryptophan and lysine, which are deficient in cereals. In the present era of healthy eating by cutting down the calories, saturated fat and cholesterol, mushrooms are found to attract the human attention. As a low calorie, high protein diet with almost no starch and sugars, mushrooms are the 'delight of diabetic'. Mushrooms also contain fairly good amount of vitamin C, vitamin B complex, minerals like potassium, sodium etc., besides, it is also known for its high fibre content, hence form the best choice of dietitians for those suffering from hyperacidity, constipation and are also believed to have anticancerous properties (Rai and Sohi, 1988). These qualities finally led mushroom to be described as 'the ultimate health food' (King, 1993).

However, the problem faced by the mushroom growers is its high perishability, the onset of deterioration follows immediately with the harvest, ending up in a brownish soft deteriorated material within a few hours resulting in an unacceptable produce, situations become still worse with high environmental temperatures. Unlike other horticultural produce, mushrooms are having a high respiration rate, hence a short shelf-life. This cautions to develop any suitable technique to extend the storage life of mushroom in fresh or processed form.

A variety of methods and innovations are applied which include irradiation, chemical treatments, refrigeration, modified atmospheres, dehydration, canning, sun-drying, pickling etc. However, handling and transportation of fresh mushrooms still poses a problem to the producers who often finds discolouration and fast spoilage of mushrooms while in handling and transportation, which considerably reduces the marketability of the produce.

Under these circumstances, developing suitable methods to extend the shelf-life of fresh mushrooms and to preserve the mushrooms during market glut becomes inevitable.

Hence the present study was taken up with the following specific objectives.

1. To extend the shelf-life of fresh produce, especially in transit and handling, till it reaches a refrigerated storage.
2. To improve the method and quality of the present packaging and dehydration technique meant for long term storage.

# Review of Literature

# 2. REVIEW OF LITERATURE

Mushroom, a fast perishable vegetable deteriorates immediately after harvest owing to its high respiration rate compared to other horticultural crops and contains large quantities of phenols, which are oxidised, resulting in browning and wilting after harvest. Unlike fruits and vegetables, they lack a thick protective surface coating of suberin or cuticle, thus leads to fast deterioration resulting in loss of texture, development of off-flavour and colour ending in reduced marketability and consumer acceptability. Therefore development of appropriate storage and processing techniques to extend their life and to improve marketability imbibes great significance. Short term preservation methods like pre-packaging coupled with low temperature storage, irradiation and steeping preservation help to prolong the storage life from one to three weeks. Long term preservation methods such as canning, drying, pickling etc. could make the availability of mushroom throughout the year at reasonable price.

Literature on related works hitherto at different places is reviewed and presented here under the two broad titles.

2.1 Handling and storage of fresh mushroom

2.2 Storage of processed mushroom

## 2.1 Handling and storage of fresh mushroom

Mushrooms have very short shelf-life and can remain acceptable only for a few hours both under tropical and subtropical climatic conditions. In India, it is mostly sold as fresh and only negligible amount is used for processing. The mushroom growers find it extremely difficult to keep them fresh or without discolouration till it reaches the consuming centres or cold storages. Therefore

development of means and methods to keep them fresh or near fresh during transport deserves priority.

According to Sethi *et al.* (1991) mushrooms start deteriorating immediately after harvest due to enzymatic action resulting in the browning and softening of mushroom crops, which is faster at higher temperatures. Rajarathnam and Bano (1988) and Saxena and Rai (1988) opined that mushrooms are predisposed to active desiccation due to high moisture content of the fruiting bodies affecting the texture, flavour and saleable weight of the produce. The storage temperature increased the rate of metabolic changes taking place during storage, which resulted in quality deterioration (Rai and Saxena, 1989). The loss in quality is mainly due to their discolouration which results from the action of O-diphenol oxidase (polyphenol oxidase) on phenolic compounds (Murr and Morris, 1975b).

### 2.1.1 Pretreatments

The main objective of preservation of mushrooms is to use them in their original taste with all nutritive value intact. The changes in taste and nutritive value are commonly due to the activities of the enzymes present in the food and also due to the growth of microorganisms. Therefore it is imperative to inactivate the enzymes and also to arrest the growth of microorganisms.

Bano and Singh (1972) suggested a preservation method for *Agaricus bisporus*, wherein 200 g mushrooms were blanched and preserved in a steeping solution containing sodium chloride 2.5 per cent, ascorbic acid 0.1 per cent, citric acid 0.2 per cent, sodium bicarbonate 0.1 per cent and potassium metabisulphite (KMS) 0.1 per cent for a period of 10 days at 21 to 28°C. The steeped mushrooms were free from microbial spoilage and were organoleptically acceptable to the panel of judges.

Ramaswamy and Kandaswamy (1978) recommended the use of sodium chloride or ascorbic acid or citric acid solutions for enhancing the storage life of paddy straw mushrooms.

McCord and Kilara (1983) in their study found that citric acid was having the capacity to inhibit both enzymatic (by lowered pH) and non-enzymatic activity (by citric molecule).

Adsule *et al.* (1981) conducted studies to prolong the shelf-life of oyster mushrooms (*Pleurotus sajor-caju)*. The mushrooms were harvested, trimmed, washed and blanched (in water containing 0.1 per cent citric acid) at 85 to 90°C for four minutes. The blanched mushrooms after cooling were packed in glass bottles, covered with water containing 5.0 per cent salt, 0.2 per cent citric acid and 0.1 per cent KMS and subsequently screw capped. Such bottles could be kept for three months without loosing much of its organoleptic attributes, at room temperature.

Mushrooms were preserved by steeping in different solutions by Pruthi *et al.* (1984) in order to maintain the whiteness and to extend the shelf-life and for transportation to different places. Various concentrations of acetic acid, citric acid, ascorbic acid and KMS were utilised for steeping preservation of mushrooms. Water blanched mushrooms steeped in solution containing 0.5 per cent citric acid and 500 ppm $SO_2$ was the best treatment. Mushrooms could be steeped in this solution without loosing much flavour and texture. Dipping of mushrooms in dilute solutions of $H_2O_2$ 30 volume (1:3) for half an hour and then steeping in water containing 0.25 per cent citric acid and 500 ppm sulphur dioxide ($SO_2$) solution had shown significant effect and it helped in maintaining the whiteness.

Sethi and Anand (1984) found that the treatment with a solution of salt (2%) and sodium bisulphite (0.15%) was effective in reducing discolouration.

A study conducted by Chopra *et al.* (1985) revealed that mushroom treated with honey (0.5 to 1.0%) for 18±2 hours before harvest, air dried to remove surface moisture, packed in 100 gauge polyethylene pouches with 0.5 per cent venting area and stored at 3°C to 5°C, reduced the physiological weight loss and polyphenol oxidase activity. Veil opening was delayed and shrivelling was negligible even after 21 days of storage. The shelf-life was increased by more than a week over control at 3°C to 5°C and two to three days at ambient temperature.

Sudhakar *et al.* (1997) could reduce the browning to a certain extent by placing $SO_2$ papers (grape guard) inside the polythene bags.

Saxena and Rai (1988) reported that washing of mushrooms in 0.5 per cent KMS improved the whiteness which had eventually deteriorated slowly during storage. Maini *et al.* (1987) also found similar applications of lower concentration of KMS for short term storage (24 hours). However for long term storage, citric acid (0.1%) and KMS (0.03%) or a combination of citric acid (0.1%) and tartaric acid (0.3%) were found most suitable and white colour was retained upto a period of 48 hours. However, in the treatment, when KMS was added to the citric acid and tartaric acid combination, development of yellowish colour at the end of storage period of 36 hours was noted.

The treatment of fresh mushrooms with 2.0 per cent Sodium chloride (NaCl) + 0.1 per cent ascorbic acid with or without 0.1 per cent citric acid and low temperature storage prevented browning and the development of off-flavour after three days storage which developed in water stored mushrooms held at ambient temperatures (Sihobing, 1987).

The effect of postharvest dip treatment of mushrooms in different concentrations of ascorbic acid and sodium bisulphite for 10, 20 and 30 minutes

were studied by Singh *et al.* (1997). Ascorbic acid (1%) dip for 20 minutes gave minimum polyphenol oxidase activity and enzymatic browning. In the study fresh dhingri mushrooms were washed in boiling water for pre-cooking, then the water was decanted and the mushrooms were steeped in a solution of common salt (22 to 25%) and were placed in barrels or other containers which contained a brine solution, consisting of 18 to 20 per cent common salt, and citric acid @ 80 gm for each 100 kg of salt solution, in order to reduce the pH of the solution to 3.5. The preserved mushrooms could be consumed after desalting by washing gently in warm water.

### 2.1.2 Packaging

Mushrooms rich in moisture are sensitive to desiccation when exposed open and will undergo fast discolouration. Therefore providing suitable package is an important proposition.

According to Maini *et al.* (1983), washing of mushrooms prior to packing is very important for enhancing shelf-life and thus extending the marketing period. Mushrooms are usually packed in polypropylene (PP) bags of 250-500 g capacity; quantities more than this have a tendency to loose acceptability.

Nichols and Hammond (1973) packed the freshly picked mushrooms in styrene, white fibre or waxed card punnets and they were either overwrapped with a poly vinyl chloride (PVC) stretch film or left unwrapped. They found that the loss of weight from open punnets were marked amounting to as much as 9.0 per cent of the fresh weight after five days at 2°C, or upto 37 per cent after five days at 18°C. Mushrooms in styrene punnets lost the least weight, but difference between the types of punnets was of little significance, when compared with the difference between wrapped and unwrapped punnets.

Gormley and MacCanna (1967) reported that the shelf-life of mushroom could be increased by overwrapping with PVC films. They contributed the benefits of conservation of water and indicate that artificial atmosphere might create chemical changes.

Overwrapping of mushrooms with plastic film improved their quality as observed by rate of cap opening, colour and reduction in weight loss (Nichols and Hammond, 1975). Gormley (1975) recorded that the longer the refrigeration time, the whiter the mushrooms, but the rate of loss of whiteness was similar whether the mushrooms were refrigerated for 10 or 11 days.

Goodenough (1976) studied the effects of chilled storage on the physiology of mushrooms. Colour changes at 2°C and 10°C were negligible for 10 days, but at 25°C colour was unacceptable after four days, and deteriorated rapidly after six days. Polyphenol oxidase activity at 25°C rose sharply for about 15 days, but thereafter declined rapidly. At 2°C, enzyme activity attained a peak after eight days, after which there was little change and mushrooms could be maintained in excellent condition for upto 40 days.

Pantastico *et al.* (1975) recommended a temperature of 0°C with 95 per cent relative humidity (RH) to extend the marketable life of mushrooms for about 10 days.

In a study conducted by Bush and Cook (1976) mushrooms were covered with perforated or nonperforated plastic film and were kept at 2 to 25°C and 30 to 90 per cent RH for upto four days. The effects were assessed on their appearance, weight loss and shape. The optimum conditions for retaining the most acceptable colour and appearance were in perforated packs at 4°C to 7°C and 40 to 50 per cent RH. The least weight loss and change in shape occurred in unperforated packs.

Goodenough and Ricketts (1977) studied the effects of different storage conditions on the senescence in mushrooms, *Agaricus bisporus*. The mushrooms were packed in styrene punnets, overwrapped with perforated polyethylene (PE) film and stored at 0°C to 2°C, 10°C or 25°C and 45 to 56 per cent RH. At 25°C, mushrooms remained in good physical condition for upto three days, at 10°C there was no marked deterioration during 15 days of storage and at 0°C, deterioration was slight for 30 days. However, transfer of mushrooms from 10°C or 0°C after eight days to 25°C resulted in very rapid deterioration.

Rajarathnam *et al.* (1983) suggested a method to extend the shelf-life of mushroom. When mushrooms were packed in 25 μm PE bags with one pin hole on either side, they stored well upto 24 hours at ambient temperature and upto six days at 5±2°C in intact bags.

Sethi and Anand (1984) reported that mushrooms when stored at high temperature, resulted in brown discolouration of the surfaces, elongation of stalks and opening of veils. Storage in refrigerator for a few days was possible when mushrooms were placed between moist paper towel. Freshly picked mushrooms were kept in prime condition (after washing and draining) at 32°F for five days in a ventilated PE bag, at 40°F for two days and at 50°F for one day.

Chopra *et al.* (1985) recommended 100 gauge PE bags with 0.5 per cent venting area for packing for the refrigerated storage.

Jandaik and Sharma (1987) studied the effect of different storage conditions on shelf-life and reported that perforated PP or PE bags were effective in reducing moisture loss as compared to unpacked condition, in which the loss of moisture was about 32 to 35 per cent at 15 to 18°C and 6.0 per cent at 6°C to 8°C after 72 hours. There was no loss of moisture in packed bags, but the fruiting bodies

were slimy in appearance due to the accumulation of excess of moisture inside the bags which resulted in liquefaction and unacceptability of fruit bodies.

Contradictory to the reports of Jandaik and Sharma (1987), Rajarathnam and Bano (1988) and Saxena and Rai (1988) suggested small nonperforated PE packets (< 100 gauge thickness) as the most common retail pack for prolonging the shelf-life of mushrooms.

Umiecka (1986) found that the best conditions for storage of mushrooms were a temperature of 0 to 1°C and a relative air humidity of 90 per cent with pre-storage cooling and washing with water. Paper containers with 200 g capacity were best and a covering of plastic film helped to reduce weight loss and maintained the optimal air humidity. At 0°C to 1°C, mushroom could be stored for seven to nine days.

Suharban (1987) reported that the samples kept under refrigeration started deteriorating with the accumulation of moisture in plastic bags and a liquid started oozing from the mushroom which made them unfit for consumption. However mushrooms when kept in open PE bags of 500 gauge thickness remained fresh for five days. Those covered in plain paper started discolouration after 24 hours.

Mehta and Jandaik (1989) suggested that freshly harvested fruiting bodies of *Pleurotus sapidus* can easily be stored in completely sealed nonperforated PE bags upto 72 hours at room temperature (20-30°C) and 15 days at low temperature (0-5°C).

Storage of *Agaricus bitorquis* mushrooms upto 144 hours at different temperatures (15, 20 and 25°C) with or without chemical pretreatment and in perforated and nonperforated PE bags were studied by Dhar (1992). Mushrooms

exhibited better shelf-life in nonperforated bags, maintaining quality upto six days with little change in colour either at 15 or 20°C. Mushrooms stored in perforated bags began to rot within four days. Intense browning, extensive veil opening, increased cap diameter and heavy water condensation were observed in perforated bags at 20°C and 25°C. Pretreatment with 0.25 per cent KMS solution dip resulted in faster loss of quality than in untreated samples.

Mushrooms can be packed most conveniently in PE bags of less than 100 gauge thickness (Anonymous, 1990). This study has shown that the PE bags should be sealed properly at the mouth and need not be perforated. In these air tight packs, mushrooms retained their freshness upto four days at 5°C.

Vijay and Gupta (1994) reported that mushroom bags could be sealed without any perforations and due to the build up of carbon dioxide in the bags, the metabolism of mushrooms and the partial depletion of oxygen was slowed down which would increase its storage condition.

To minimise the deterioration of fresh mushrooms, care has to be taken to eliminate unnecessary handling, bruising and unnecessary exposure to strong air currents (Pradeep and Abraham, 1995).

Mushrooms can be preserved in fresh condition for eight days without any change in quality by packing in PP bags with space under refrigeration (Suharban and Natarajan, 1995).

Roy *et al.* (1995) studied the effect of over wrapping mushrooms with different types of perforated or nonperforated films on quality of mushrooms during storage. They found that water condensation occurred in the underside of the nonperforated film, making the appearance of the pack unattractive, while excessive

water loss was observed in those packed in perforated films resulting in a wrinkled and discoloured patches on the mushroom surfaces. They also found that loss of whiteness in mushrooms was proportional to water loss during storage whether covered or uncovered.

Geetha *et al.* (1995) reported that mushrooms packed in PE covers (150 gauge) provided with holes (10 holes of five mm diameter) and kept under refrigerated condition remained fresh for four days, while those packed in PE covers without holes started deteriorating after 72 hours with the accumulation of moisture in plastic bags. The mushrooms packed in paper packets showed burnt up tips after 24 to 36 hours. Those packed in thermocol box with ice cubes remained fresh for 45 hours. Packing in banana sheath, paper bits and straw bits were effective in preserving the mushrooms only upto 24 hours after which the mushrooms became dull and slimy.

Storing the fresh mushrooms in perforated (single pin holes) PE bags (100 gauge) at 5°C extended the shelf-life of mushrooms by eight to ten days (Bano *et al.*, 1992). They suggested that pin holes of the package expelled the $CO_2$ built in; the refrigeration prevented the water loss, retarded the enzymatic activities and drastically reduced the rate of respiration. At the end of storage life (eight to ten days), the mushrooms were ranked for acceptability in terms of biting texture, nondevelopment of off-flavour and firmness.

Saray *et al.* (1995) studied the importance of packaging and modified atmospheres in maintaining the quality of cultivated mushrooms. Mushrooms (*Agaricus bisporus*) were packed in pouches made of perforated PP film (0.2%, 3% or 6% perforated surface) or in pouches with a modified atmosphere and stored at 5°C for seven days. After the storage, the quality was the best with PP films

perforated to 3.0 per cent of its surface area. Transpiration loss and the microbial count were lowest in modified atmosphere, but flavour was impaired.

Balakrishnan (1994) observed that unwashed mushrooms immediately after harvest packed with little air in nonperforated PP (100 gauge) covers, sealed in flame, could be kept in refrigerator for about 10 days or even more without any damage as against locally practised method of packing of fresh mushrooms in perforated PE bags under refrigerated conditions which showed discolouration and decaying by fourth day of storing.

The shelf-life of freshly harvested mushrooms could be extended from one day at 24°C to 13 days by packing in 100 gauge PE bags and storing at 0°C (Sudhakar *et al.*, 1997). They could be stored in good condition for nine days at 4°C and six days at 7°C. Use of newspaper lining or silicated packs inside the PE bags helped in absorbing the excess condensed moisture, reduction of browning and sliminess. Pre-cooling to 0±1°C extended the shelf-life of oyster mushrooms packed in PE bags to 15 days at 0°C.

### 2.1.3 Controlled Atmospheric storage / Modified Atmospheric storage

In the recent years, controlled atmospheric storage (CA), a novel preservation technique is catching up fast for all types of fruits and vegetables. In this method, the concentrations of carbon dioxide ($CO_2$) and oxygen ($O_2$) are altered in the environment where the product is packed. The respiration rate also gets altered due to this, the brown discolouration (enzymatic browning) is reduced and the storage life is extended (Lopez-Briones *et al.*, 1992).

But CA storage is costly and not practised for short term storage of produce with short life, such as mushrooms. Any beneficial effects of CA storage is

lost as soon as the produce is removed from CA. Modified atmosphere packaging (MAP) has continuing beneficial effects until the package is opened and can be very useful for extending the shelf-life of fresh produce. MAP can provide an economical and effective way of extending the shelf-life of fresh mushrooms during shipment and marketing (Singh *et al.*, 1970).

Sveine *et al.* (1967) while investigating the storage life of mushrooms reported that high $CO_2$, low $O_2$, and low temperatures prevented the cap opening. They found that nitrogen ($N_2$), with 0.1 per cent $O_2$ and 5.0 per cent $CO_2$ in storage was optimum for maximum shelf-life.

Nichols and Hammond (1973) used different in-package gaseous concentrations in pre-packs stored at 2°C and 18°C using different films. Packages with $CO_2$ of 10 to 12 per cent and $O_2$ of one to two per cent stored at 18°C resulted in mushrooms with slowest opening of the films and colour deterioration. At 2°C, $CO_2$ and $O_2$ concentrations came to equilibrium at about four to ten per cent and 11 to 17 per cent respectively, depending on film overwrap. At that temperature, mushrooms tended to discolour, which may have been due to the high $CO_2$.

Controlled atmospheric storage prolonged the shelf-life of mushrooms (*Agaricus bisporus*), when the $O_2$ concentration was nine per cent or the $CO_2$ concentration was 25 or 50 per cent (Murr and Morris, 1975a). Hatton *et al.* (1975) noted the beneficial effects of CA in preventing mold growth and retarding cap opening at $CO_2$ levels as high as 20 per cent; the atmosphere with less than 10 per cent $O_2$ was found to be injurious.

Dang *et al.* (1980) reported that storage under CA by lowering $O_2$ and/or increasing the $CO_2$ at low temperature extended the storage life of harvested fruits and vegetables. They also suggested storage under low temperature as an excellent

method for restricting deterioration for harvested mushrooms for a limited period of time.

Saray (1986) recommended the optimum atmospheric composition for cold storage (1°C and 80% RH) of cultivated mushrooms as 15 per cent $CO_2$ + 10 per cent $O_2$ + 75 per cent $N_2$. After 21 days of storage, 82 per cent mushrooms were marketable, the loss due to shrinkage being seven to eight per cent.

Burton *et al.* (1987) reported an improvement in colour of mushrooms stored in MAP. Reduced $O_2$ during storage can influence colour by suppression of enzymatic browning and by reduction of microbial population (Doores *et al.*, 1987; Beelman *et al.*, 1989).

Burton and Maher (1991) suggested that MAP successfully delayed senescence and maintained the quality after harvest in the system. Beit-Halachmy and Mannheim (1992) stated that the beneficial effect of MAP on appearance may be due to a microstatic effect, since MAP did not affect the rate of respiration.

Roy *et al.* (1995) studied the effect of $O_2$ concentration at two to six per cent $CO_2$ on shelf-life of fresh mushrooms in MAP. For mushrooms, optimum in-package $O_2$ was six per cent to reduce cap development. Precise control of RH was recommended. MAP reduced weight loss in normally grown mushrooms, compared to conventional packages (with 2 holes).

A study conducted by Sahoo and Anjaneyulu (1995) indicated that lowering of $O_2$ level in MAP environment helped in extending the shelf-life of the product by reducing metabolic rates and chemical oxidation rates. But they also suggested that it could stimulate the growth of anaerobic pathogens. Carbon dioxide is mainly responsible for bacteriostatic effect on the microorganisms found in

modified atmosphere environment. The gas selectively inhibited the growth of gram-negative bacteria which grow rapidly and produces off-odours and off-flavours. For maximum anti-microbial effect, the storage temperature of a MAP product should be kept as low as possible, because the solubility of $CO_2$ decreases drastically with increasing temperature.

Burton and Twying (1989) studied the effect of MAP and cooling on the shelf-life of mushrooms. The clean white button mushrooms were weighed into polystyrene punnets which were left open or wrapped with standard lidding film, with or without patches of microporous films inserted. Punnets were stored continuously at 18°C, 10°C or 2°C for four, eight and fourteen days respectively, or were held initially at 2°C or 10°C for two days before transferring to 18°C. Atmosphere in punnets wrapped with unmodified lidding film was highly modified within 24 hours. Oxygen concentration increased and $CO_2$ content decreased when microporous film was inserted. At lower temperature, the insertion of microporous film had less effect. Wrapping punnets greatly decreased the weight loss during storage.

## 2.2 Storage of processed mushroom

Since the present study emphasise only on dehydration under processed mushroom, work done on dehydration alone was reviewed.

### 2.2.1 Dehydration

Owing to the highly perishable nature, the preservation of mushrooms into more stable products derives great significance. So the development of appropriate technology for storage and processing becomes inevitable. Long term preservation methods such as canning, drying, pickling etc. can make the

availability of mushroom of a good quality throughout the year. Freezing and freeze drying methods have also been recommended for long term storage, but these are energy intensive, sophisticated and cost prohibitive techniques to be adopted for local markets. Pickling and dehydration methods are comparatively viable methods of preservation. Speciality mushrooms like oyster mushrooms and *Shiitake* are mostly traded in dried form (Rai and Sharma, 1994).

According to Saxena and Rai (1989), dehydration is the most prevalent method for long term storage of oyster mushrooms.

Drying refers to the removal of water by heat to such a level that the biochemical and microbial activity is checked due to reduced water activity in the product. Dehydration of mushrooms by sun-drying has been advocated by Anand (1975) to be an appropriate technology because of the inexhaustible free source of energy and minimal investment in capital cost. However, dehydration in a cabinet drier equipped with hot air circulation was found to be superior to sun-drying (Mudahar and Bains, 1982).

Dang and Singh (1978) pointed out that sulphited mushroom dried at 60°C, retained the original colour and flavour for zix to seven months, when stored in hermaetically sealed containers.

Pruthi *et al.* (1978) standardised the conditions of dehydration of tropical paddy straw mushroom, *Volvariella volvacea*. For the inactivation of peroxidase and catalase prior to dehydration, the optimum time of water blanching was three to four minutes. The dehydration process in a cross flow drier at 60°C took about eight hours, while dehydration in a phased manner at 70 - 65 - 60°C took about seven hours. An optimum tray load of 2 kg per tray or 6.25 kg per square metre surface area was recommended. Overnight steeping of blanched mushrooms in 1.0 per cent

KMS solution containing 0.2 per cent citric acid considerably improved the colour, texture and reconstitution properties.

Kumar *et al.* (1980) carried out packaging and storage studies on two types of mushrooms. The study, showed that the unblanched sample had very poor storage stability and hence not evaluated for sensory qualities. The blanched and treated samples at the normal storage condition, indicated a shelf-life upto three months when packed in foil laminate and only one month when packed in high density polyethylene (HDPE) pouches.

Deshpande and Tamhane (1981) reported that water blanching for three minutes inactivated polyphenol oxidase, which causes browning during drying of mushroom.

Pruthi *et al.* (1984) carried out dehydration studies in *Agaricus bisporus* and *Volvariella volvacea.* Prior to dehydration, mushrooms were thoroughly washed and cut into small pieces longitudinally as well as cross slitting separately. After blanching, they were dried in a cross flow drier at 60°C to a moisture level of 7.0 per cent. During the storage, it was observed that the dehydrated mushrooms kept in 'friction top' tins maintained very good colour and texture upto nine months at room temperature (18-38°C). On the contrary, those kept in PE bags turned pale yellow during storage and remained hardly for five to six months.

Mudahar and Bains (1982) reported that about 10½ hours was required for the hot air dried product to reach about 5.0 per cent moisture. No appreciable variation was observed among the samples subjected to various treatments. The hot dried produces were looking attractive as compared to the sun dried products which turned perceptibly darker. Among the various treatments, bisulphite in combination with citric acid produced a superior product as compared to the control which

turned distinguishably brown. Dehydration ratios of mushrooms were seemingly constant in all cases, irrespective of pretreatments. A drying temperature of 50°C was recommended since drying at 100°C resulted in caramelization and formation of melanoidins. Hot air dried mushrooms had higher rehydration ratio and superior cooking quality. The discolouration was minimum when bisulphite and citric acid were mixed together as an immersion media for blanching.

According to Sethi and Anand (1984), mushrooms can be dried in the sun or in a solar or mechanical dehydrator at 60 to 70°C. Although, mushrooms are mostly sun-dried in the open, the relative advantages of quicker drying in a solar or mechanical drier in a dust free atmosphere are obvious. After the completion of drying, weight was reduced to one eighth to its original. The dried mushrooms should be stored in air-tight containers in a cool dry place. Dried mushrooms can also be ground into mushroom powder which can be used for making mushroom soup. The powder must be packed in perfectly air-tight plastic pouches to prevent caking and loss of quality.

Katiyar (1985) noted that blanching did not help in improving the dried product. Blanching time for button mushroom ranges between four and six minutes (Tanga, 1974). Sharma *et al.* (1991) also reported the effect of blanching media on the weight loss and final quality of button mushroom.

Drying in mechanical dehydrator was reported to be faster by Katiyar (1985) because of higher air temperature and forced air-circulation as compared to sun-drying. The mean dehydration time was 8.4 hours whereas 16.8 sunhours was needed in sun-drying. A storage life of more than six months was reported for pretreated unblanched mushrooms (0.5% KMS + 0.2% citric acid for 12 hours) (Kumar, 1992).

*Pleurotus* spp. could be easily dried in sun or mechanical dehydrator at 50°C and rehydrated without loss of flavour (Jandaik, 1978). Jandaik and Sharma (1987) studied the effect of different drying methods and stated that sun-dried fruit bodies have three to four per cent moisture in comparison to 2.0 per cent in fruit bodies dried at 40 to 45°C. The change in colour was also slight in sun-drying as compared to hot air drying (55 to 60°C) which resulted in dark brown colour.

Lal *et al.* (1990) opined that a 16 hour soaking 1.0 per cent KMS + 0.2 per cent citric acid + 6.0 per cent sugar + 3.0 per cent salt solution followed by drying at 60±2°C for 8.5 hours gave the best produce with higher yield as well as shelf-life.

Suharban (1987) stated that properly dehydrated mushroom either by sun-drying or drying in a drier, preserved effectively when kept in PE bags.

Bano *et al.* (1992) in their experiments on dehydration of mushrooms, found that samples when treated in KMS solution without blanching did not stay for a long time, evidently reflecting on the enzymatic browning. Though water blanching was found very effective in the control of browning there was a loss in weight and flavour. Hence they suggested steam blanching. While comparing the different methods of drying, the authors stated that sun-drying, though the most economical, it required the assurance of enough exposure to sunlight so as to reach a minimum moisture content in the product and also the appearance of final produce was not good. They found that drying in cross flow driers or through flow driers at 60°C requires about eight and six hours respectively, to dry the mushrooms to a moisture content of 5.0 per cent.

Singh *et al.* (1995) reported that mushroom can also be processed by microwaves. The mushrooms when dried with combined hot air-microwave

treatments at different hot air flow temperatures, viz., 35, 40, 60 and 75°C showed that the combined treatment shortened the processing time, yielding a good quality final product. However, retention of the characteristic aroma compound (1-octen-3-ol) and its oxidation product (1-octen-3 one) was positively affected by microwave drying (Riaz *et al.*, 1991). A comparative study on the efficiency of drying by hot air and a combined hot air-microwave treatments at different temperatures showed that the use of combined treatment was better and it gave a quality product of satisfactory rehydration and flavour retention (Rao *et al.*, 1995).

Suguna *et al.* (1995) conducted studies on dehydration of mushrooms by sun-drying, thin-layer drying, fluidized bed drying, and solar cabinet drying. Rehydration ratio of sun-dried mushrooms was lesser and the browning index value was higher than those of hot air dried mushrooms. Among thin-layer and fluidized bed drying, higher rehydration ratio and lower browning index were noticed in fluidized bed drying.

Nehru *et al.* (1995) fabricated a solar mushroom drier to dry 2.5 kg fresh oyster mushroom and they were tested with four different treatments. The drying time required to dry the mushroom from 92.6 per cent to 10 per cent moisture content was found to be 5.5 to 6.5 hours. Among the treatments, the mushrooms dried after treating with preservatives such as KMS and sodium benzoate at 0.5 per cent concentration for 15 minutes had the same amount of nutrients as fresh mushrooms. The maximum rehydration ratio of 5.2 was obtained for KMS treated samples. The organoleptic evaluation of the dried product revealed that mushrooms dried for 15 minutes after 0.5 per cent KMS treatment was superior to other treatments.

Geetha *et al.* (1995) reported that mushrooms dried in a mechanical drier retained the white colour, whereas mushrooms dried either by a solar drier or

sun-drying showed a brown discolouration. Among the treatments tested, blanched mushrooms showed slight brown discolouration, while blanched and sulphited mushrooms appeared yellow. The loss in weight was lower in the sun-dried mushrooms as compared to those dried in a mechanical drier. In general, the mushrooms dried in a mechanical drier had a better appearance.

Suharban and Natarajan (1995) showed that fresh mushrooms can be dried in the sun or in dehydrator at 60°C, and can be stored in air-tight PP covers without any change for about an year.

Batagurki *et al.* (1997) conducted studies on dehydration of oyster mushroom *Pleurotus sajor-caju* using an electrical drier. Mushroom samples were pretreated with KMS, ascorbic acid and citric acid with one per cent concentration each and it was observed that KMS was effective in preventing browning. Mushroom samples both in the form of whole and sliced were pretreated with these chemicals and the sliced pieces were found to be better than whole mushroom. Steam blanching of mushroom samples for two minutes yielded dark brown coloured and rubbery dried product.

It was also found that a temperature range of 60°C to 70°C resulted in better quality product based on dehydration characteristics, rehydration properties and sensory evaluation scores. Air flow rates of 3 $m^3$ per minute was found optimum.

Tiwari *et al.* (1997) conducted studies on the dehydration of oyster mushrooms with the objective to improve the quality of dried mushrooms. Freshly harvested oyster mushrooms were washed, subjected to various pretreatments viz., water steam blanching, dipping in solutions of KMS, citric acid and ascorbic acid and in different combinations. Hot water blanching (90°C) or steam blanching for

two minutes was found sufficient. After pretreatments, mushrooms were dried in cabinet drier at 55 to 60°C for 16 to 18 hours; packed in 400 gauge PE bags, vacuum sealed and stored. Yield of dried mushrooms was in a range of 7.48 to 9.28 per cent; moisture content 3.89 to 6.44 per cent; drying ratio of 10.8:1 to 13.4:1, while rehydration ratio ranged from 1:2.6 to 1:4.5.

Blanching at 80°C for two minutes was adequate to inactivate the activity of peroxidase enzymes in *Pleurotus ostreatus* (Riaz *et al.*, 1991).

Singh *et al.* (1996) suggested the preservation of mushrooms by dehydration technique, although expensive due to the use of mechanical drier and high energy input etc. But it may be practicable because dehydrated mushrooms have longer storage life.

According to Suharban (1990), mushrooms can be dried in open sun during summer and is the efficient and cheap method. According to the author, mechanical dehydrators can also be used for drying mushrooms after which they have to be properly packed and stored in a cool dry place. It can also be ground into powder for use in making mushroom soup. By drying, usually the mushrooms are reduced to one tenth of its original weight.

Fresh mushrooms after picking, cleaning properly and slicing longitudinally can be dehydrated under hot air continuously for four to five hours at a temperature of 50°C to 55°C. The dried mushrooms are crisp and are packed in air-tight containers immediately to avoid resorption of moisture. Dried mushroom segments, especially the small pieces can also be powdered, mixed with powdered pepper and cloves and used in tasting soups and sauces (Khader, 1993).

# Material and Methods

# 3. MATERIALS AND METHODS

The present investigation on the extension of shelf-life of freshly harvested oyster mushrooms, was carried out at the department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala during 1997-1998. Vellanikkara enjoys a typical warm humid climate throughout the year.

Harvested fresh *Pleurotus* can remain acceptable only for a few hours, under ambient conditions. In the present study, an attempt has been made to develop a simple and cheap storage technique to extend the shelf-life of freshly harvested oyster mushrooms by controlling the physiological loss in weight, discolouration and decay; and also to improve the quality of dehydration in mushroom, which forms a long term storage technique.

The whole programme was divided into two major experiments.

3.1 Standardisation of the packaging technique and pretreatment methods to extend the shelf-life of fresh mushrooms both under ambient and refrigerated conditions

3.2 Quality improvement in dehydration and storage

## 3.1 Standardisation of the packaging technique and pretreatment methods to extend the shelf-life of fresh mushrooms both under ambient and refrigerated conditions

### 3.1.1 Source of mushrooms for the study

The experiment was carried out with oyster mushrooms of two speces (Plate 1).

a) *Pleurotus florida*

b) *Pleurotus sajor-caju*

Fresh samples of mushrooms were obtained from Mushroom Production Unit attached to the College of Horticulture, Vellanikkara (Plate 1).

### 3.1.2 Preparation of mushroom

Harvesting was done in the morning hours, before 10 am to minimise transpiration loss. They were taken to the laboratory for further treatments.

Mushrooms were sorted out for any insect spoilage, damage or discolouration; if observed, they were discarded. In each replication, 100 g samples were taken. Weight of mushrooms was taken on an electronic balance (OHAUS 200 portable standard) with 200 mg accuracy.

### 3.1.3 Treatments

The following were the treatments.

*$T_1$ Packaged in 100 gauge polypropylene (PP) bags with 0.4 per cent ventilation

**$T_2$ Packaged in 100 gauge PP bags with 0.1 per cent ventilation and with in-package fumigant (muslin cloth sachets containing 1.0% KMS + 0.3% citric acid on weight basis)

$T_3$ Packaged in PP bags without ventilation, but with in-package fumigant as above

$T_4$ Packaged in kraft paper bags without ventilation but with in-package fumigant

***$T_5$ Packaged in cartons (cake boxes) with in-package fumigant in filter paper sachets pasted in the inner side of the upper lid and 0.4 per cent ventilation but overwrapped with cling film

Plate 1a. Internal view of the mushroom unit

Plate 1b. *P. florida* and *P. sajor-caju* grown on paddy straw bed


Pleurotus florida
Pleurotus sajor-caju

$T_6$ Steeped in citric acid solution (0.5%) for 15 minutes, drained, air dried and packaged in 0.4 per cent ventilated PP bags

$T_7$ Packaged in PP bags of 100 gauge and air blown in

$T_8$ Packaged in 100 gauge PP bags without ventilation

$T_9$ Control - Unpackaged, open stored samples under ambient conditions

$T_{10}$ to $T_{17}$ All the above treatments were repeated, but stored under refrigerated temperature

$T_{18}$ to $T_{34}$ The above treatments given for *P. florida* were repeated sequentially for *P. sajor-caju*

* PP bags of size 30 x 25 cm with 21 holes of 3 mm radius to make 0.4 per cent ventilation

** PP bags of size 30 x 25 cm with 5 holes of 3 mm radius to make 0.1 per cent ventilation

*** Cake boxes having surface area of 950 $cm^2$, given 2 holes of size 1.9 x 1.0 $cm^2$, to give 0.4 per cent ventilation

The PP bags were heat sealed using a heat sealing machine (Quick seal TM of Sevane (India) Ltd.).

### 3.1.4 Layout

All the experiments were laid out in a Completely Randomised Design (CRD) with three replications each.

### 3.1.5 Observations

Observations on both physical and chemical changes during storage were taken at 12 hours interval as detailed below.

3.1.5.1 Physical observations

3.1.5.1.1 Physiological loss in weight (PLW)

The physiological loss in weight (PLW) was calculated on the initial weight basis as suggested by Srivastava and Tandon (1968) and expressed as percentage.

$$PLW\ \% = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

3.1.5.1.2 Decay percentage

The decay percentage was calculated as per the formula given by Bhatnagar *et al.* (1980).

$$\text{Per cent decay of mushroom} = \frac{\text{Weight of the mushrooms decayed in the pack}}{\text{Total weight of the mushrooms in the pack}} \times 100$$

3.1.5.1.3 Marketability

Marketability was calculated based on cumulative spoilage and PLW (Onwuzulu *et al.*, 1995).

Per cent marketable fruits = 100 - (% spoilage + PLW)

3.1.5.1.4 Termination of the observations

Observations were terminated when 50 per cent or more of the original sample was discarded as suggested by Kapitsmadi (1989).

3.1.5.2 Chemical analyses

Composite samples selected at random in respect of each treatment were drawn at an interval of 12 hours for the estimation of ascorbic acid, protein and residual $SO_2$.

The samples were washed and wiped dry with a clean muslin cloth, for chemical analyses. Analytical grade chemicals of standard companies were used for this purpose.

3.1.5.2.1 Ascorbic acid

Ascorbic acid content of the mushrooms during the storage period was determined by 2,6-dichlorophenol indophenol dye method as suggested by Ranganna (1986).

3.1.5.2.2 Protein

Protein content was analysed in dried samples. Nitrogen content was estimated by Microkjeldhal digestion and distillation as described by Jackson (1958), which was then multiplied with a factor of 6.25 to get the protein content.

3.1.5.2.3 Residual $SO_2$

Residual $SO_2$ was determined as per the method suggested by Ranganna (1986).

## 3.2 Quality improvement in dehydration and storage

This experiment was formulated with the objective of improving in the method of dehydration for better quality and storage.

### 3.2.1 Preparation of mushrooms for dehydration

Mushrooms were harvested before 10 am to minimise transpiration loss. They were sorted out for spoilage, insect damage or discolouration and such damaged materials were discarded. Mushrooms were separated from each other, and the stalk ends were trimmed and washed in clean water. The stalk portions, due to being thicker than cap were split into two. Samples of 200 g in each replication were taken for the study.

### 3.2.2 Pretreatments

The following were the pretreatments

$T_1SD_{PP}$ Blanched in boiling water for 3 to 4 minutes, sun-dried (SD) and packed in 100 gauge polypropylene (PP) bags

$T_1SD_{PE}$ Treatment same as above, but packed in 100 gauge polyethylene (PE) bags

$T_1MD_{PP}$ Blanched in boiling water for 3 to 4 minutes, mechanically dried (MD) and packed in PP bags

$T_1MD_{PE}$ Treatment same as above, but packed in PE bags

$T_1MW_{PP}$ Blanched in boiling water for 3 to 4 minutes, microwave oven dried (MW) and packed in PP bags

$T_1MW_{PE}$ Treatment same as above, but packed in PE bags

$T_2SD_{PP}$ Blanched in boiling water containing 0.3 per cent citric acid for 3 to 4 minutes, SD and packed in PP bags

$T_2SD_{PE}$ Treatment same as above, but packed in PE bags

$T_2MD_{PP}$ Blanched in boiling water containing 0.3 per cent citric acid for 3 to 4 minutes, MD and packed in PP bags

$T_2MD_{PE}$ Treaement same as above, but packed in PE bags

$T_2MW_{PP}$ Blanched in boiling water containing 0.3 per cent citric acid for 3 to 4 minutes, MW and packed in PP bags

$T_2MW_{PE}$ Treatment same as above, but packed in PE bags

$T_3SD_{PP}$ Blanched in boiling water containing 2.0 per cent salt + 0.3 per cent citric acid solution for 3 to 4 minutes, steeped in KMS solution (1500 ppm $SO_2$) + 0.1 per cent citric acid for 30 minutes, SD and packed in PP bags

$T_3SD_{PE}$ Treatment same as above, but packed in PE bags

$T_3MD_{PP}$ Pretreatment same as $T_3SD_{PP}$, but MD and packed in PP bags

$T_3MD_{PE}$ Pretreatment same as above, but packed in PE bags

$T_3MW_{PP}$ Pretreatment same as $T_3SD_{PP}$, but MW and packed in PP bags

$T_3MW_{PE}$ Treatment same as above, but packed in PE bags

$T_4SD_{PP}$ Sun-dried without any pretreatment, packed in PP bags

$T_4SD_{PE}$ Treatment same as above, but packed in PE bags

$T_4MD_{PP}$ Mechanically dried without any pretreatment but packed in PP bags

$T_4MD_{PE}$ Treatment same as above, but packed in PE bags

$T_4MW_{PP}$ Microwave oven dried without any pretreatment, but packed in PP bags

$T_4MW_{PE}$ Treatment same as above, but packed in PE bags

All the above treatments were repeated sequentially with *P. sajor-caju.*

The PE or PP bags were heat sealed in the same way as that of fresh sample storage.

### 3.2.3 Layout

The experiment was laid out in a Completely Randomised Design (CRD) with 3 replications each.

### 3.2.4 Drying methods

#### 3.2.4.1 Sun-drying (SD)

Freshly harvested mushrooms, *P. florida* and *P. sajor-caju* having 92.4 per cent and 89.8 per cent moisture respectively were washed, trimmed to remove damaged portions and subsequently were given various pretreatments. Pretreated samples were sun-dried to a moisture content of five to six per cent by spreading on aluminium trays. It took about 14 hours to complete the drying in pretreated samples and only 12 hours for those samples dried without any pretreatment.

#### 3.2.4.2 Mechanical drying (MD)

A cabinet dryer with inner dimensions as 0.9 x 1 x 0.61 m with 2.5 KW heating capacity was used. Two stage dehydration was given to the samples. Temperature was maintained at 60°C for the first 4 hours and later at 50°C for the rest of the period of drying upto a final moisture content of five to six per cent. It took about 11 hours to complete drying in pretreated samples whereas for the samples without any pretreatment, it was only eight hours.

#### 3.2.4.3 Microwave oven drying (MW)

Microwave oven used for drying was T-23 Touch Electronic model manufactured by M/s.Kelvinator (India). The size of oven was 394 x 279 x 213 mm (inner dimensions) and 578 x 305 x 308 mm (outer dimensions) with 23 litre

capacity. The power output was 700 watts with microwave frequency of 2450 Hz. The non-ionising electromagnetic waves, when bombard the food, are absorbed and penetrate to a depth of 2 to 4 cm; thus they excite the molecules in the food and causes the molecules to vibrate 2,450 million times per second which causes friction and produce heat.

Three stage drying was given to the samples. Initial power level selected as 100 per cent for a period of 20 minutes followed by 60 per cent for another 20 minutes and 20 per cent for the rest of the period of drying. The time taken to complete drying was 90±10 minutes for pretreated samples and 70±10 minutes for the samples without in pretreatment to reach a moisture level upto five to six per cent.

3.2.5 Observations

3.2.5.1 Physical observations

3.2.5.1.1 Dehydration ratio

The dehydration ratio was calculated as per the formula given by Pruthi *et al.* (1978).

$$\text{Dehydration ratio} = \frac{\text{Weight of mushroom taken for dehydration}}{\text{Weight of the dried mushrooms}}$$

3.2.5.1.2 Drying rate and dehydration parameters

Drying rate was found out using the method described by Narasimham and John (1995). Mushrooms which were put for dehydration were taken at different intervals and their weight as percentage to original weight was found out.

The temperature ranged from 21.6°C to 35.7°C during the period of SD. The density of spread of mushrooms in MD was 6 kg/m$^2$.

3.2.5.1.3 Shrinkage rate

For the determination of volume shrinkage, dimensions of random samples were measured, using vernier callipers before and after dehydration. Shrinkage was calculated (Ocansey, 1984) as below:

$$\text{Per cent volume shrinkage} = \frac{\text{(Initial volume) - (Final volume obtained after dehydration)}}{\text{Initial volume}} \times 100$$

Per cent volume shrinkage was measured at regular intervals during drying to find out the shrinkage rate.

3.2.5.1.4 Shrinkage ratio

The shrinkage ratio was determined as per the formula given by Ocansey (1984) as below:

$$\text{Shrinkage ratio} = \frac{\text{Final volume obtained after dehydration}}{\text{Initial volume}}$$

3.2.5.1.5 Reconstitution rate

Weighed samples of dried mushrooms were reconstituted with hot water and at regular intervals, the weight pick up was assessed using electronic balance.

3.2.5.1.6 Reconstitution ratio

Reconstitution ratio was calculated using the formula given by Pruthi *et al.* (1978).

$$\text{Reconstitution ratio} = \frac{\text{Weight of sample after maximum reconstitution}}{\text{Weight of the original dried sample}}$$

3.2.5.1.7 Residual moisture

Moisture content was found out by drying the samples in hot air oven at 70±2°C till the samples attained constant weight. The moisture content was expressed in percentage (Ranganna, 1986).

3.2.5.1.8 Extent of discolouration due to drying

Colour changes due to various pretreatments were assessed visually and classified into 4 categories, that is, creamy white, creamy yellow, light brown and brown.

3.2.5.2 Chemical analyses

All the chemical analyses given under 3.1.5.2 were carried out here also.

## 3.3 Sensory evaluation

Sensory evaluation was carried out with the help of a trained panel consisting of 15 members who were asked to evaluate the samples for its overall

appearance, colour, flavour and texture in comparison with freshly harvested mushrooms on a 10 point hedonic scale. The ratings were as follows:

| | |
|---|---|
| 0-2 | Poor |
| 3-5 | Satisfactory |
| 6-8 | Good |
| 9-10 | Excellent |

## 3.4 Tabulation and statistical analyses

Observations under each experiment were tabulated and analysed statistically in a Completely Randomised Design (CRD) or factorial CRD, wherever appropriate as proposed by Panse and Sukhatme (1976). The treatments were ranked according to Duncan's Multiple Range Test and scores of organoleptic evaluation were analysed by Kruskal-Wallis one-way analysis of variance (Siegel, 1956).

# Results

# 4. RESULTS

The results of the studies conducted in the Department of Processing Technology, College of Horticulture, Vellanikkara during 1997-98 to extend the shelf-life of mushrooms under ambient and refrigerated conditions and to improve the quality of dehydration in oyster mushrooms, viz., *Pleurotus florida* and *Pleurotus sajor-caju* are presented in this chapter.

## 4.1 Standardisation of the packaging technique and pretreatment methods to extend the shelf-life of fresh mushrooms both under ambient and refrigerated conditions

The effect of different packaging techniques and pretreatment methods on the shelf-life of fresh mushrooms viz., *P. florida* and *P. sajor-caju* under ambient and refrigerated conditions were evaluated. The results are tabulated and presented in Tables 1a to 4a and 1b to 4b respectively for *P. florida* and *P. sajor-caju.*

### 4.1.1 Physiological loss in weight (PLW), decay percentage and marketability of fresh mushroom

Changes in PLW, decay percentage and marketability of fresh mushrooms of *P. florida* and *P. sajor-caju* recorded at 12 hours interval are presented in Tables 1a, 1b, 2a and 2b.

#### 4.1.1.1 Physiological loss in weight (PLW)

Mushrooms (*P. florida*) packaged in PP without ventilation after 12 hours of storage ($T_8$) recorded the lowest PLW (0.35%) and was in comparison to those packaged in PP with air blown in (0.40%) ($T_7$). Similar trend continued till 36 hours

Table 1a. PLW, decay percentage and marketability of fresh mushroom *P. florida*, under different ambient storage techniques

| Treatments | | PLW (%) | | | Decay (%) | | | Marketability (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 12 | 24 | 36 | 12 | 24 | 36 (hours) | 12 | 24 | 36 |
| $T_1$ | PP 0.4% vent | $5.96^{c}$ | $16.85^{a}$ | - | 0 | 0 | - | $94.04^{ab}$ | $83.15^{b}$ | - |
| $T_2$ | PP 0.1% vent + fumigant | $1.74^{d}$ | $8.68^{c}$ | - | 0 | 17.06 | - | $98.26^{ab}$ | $74.26^{c}$ | - |
| $T_3$ | PP no vent + fumigant | $1.06^{d}$ | - | - | 57.12 | - | - | $41.82^{e}$ | - | - |
| $T_4$ | Kraft paper bags + fumigant | $24.54^{b}$ | - | - | 0 | - | - | $75.46^{c}$ | - | - |
| $T_5$ | Cake box 0.4% vent + cling film + fumigant | $6.74^{c}$ | $16.14^{b}$ | - | 0 | 0 | - | $93.26^{b}$ | $83.86^{d}$ | - |
| $T_6$ | Citric acid treated mushroom in PP 0.4% vent | $1.94^{d}$ | $8.52^{d}$ | - | 0 | 65.73 | - | $98.06^{ab}$ | $25.75^{d}$ | - |
| $T_7$ | Air blown PP | $0.40^{d}$ | $0.41^{e}$ | 1.40 | 0 | 0 | 0 | $99.60^{a}$ | $99.59^{a}$ | 98.6 |
| $T_8$ | No vent PP | $0.35^{d}$ | $0.35^{f}$ | 0.80 | 0 | 0 | 0 | $99.65^{a}$ | $99.65^{a}$ | 99.2 |
| $T_9$ | Control | $47.19^{a}$ | - | - | - | - | - | $54.48^{d}$ | - | - |

The values represent means of 3 replications
The values having different superscripts differ significantly at 5% level
- Denote the treatments terminated due to decay or drying

Table 1b. PLW, decay percentage and marketability of fresh mushroom *P. sajor-caju*, under different ambient storage techniques

| Treatments | | PLW (%) | | | Decay (%) | | | Marketability (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 12 | 24 | 36 | 12 | 24 | 36 (hours) | 12 | 24 | 36 |
| $T_{18}$ | PP 0.4% vent | $4.95^{d}$ | $9.97^{b}$ | - | 0 | 6.76 | - | $95.05^{b}$ | $87.90^{b}$ | - |
| $T_{19}$ | PP 0.1% vent + fumigant | $1.12^{e}$ | $7.16^{c}$ | - | 0 | 21.53 | - | $98.88^{a}$ | $71.30^{c}$ | - |
| $T_{20}$ | PP no vent + fumigant | $1.09^{e}$ | - | - | 56.2 | - | - | $42.68^{f}$ | - | - |
| $T_{21}$ | Kraft paper bags + fumigant | $20.57^{b}$ | - | - | 0 | - | - | $79.43^{d}$ | - | - |
| $T_{22}$ | Cake box 0.4% vent + cling film + fumigant | $6.77^{c}$ | $14.41^{a}$ | - | 0 | - | - | $93.23^{c}$ | $85.59^{b}$ | - |
| $T_{23}$ | Citric acid treated mushroom in PP 0.4% vent | $1.02^{e}$ | $6.92^{c}$ | - | 0 | 58.36 | - | $98.98^{a}$ | $34.71^{d}$ | - |
| $T_{24}$ | Air blown PP | $0.35^{e}$ | $0.84^{d}$ | 1.23 | 0 | 0 | 0 | $99.65^{a}$ | $99.16^{a}$ | 98.76 |
| $T_{25}$ | No vent PP | $0.33^{e}$ | $0.55^{d}$ | 0.68 | 0 | 0 | 0 | $99.67^{a}$ | $99.44^{a}$ | 99.32 |
| $T_{26}$ | Control | $39.39^{a}$ | - | - | - | - | - | - | - | - |

The values represent means of 3 replications
The values having different superscripts differ significantly at 5% level
- Denote the treatments terminated due to decay or drying

of storage with a final PLW of 0.8 and 1.4 per cent respectively, whereas control samples recorded 47.19 per cent PLW, even at 12 hours of storage (Table 1a).

Under low temperature (4±1°C) also, the same packages showed the similar trend with minimum of PLW (3.49%) in PP without ventilation ($T_{17}$) and PP with air blown ($T_{16}$) (4.40%) both comparable after 10 days of storage and the maximum was in those packaged with 0.4 per cent ventilation (23.51%) ($T_{10}$) and remained only for seven days (Table 2a).

In the case of *P. sajor-caju*, the results are same as above, but with slight changes in the respective values (Table 1b and 2b).

4.1.1.2 Decay percentage

Under ambient conditions, *P. florida* packaged in PP without ventilation ($T_8$) and those packaged in PP with air blown ($T_7$) showed no decay even after 36 hours of storage (Plate 2 and 3), whereas all other treatments showed varying levels of decay with maximum in those packaged in PP without ventilation, but with in-package fumigant which decayed completely within 12 hours of storage followed with those packaged in PP with 0.1 per cent ventilation and in-package fumigant, both decayed completely by 24 hours of storage (Table 1a). Samples packaged in kraft paper bags ($T_4$) and those in cake box ($T_5$) however did not decay but dried after 24 hours of storage.

Under low temperature (4±1°C) also all treatments showed varying levels of decay with maximum in those packaged in PP without ventilation but with in-package fumigant ($T_{12}$) and those in PP having 0.1 per cent ventilation + in-package fumigant ($T_{11}$); retained only for a day and the minimum decay (5.0% and 6.7%

Plate 2a. *P. florida* packaged with PP with no ventilation (2) in comparison to control (1)

Plate 2b. *P. florida* withdrawn from PP package with no ventilation after 36 hours of storage at ambient temperature (2) in comparison to control (1)


1
2


1
2

Table 2a. PLW, decay percentage and marketability of fresh mushroom *P. florida*, stored with different storage techniques under refrigeration (4±1°C)

| Treatment | | PLW (%) | | | | Decay (%) | | | | Marketability (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 7 | 10 | 1 | 2 (days) | 7 | 10 | 1 | 2 | 7 | 10 |
| $T_{10}$ | PP 0.4% vent | $6.75^{c}$ | $6.76^{a}$ | $23.51^{a}$ | - | 0 | 0 | 0 | - | $93.25^{c}$ | $93.24^{d}$ | 76.49 | - |
| $T_{11}$ | PP 0.1% vent + fumigant | $5.36^{d}$ | - | - | - | 7.44 | 96.24 | - | - | $87.20^{c}$ | - | - | - |
| $T_{12}$ | PP no vent + fumigant | $4.92^{e}$ | - | - | - | 64.41 | - | - | - | $30.67^{g}$ | - | - | - |
| $T_{13}$ | Kraft paper bags + fumigant | $33.42^{a}$ | - | - | - | 0 | - | - | - | $66.58^{f}$ | - | - | - |
| $T_{14}$ | Cake box 0.4% vent + cling film + fumigant | $9.22^{b}$ | - | - | - | 0 | - | - | - | $90.78^{d}$ | - | - | - |
| $T_{15}$ | Citric acid treated mushroom in PP 0.4% vent | $2.53^{f}$ | $5.11^{b}$ | - | - | 0 | 0 | - | - | $97.47^{b}$ | $94.89^{c}$ | - | - |
| $T_{16}$ | Air blown PP | $0.00^{g}$ | $0.71^{c}$ | $3.06^{b}$ | 4.40 | 0 | 0 | 0 | 6.7 | $100.00^{a}$ | $99.29^{b}$ | 96.94 | 88.87 |
| $T_{17}$ | No vent PP | $0.00^{g}$ | $0.00^{d}$ | $2.68^{c}$ | 3.49 | 0 | 0 | 0 | 5.0 | $100.00^{a}$ | $100.00^{a}$ | 97.32 | 90.21 |

The values represent means of 3 replications
The values having different superscripts differ significantly at 5% level
- Denote the treatments terminated due to decay or drying

Plate 3a. *P. florida* packaged in PP with air blown in (1a) and PP with 0.4% ventilation (2a)

Plate 3b. *P. sajor-caju* packaged in PP with no ventilation along with the withdrawn samples (4) in comparison to the control samples (3) after 36 hours of storage


1a
2a


3
4

Table 2b. PLW, decay percentage and marketability of fresh mushroom *P. sajor-caju*, stored with different storage techniques under refrigeration (4±1°C)

| Treatment | | PLW (%) | | | | Decay (%) | | | | Marketability (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 7 | 10 | 1 | 2 (days) | 7 | 10 | 1 | 2 | 7 | 10 |
| $T_{27}$ | PP 0.4% vent | $5.13^{c}$ | $8.54^{a}$ | $18.67^{a}$ | - | 0 | 0 | 0 | - | $94.90^{c}$ | $94.61^{b}$ | $81.33^{b}$ | - |
| $T_{28}$ | PP 0.1% vent + fumigant | $4.90^{c}$ | - | - | - | 6.06 | - | - | - | $89.10^{e}$ | - | - | - |
| $T_{29}$ | PP no vent + fumigant | $4.86^{c}$ | - | - | - | 57.98 | - | - | - | $37.15^{g}$ | - | - | - |
| $T_{30}$ | Kraft paper bags + fumigant | $29.21^{a}$ | - | - | - | 0 | - | - | - | $70.79^{f}$ | - | - | - |
| $T_{32}$ | Cake box 0.4% vent + cling film + fumigant | $8.48^{b}$ | - | - | - | 0 | - | - | - | $91.52^{d}$ | - | - | - |
| $T_{33}$ | Citric acid treated mushroom in PP 0.4% vent | $1.81^{d}$ | $0.53^{b}$ | - | - | 0 | - | - | - | $98.19^{b}$ | $0.00^{c}$ | - | - |
| $T_{34}$ | Air blown PP | $0.12^{e}$ | $0.24^{c}$ | $2.71^{b}$ | 3.60 | 0 | 0 | 0 | 0 | $99.88^{a}$ | $99.76^{a}$ | $97.29^{a}$ | 87.60 |
| $T_{35}$ | No vent PP | $0.00^{e}$ | $0^{c}$ | $2.56^{b}$ | 3.20 | 0 | 0 | 0 | 0 | $100.00^{a}$ | $100.00^{a}$ | $97.44^{a}$ | 91.73 |

The values represent means of 3 replications
The values having different superscripts differ significantly at 5% level
- Denote the treatments terminated due to decay or drying

respectively) was observed in those samples packaged in PP without ventilation and PP with air blown in and they remained for 10 days (Table 2a) (Plate 4).

The results are similar with respect to treatments in *P. sajor-caju* but with slight difference in values (Tables 1b and 2b).

4.1.1.3 Marketability

Percentage marketability was recorded maximum in those packaged in PP without ventilation and those in PP with air blown in (99.2 and 98.6% respectively) even after 36 hours of storage whereas all other treatments failed to have marketability at 36 hours (Table 1a).

Under the low temperature also, the same treatments showed maximum marketability (90.21% and 88.87% respectively) even after 10 days of storage; all other treatments except $T_{10}$ (PP + 0.4% ventilation) lost their marketability within one or two days of storage, but $T_{10}$ retained marketability (76.49%) till seven days (Table 2a).

Similar results were obtained for *P. sajor-caju* also under both ambient and refrigerated storage, but with values different (Tables 1b and 2b).

4.1.2 Ascorbic acid, protein and residual $SO_2$ of fresh mushrooms

Changes in ascorbic acid, protein and residual $SO_2$ content of fresh mushrooms of *P. florida* and *P. sajor-caju* recorded at 12 hours interval are presented in Tables 3a, 3b, 4a and 4b.

Plate 4. *P. florida* refrigerated for 10 days at 4±1°C, when packaged in PP with no ventilation

Table 3a. Ascorbic acid and protein content of fresh mushroom *P. florida*, under different ambient storage techniques

| Treatment | | Ascorbid acid (mg/100 g) (Fresh weight basis) | | | Protein (%) (Dry weight basis) | | |
|---|---|---|---|---|---|---|---|
| | | 12 | 24 | 36 | 12 (hours) | 24 | 36 |
| $T_1$ | PP 0.4% vent | $3.80^{b}$ | $3.77^{b}$ | - | 25.58 | 25.53 | - |
| $T_2$ | PP 0.1% vent + fumigant | $3.85^{ab}$ | $3.80^{ab}$ | - | 25.57 | 25.55 | - |
| $T_3$ | PP no vent + fumigant | $3.00^{c}$ | - | - | 25.56 | - | - |
| $T_4$ | Kraft paper bags + fumigant | $2.85^{f}$ | - | - | 25.57 | - | - |
| $T_5$ | Cake box 0.4% vent + cling film + fumigant | $3.40^{d}$ | $2.69^{d}$ | - | 25.53 | 25.50 | - |
| $T_6$ | Citric acid treated mushroom in PP 0.4% vent | $3.60^{c}$ | $3.05^{c}$ | - | 25.56 | 25.54 | - |
| $T_7$ | Air blown PP | $3.86^{ab}$ | $3.81^{ab}$ | 3.73 | 25.58 | 25.57 | 25.52 |
| $T_8$ | No vent PP | $3.90^{a}$ | $3.84^{a}$ | 3.75 | 25.57 | 25.52 | 25.51 |
| $T_9$ | Control | $2.83^{f}$ | - | - | 25.57 | - | - |

(Fresh mushroom ascorbic acid 4.0 mg/100 g, protein 25.60%)
The values represent means of 3 replications
The values having different superscripts differ significantly at 5% level
- Denote the treatments terminated due to decay or drying

Table 3b. Ascorbic acid and protein content of fresh mushroom *P. sojar-caju*, under different ambient storage techniques

| Treatment | | Ascorbid acid (mg/100 g) (Fresh weight basis) | | | Protein (%) (Dry weight basis) | | |
|---|---|---|---|---|---|---|---|
| | | 12 | 24 | 36 | 12 (hours) | 24 | 36 |
| $T_{18}$ | PP 0.4% vent | $4.10^{b}$ | $3.77^{c}$ | - | 35.43 | 35.40 | - |
| $T_{19}$ | PP 0.1% vent + fumigant | $4.00^{b}$ | $3.42^{d}$ | - | 35.43 | 35.39 | - |
| $T_{20}$ | PP no vent + fumigant | $3.89^{c}$ | - | - | 35.41 | - | - |
| $T_{21}$ | Kraft paper bags + fumigant | $3.87^{c}$ | - | - | 35.42 | - | - |
| $T_{22}$ | Cake box 0.4% vent + cling film + fumigant | $3.83^{c}$ | $3.44^{d}$ | - | 35.41 | 35.38 | - |
| $T_{23}$ | Citric acid treated mushroom in PP 0.4% vent | $3.85^{c}$ | $3.77^{c}$ | - | 35.40 | 35.39 | - |
| $T_{24}$ | Air blown PP | $4.41^{a}$ | $4.17^{b}$ | 4.06 | 35.42 | 35.43 | 35.40 |
| $T_{25}$ | No vent PP | $4.43^{a}$ | $4.31^{a}$ | 4.12 | 35.41 | 35.40 | 35.38 |
| $T_{26}$ | Control | $2.86^{d}$ | - | - | 35.42 | - | - |

(Fresh mushroom ascorbic acid 4.66 mg/100 g, protein 35.44%)
The values represent means of 3 replications
The values having different superscripts differ significantly at 5% level
- Denote the treatments terminated due to decay or drying

4.1.2.1 Ascorbic acid

The trend in the ascorbic acid content shows a gradual reduction with the advancement of storage time irrespective of treatments. But the rate of reduction varied with treatments, with maximum reduction observed in control ($T_9$) (2.83 mg/100 g) after 12 hours storage, with minimum loss observed in samples packaged in PP without ventilation ($T_8$) (3.75 mg/100 g) and in samples in PP with air blown in ($T_7$) (3.73 mg/100 g) after 36 hours of storage (Table 3a).

Under low temperature also, samples packaged in PP without ventilation ($T_{17}$) and PP with air blown ($T_{16}$) in retained maximum ascorbic acid even after 10 days of storage (3.61 mg/100 g and 3.52 mg/100 g respectively); and samples packaged in cake box with in-package fumigant though remained only for a day, the ascorbic acid content was reduced to 3.30 mg/100 g from 4.0 mg/100 g (Table 4a).

In the case of *P. sajor-caju* also, the trends were similar with least reduction in samples packaged in PP without ventilation and PP with air blown in (4.12 mg/100 g and 4.06 mg/100 g respectively) after 36 hours of storage and maximum reduction in control at ambient (2.86 mg/100 g) which remained only for 12 hours. Under low temperature also, the same treatments retained maximum ascorbic acid even after 10 days of storage (Tables 3b and 4b).

4.1.2.2 Protein

For both *P. florida* and *P. sajor-caju* under ambient or refrigerated storage, protein content did not differ significantly with respect to time of storage or treatments (Tables 3a, 3b, 4a and 4b).

Table 4a. Ascorbic acid and protein content of fresh mushroom *P. florida*, stored with different storage techniques under refrigeration (4±1°C)

| Treatment | | Ascorbid acid (mg/100 g) (Fresh weight basis) | | | | Protein (%) (Dry weight basis) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 7 | 10 | 1 (days) | 2 | 7 | 10 |
| $T_{10}$ | PP 0.4% vent | 3.90[a] | 3.82[b] | 3.30 | - | 25.57 | 25.53 | 25.52 | - |
| $T_{11}$ | PP 0.1% vent + fumigant | 3.90[a] | - | - | - | 25.58 | - | - | - |
| $T_{12}$ | PP no vent + fumigant | 3.90[a] | - | - | - | 25.55 | - | - | - |
| $T_{13}$ | Kraft paper bags + fumigant | 3.50[b] | - | - | - | 25.53 | - | - | - |
| $T_{14}$ | Cake box 0.4% vent + cling film + fumigant | 3.30[c] | - | - | - | 25.55 | - | - | - |
| $T_{15}$ | Citric acid treated mushroom in PP 0.4% vent | 3.51[b] | 3.41[c] | - | - | 25.53 | 25.52 | - | - |
| $T_{16}$ | Air blown PP | 3.90[a] | 3.83[b] | 3.71 | 3.52 | 25.56 | 25.55 | 25.51 | 25.50 |
| $T_{17}$ | No vent PP | 3.98[a] | 3.90[a] | 3.71 | 3.61 | 25.58 | 25.56 | 25.55 | 25.51 |

(Fresh mushroom ascorbic acid 4.0 mg/100 g, protein 25.60%)
The values represent means of 3 replications
The values having different superscripts differ significantly at 5% level
- Denote the treatments terminated due to decay or drying

Table 4b. Ascorbic acid and protein content of fresh mushroom *P. sajor-caju*, stored with different storage techniques under refrigeration (4±1°C)

| Treatment | | Ascorbid acid (mg/100 g) (Fresh weight basis) | | | | Protein (%) (Dry weight basis) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 7 | 10 | 1 (days) | 2 | 7 | 10 |
| $T_{27}$ | PP 0.4% vent | $4.52^{ab}$ | $4.16^{bc}$ | $3.79^{c}$ | 3.95 | 35.43 | 35.41 | 35.39 | - |
| $T_{28}$ | PP 0.1% vent + fumigant | $4.49^{ab}$ | - | - | - | 35.44 | - | - | - |
| $T_{29}$ | PP no vent + fumigant | $4.46^{b}$ | - | - | - | 35.42 | - | - | - |
| $T_{30}$ | Kraft paper bags + fumigant | $4.12^{d}$ | - | - | - | 35.41 | - | - | - |
| $T_{32}$ | Cake box 0.4% vent + cling film + fumigant | $4.24^{c}$ | - | - | - | 35.41 | - | - | - |
| $T_{33}$ | Citric acid treated mushroom in PP 0.4% vent | $4.23^{c}$ | $4.11^{c}$ | - | - | 35.42 | 35.40 | - | - |
| $T_{34}$ | Air blown PP. | $4.56^{a}$ | $4.21^{b}$ | $3.95^{b}$ | 3.84 | 35.43 | 35.41 | 35.41 | 35.39 |
| $T_{35}$ | No vent PP | $4.57^{a}$ | $4.38^{a}$ | $3.99^{a}$ | 3.88 | 35.42 | 35.40 | 35.39 | 35.37 |

(Fresh mushroom ascorbic acid 4.66 mg/100 g, protein 35.44%)
The values represent means of 3 replications
The values having different superscripts differ significantly at 5% level
- Denote the treatments terminated due to decay or drying

Table 5. Organoleptic evaluation of mushroom samples

| Treatments | *P. florida* | | | | Treatments | *P. sajor-caju* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Colour | Flavour | Texture | Overall appearance | | Colour | Flavour | Texture | Overall appearance |
| $T_7$ Air blown PP | $7.80^b$ | $8.20^a$ | $8.07^a$ | $7.70^b$ | $T_{24}$ Air blown PP | $7.30^b$ | $8.13^a$ | $7.53^a$ | $6.73^b$ |
| $T_8$ No vent PP | $8.20^a$ | $8.13^a$ | $8.07^a$ | $8.13^a$ | $T_{25}$ No vent PP | $7.60^a$ | $8.20^a$ | $7.33^a$ | $7.27^a$ |
| Fresh | $8.07^a$ | $8.07^a$ | $8.13^a$ | $8.07^a$ | Fresh | $7.53^a$ | $8.33^a$ | $7.40^a$ | $8.00^a$ |

The values represent means of 15 replications
The values with different superscripts differ significantly at 5% level

4.1.2.3 Residual $SO_2$

Residual $SO_2$ could not be detected in all the samples stored with KMS as an in-package fumigant after washing and cooking the stored pieces in boiling water for 5 minutes.

4.1.3 Sensory evaluation

Fresh mushrooms stored in PP without ventilation and PP with air blown in, remained for 36 hours under ambient conditions without any deterioration, therefore sensory evaluation of these samples were conducted. These samples after cooking in boiling water for 5 minutes with 0.5 per cent salt were compared with freshly harvested mushrooms cooked in the same way to ascertain the quality and the results are given in Table 5.

Results showed that no significant difference could be established by the panelists on quality attributes like colour, flavour, texture and overall appearance in *P. florida* between the samples stored for 36 hours in PP without ventilation and that of fresh samples; but samples stored in PP with air blown in, was comparable with fresh samples only in terms of flavour and texture whereas colour and appearance was rated significantly inferior to fresh samples (5% level). In *P. sajor-caju* also, all the quality attributes were comparable to that of fresh samples when stored in PP without ventilation, but samples in PP with air blown in showed the same results as that of *P. florida* (Table 5).

## 4.2 Quality improvement in dehydration and storage

Combinations of different drying methods and different pretreatments were tried for the quality improvement in dehydration for better colour retention,

lesser shrinkage, faster reconstitution and for better storage in the case of *P. florida* and *P. sajor-caju*. The results are tabulated and presented in Tables 6 to 13 and Figures 1a to 6a and 1b to 6b.

### 4.2.1 Dehydration ratio, shrinkage ratio, reconstitution ratio and extent of discolouration due to drying

The effect of different combinations of drying methods and pretreatments on the dehydration ratio, shrinkage ratio and reconstitution ratio for the varieties *P. florida* and *P. sajor-caju* are presented in Table 6.

#### 4.2.1.1 Dehydration ratio

Significant difference in the dehydration ratio (DR) was observed both between pretreatments and between methods of drying ($P < 0.05$) with microwave oven drying being the best when compared to other methods of drying viz. mechanical and sun-drying in the respective order. Dehydration ratio when compared between various pretreatments prior to drying, $T_3$ (KMS + citric acid + salt combination) showed the best pretreatment which was significantly different to all other pretreatments ($P < 0.05$). While comparing the combinations of pretreatments and methods of drying, $T_3$ MW was found to be the best method of drying (DR, 7.96) (Table 6).

Similar results were obtained in the case of *P. sajor-caju* also (Table 6).

#### 4.2.1.2 Shrinkage ratio

Higher the shrinkage ratio, better is the dehydrated product. Shrinkage ratio was maximum (0.236) in the samples dried in microwave after pretreating

with KMS + citric acid + salt ($T_3$MW) and the lowest value was noted (0.182) in the samples dried under sun without any pretreatment ($T_4$SD). Between the methods of drying no significant difference in the shrinkage ratio was observed between microwave oven and mechanical drying ($P < 0.05$); however, they differed significantly with sun-drying (Table 6).

Similar to *P. florida*, maximum shrinkage ratio was obtained in $T_3$MW for *P. sajor-caju* also (0.203), but when methods of drying was compared, no significant difference was observed between mechanical and sun-drying ($P < 0.05$), but both significantly differed with microwave oven drying (Table 6).

4.2.1.3 Reconstitution ratio

Comparing the reconstitution ratio of *P. florida* between the methods of drying and types of pretreatments, microwave oven drying ($T_4$MW) without any pretreatment recorded the highest ratio (4.09) which was significantly different from all other treatments ($P < 0.05$) except $T_4$MD, that is, mechanical drying without any pretreatment (3.99) which was on par with $T_4$MW. Among the rest of the treatments, $T_4$SD (sun-drying without any pretreatment) was significantly different from others (2.48) (Table 6). Irrespective of the methods of drying, all the samples without any pretreatment showed higher values compared with pretreated samples.

Reconstitution ratio in *P. sajor-caju* also followed the similar pattern as that of *P. florida* but $T_4$MW in *P. sajor-caju* showed significant difference with that of $T_4$MD (3.17 and 2.92 respectively) ($P < 0.05$), except this, all other results were similar (Table 6).

Table 6. Dehydration ratio, shrinkage ratio, reconstitution ratio and extent of discolouration due to drying of mushroom *P. florida* and *P. sajor-caju* dried under different techniques

| Treatment | *P. florida* | | | | *P. sajor-caju* | | | |
|---|---|---|---|---|---|---|---|---|
| | Dehydration ratio | Shrinkage ratio | Reconstitution ratio | Extent of discolo-ation due to drying | Dehydration ratio | Shrinkage ratio | Reconstitution ratio | Extent of discolo-ration due to drying |
| $T_1SD$ | $10.99^{a}$ | $0.197^{cde}$ | $2.10^{f}$ | B | $11.25^{ab}$ | $0.161^{cde}$ | $1.65^{j}$ | B |
| $T_2SD$ | $10.75^{d}$ | $0.186^{de}$ | $2.10^{f}$ | B | $11.24^{b}$ | $0.161^{cde}$ | $1.65^{j}$ | B |
| $T_3SD$ | $9.97^{g}$ | $0.201^{cd}$ | $2.16^{ef}$ | LB | $10.61^{d}$ | $0.178^{bc}$ | $1.80^{f}$ | LB |
| $T_4SD$ | $10.83^{c}$ | $0.182^{e}$ | $2.48^{b}$ | CW | $11.26^{a}$ | $0.149^{e}$ | $2.82^{c}$ | CW |
| $T_1MD$ | $10.92^{b}$ | $0.206^{bc}$ | $2.18^{ef}$ | B | $10.97^{c}$ | $0.171^{bcd}$ | $1.69^{i}$ | B |
| $T_2MD$ | $9.62^{h}$ | $0.184^{de}$ | $2.02^{f}$ | B | $9.83^{f}$ | $0.171^{bcd}$ | $1.71^{h}$ | B |
| $T_3MD$ | $8.25^{j}$ | $0.212^{bc}$ | $2.26^{de}$ | CY | $9.53^{j}$ | $0.186^{ab}$ | $1.87^{e}$ | CY |
| $T_4MD$ | $10.79^{cd}$ | $0.197^{cde}$ | $3.99^{a}$ | CW | $10.15^{e}$ | $0.155^{de}$ | $2.92^{b}$ | CW |
| $T_1MW$ | $10.29^{e}$ | $0.221^{ab}$ | $2.36^{d}$ | B | $9.72^{h}$ | $0.188^{ab}$ | $1.73^{g}$ | B |
| $T_2MW$ | $9.53^{i}$ | $0.197^{cde}$ | $2.37^{d}$ | B | $9.67^{i}$ | $0.185^{ab}$ | $1.74^{g}$ | B |
| $T_3MW$ | $7.96^{k}$ | $0.236^{a}$ | $2.63^{c}$ | CY | $9.47^{k}$ | $0.203^{a}$ | $1.97^{d}$ | CY |
| $T_4MW$ | $10.20^{f}$ | $0.197^{cde}$ | $4.09^{a}$ | CW | $9.80^{g}$ | $0.158^{de}$ | $3.17^{a}$ | CW |

The values represent means of 3 replications
The values with different superscripts differ significantly at 5% level
B - Brown; LB - Light brown; CY - Creamy yellow; CW - Creamy white

4.2.1.4 Extent of discolouration due to drying

The samples dried after water blanching ($T_1$) and blanching in citric acid solution ($T_2$) turned brown, after drying. The samples mechanically dried and microwave oven dried after treatment $T_3$ (citric acid + KMS + salt combination) were showing creamy yellow colour, whereas those sun-dried after treatment $T_3$, were light brown in colour. When dried without giving any pretreatment, they were creamy white coloured in all the three methods, viz., sun-drying, mechanical drying and microwave oven drying.

4.2.2 Drying rate, shrinkage rate and reconstitution rate

4.2.2.1 Drying rate

Drying rate with respect to pretreatments under each method of drying was studied separately.

Sun-drying

On comparing the drying rate between various pretreatments followed by sun-drying in *P. florida*, samples pretreated with blanching in citric acid solution ($T_2$) showed rapid reduction in weight upto nine hours of drying (9.86%), but in the later period upto 14 hours, samples which were blanched in boiling water ($T_1$) showed a rapid reduction ending with 9.09 per cent weight which was significantly different from $T_2$ ($P < 0.05$). The treatment $T_3$ (citric acid + KMS + salt) showed significant difference from $T_1$ and $T_2$ (10.03%). Samples without any pretreatment ($T_4$) accomplished drying within 12 hours (9.23%) (Fig. 1a and Table 7). In *P. sajor-caju* also samples without any pretreatment accomplished drying within 12 hours (8.88%) and other pretreatments $T_1$ and $T_2$ were on par (8.89% and 8.90%

Table 7. Drying rate of *P. florida* and *P. sajor-caju* dried under different techniques

| Treatments | Sun-drying | | | | Mechanical drying | | | | Microwave oven drying | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hours | | | | Hours | | | | Minutes | | | |
| | 3 | 6 | 12 | 14 | 2 | 6 | 8 | 11 | 15 | 45 | 75 | 90 |
| *P. florida* | | | | | | | | | | | | |
| $T_1$ | $46.03^{c}$ | $14.51^{c}$ | $9.38^{c}$ | $9.09^{c}$ | $54.07^{c}$ | $16.46^{b}$ | $10.55^{c}$ | $9.16^{c}$ | $29.05^{b}$ | $9.94^{c}$ | $9.77^{c}$ | $9.73^{c}$ |
| $T_2$ | $43.65^{d}$ | $12.76^{d}$ | $9.48^{b}$ | $9.30^{b}$ | $58.14^{c}$ | $15.58^{b}$ | $11.69^{b}$ | $10.40^{b}$ | $23.94^{c}$ | $11.11^{b}$ | $10.68^{b}$ | $10.50^{b}$ |
| $T_3$ | $54.11^{a}$ | $19.94^{b}$ | $10.13^{a}$ | $10.03^{a}$ | $75.33^{a}$ | $26.64^{a}$ | $15.85^{a}$ | $12.12^{a}$ | $33.20^{a}$ | $12.69^{a}$ | $12.59^{a}$ | $12.56^{a}$ |
| $T_4$ | $51.76^{b}$ | $27.07^{a}$ | $9.23^{d}$ | - | $65.69^{b}$ | $10.60^{c}$ | $9.26^{d}$ | - | $29.76^{b}$ | $9.93^{c}$ | $9.81^{c}$ | - |
| *P. sajor-caju* | | | | | | | | | | | | |
| $T_1$ | $42.68^{c}$ | $12.65^{c}$ | $9.35^{d}$ | $8.89^{b}$ | $59.48^{c}$ | $23.25^{b}$ | $11.62^{b}$ | $9.12^{c}$ | $35.54^{b}$ | $13.51^{b}$ | $10.96^{b}$ | $10.29^{c}$ |
| $T_2$ | $43.74^{bc}$ | $13.54^{b}$ | $9.18^{c}$ | $8.90^{b}$ | $60.01^{c}$ | $24.01^{b}$ | $11.74^{b}$ | $10.17^{b}$ | $34.86^{b}$ | $13.25^{b}$ | $11.37^{a}$ | $10.34^{b}$ |
| $T_3$ | $52.29^{a}$ | $18.54^{a}$ | $9.54^{a}$ | $9.42^{a}$ | $77.20^{a}$ | $32.21^{a}$ | $17.41^{a}$ | $10.49^{a}$ | $39.86^{a}$ | $15.16^{a}$ | $11.48^{a}$ | $10.56^{a}$ |
| $T_4$ | $45.07^{ab}$ | $10.79^{d}$ | $8.88^{d}$ | - | $61.96^{b}$ | $11.47^{c}$ | $9.85^{c}$ | - | $35.11^{b}$ | $12.50^{c}$ | $10.20^{c}$ | - |

The values represent means of 3 replications
The values with different superscripts differ significantly at 5% level
- denotes the treatments which completed drying

respectively), but differed significantly with $T_3$ (citric acid + KMS + salt) on completion of drying after 14 hours (9.42%) (Fig. 1b and Table 7).

Mechanical drying

Comparing the drying rate between various pretreatments followed by mechanical drying in *P. florida*, rapid reduction in the weight was observed in samples pretreated with blanching alone ($T_1$) which was significantly different from other treatments (9.16%) after 11 hours of drying, followed by $T_1$ and $T_2$ which also differed significantly with each other at 5 per cent level (10.4% and 12.12% respectively). Samples without any pretreatment ($T_4$) accomplished drying within 8 hours of drying (9.26%) (Fig. 2a and Table 7).

Similar results were observed in *P. sajor-caju* also with $T_1$ having 9.12 per cent weight after 11 hours followed by $T_2$ and $T_3$ with a final weight of 10.17 per cent and 10.49 per cent respectively after 11 hours and were significantly different to each other at 5.0 per cent level. Samples without any pretreatment accomplished drying within eight hours with a final weight of 9.85 per cent (Fig. 2b and Table 7).

Microwave oven drying

Drying rate of *P. florida* under microwave oven drying showed that samples without any pretreatment ($T_4$) dried most rapidly within 75 minutes of drying whereas all other pretreated samples took 90 minutes to complete the drying. Among the various pretreatments, $T_1$ (blanching alone) was significantly different (9.73%) from other two treatments with $T_2$ (citric acid + blanching) having 10.50 per cent and $T_3$ (12.56%) (Fig. 3a and Table 7). Similar was the results in *P. sajor-caju* also, where the samples without any pretreatment completed drying

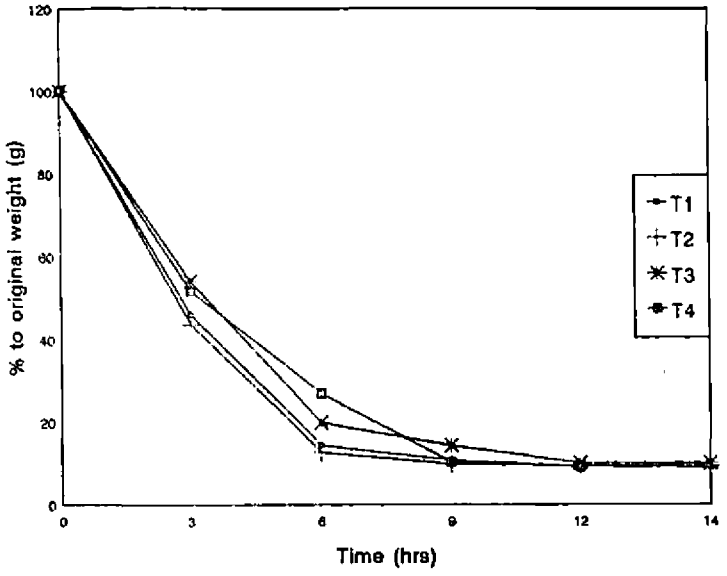



Fig.1a. Drying curve of sun-dried mushroom *P. florida* under various pre-treatments

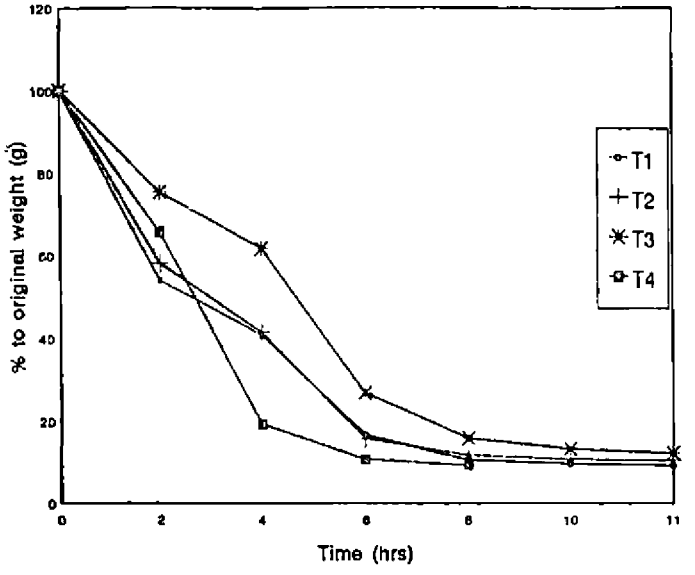



Fig.2a. Drying curve of mechanically dried mushroom *P. florida* various pre-treatments

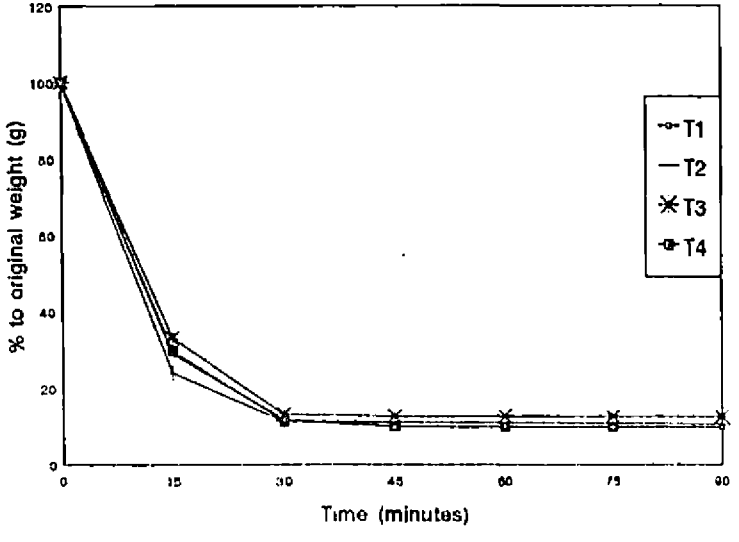



Fig.3a. Drying curve of microwave oven dried mushroom *P. florida* under various pre-treatments

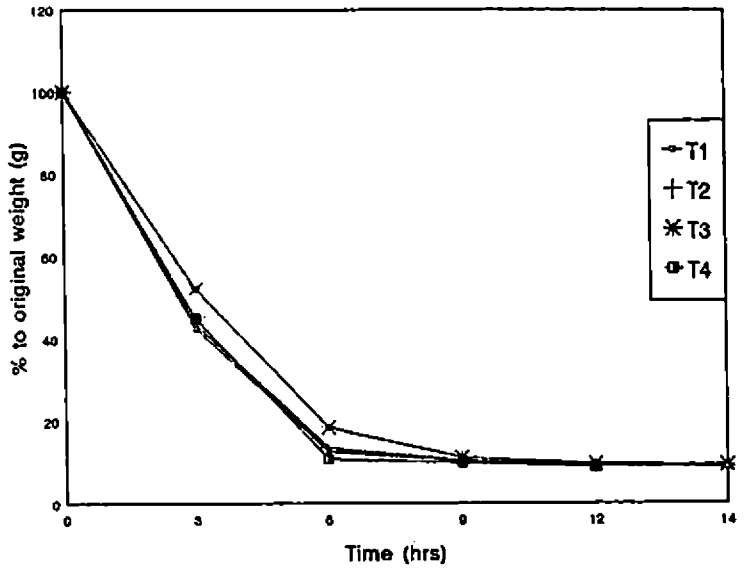



Fig.1b. Drying curve of sun-dried mushroom *P. sajor-caju* under various pre-treatments

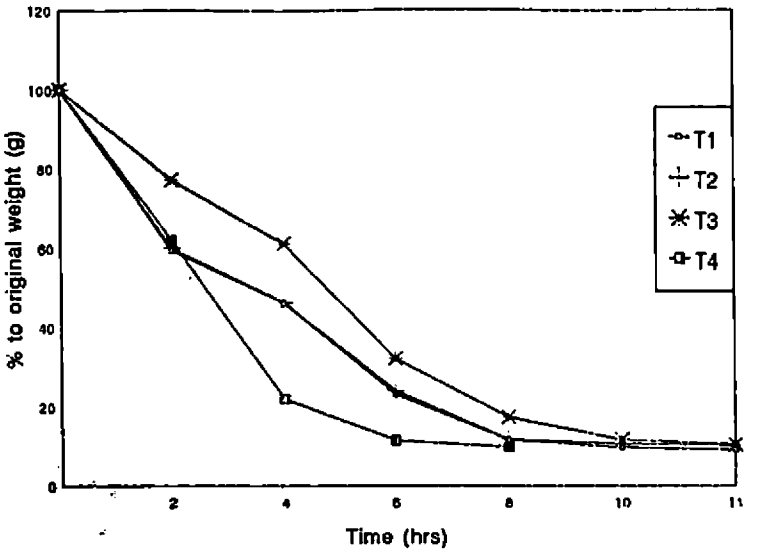



Fig.2b. Drying curve of mechanically dried mushroom *P. sajor-caju* under various pre-treatments

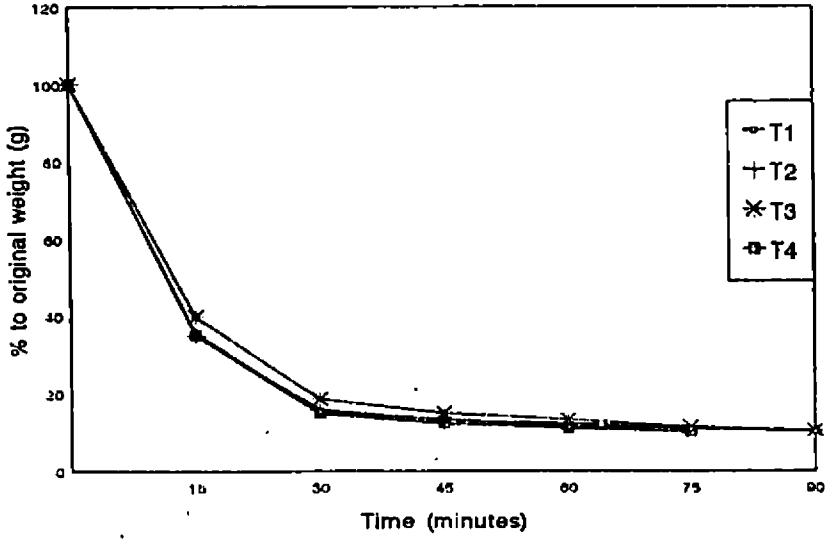



Fig.3b. Drying curve of microwave oven dried mushroom *P. sajor-caju* under various pre-treatments

within 75 minutes with a final weight of 10.2 per cent. Among other pretreatments $T_1$ (10.29%), $T_2$ (10.34%) and $T_3$ (10.56%) differed significantly with each other in the above order ($P < 0.05$) (Fig. 3b and Table 7).

4.2.2.2 Shrinkage rate

Shrinkage rate with respect to pretreatments under each method of drying was studied separately.

Sun-drying

Rate of percentage shrinkage of *P. florida* given different pretreatments followed by sun-drying are given in Table 8. It was observed that the rate of shrinkage was more in those samples without any pretreatment with the advancement of drying time from 64.25 per cent after 3 hours to 81.85 per cent after 12 hours of drying and the drying terminated after 12 hours in $T_4$ whereas the minimum shrinkage was observed in $T_3$ (KMS + citric acid + salt) (79.86%), after 14 hours of drying which was statistically superior to $T_2$ and $T_1$ ($P < 0.05$) having 81.38 per cent and 80.28 per cent shrinkage respectively after 14 hours drying showing significant difference between the treatments ($P < 0.05$).

In *P. sajor-caju* also, the results were same as above with maximum shrinkage in $T_4$ (drying without any pretreatment) (85.09%); with a minimum shrinkage and superior treatment as $T_3$ (82.20%), but between $T_2$ and $T_1$, there was no significant difference in the per cent shrinkage after the termination of drying (83.94% and 83.87% even after 14 hours of drying) (Table 8).

Table 8. Shrinkage rate of *P. florida* and *P. sajor-caju* dried under different techniques

| Treatments | Sun-drying | | | | Mechanical drying | | | | Microwave oven drying | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hours | | | | Hours | | | | Minutes | | | |
| | 3 | 6 | 12 | 14 | 2 | 6 | 8 | 11 | 15 | 45 | 75 | 90 |
| *P. florida* | | | | | | | | | | | | |
| $T_1$ | $54.66^{c}$ | $64.19^{c}$ | $78.76^{b}$ | $80.28^{b}$ | $25.23^{c}$ | $59.44^{c}$ | $75.06^{c}$ | $79.11^{b}$ | $33.36^{c}$ | $66.16^{c}$ | $74.38^{b}$ | $78.11^{b}$ |
| $T_2$ | $52.04^{d}$ | $65.90^{b}$ | $79.45^{b}$ | $81.38^{a}$ | $20.66^{d}$ | $49.08^{d}$ | $77.32^{b}$ | $80.33^{a}$ | $34.73^{c}$ | $69.72^{b}$ | $79.41^{a}$ | $81.63^{a}$ |
| $T_3$ | $60.68^{b}$ | $63.50^{c}$ | $76.32^{c}$ | $79.86^{c}$ | $28.32^{b}$ | $62.52^{b}$ | $75.61^{c}$ | $78.78^{b}$ | $37.19^{b}$ | $70.38^{ab}$ | $76.02^{b}$ | $76.41^{b}$ |
| $T_4$ | $64.25^{a}$ | $71.18^{a}$ | $81.85^{a}$ | - | $29.66^{a}$ | $66.95^{a}$ | $80.34^{a}$ | - | $39.34^{a}$ | $71.55^{a}$ | $80.34^{a}$ | - |
| *P. sajor-caju* | | | | | | | | | | | | |
| $T_1$ | $56.58^{b}$ | $69.85^{b}$ | $77.94^{c}$ | $83.87^{a}$ | $28.27^{c}$ | $63.01^{b}$ | $78.99^{b}$ | $82.92^{a}$ | $36.08^{c}$ | $68.05^{d}$ | $79.30^{b}$ | $81.17^{b}$ |
| $T_2$ | $55.36^{b}$ | $65.73^{c}$ | $78.24^{bc}$ | $83.94^{a}$ | $25.12^{d}$ | $60.91^{c}$ | $75.38^{c}$ | $82.92^{a}$ | $39.78^{b}$ | $69.70^{c}$ | $79.42^{b}$ | $81.48^{a}$ |
| $T_3$ | $62.54^{a}$ | $66.59^{c}$ | $79.33^{b}$ | $82.20^{b}$ | $31.46^{a}$ | $62.51^{b}$ | $75.21^{c}$ | $81.42^{b}$ | $41.85^{a}$ | $70.49^{b}$ | $77.68^{b}$ | $79.70^{c}$ |
| $T_4$ | $63.17^{a}$ | $72.16^{a}$ | $85.09^{a}$ | - | $30.38^{b}$ | $69.38^{a}$ | $84.52^{a}$ | - | $42.49^{a}$ | $71.50^{a}$ | $84.24^{a}$ | - |

The values represent means of 3 replications
The values with different superscripts differ significantly at 5% level
- denotes the treatments which completed drying

Mechanical drying

The rate of per cent shrinkage of *P. florida* during mechanical drying after different pretreatments is shown in Table 8. Percentage shrinkage was maximum in $T_4$ (dried without any pretreatment) which was found to be 80.34 per cent on termination of drying after eight hours. Treatment $T_3$ (KMS + citric acid + salt) recorded the minimum shrinkage of 78.78 per cent which was statistically on par with $T_1$ (79.11%) after 11 hours of drying. The rate of shrinkage in all the treatments increased with the advancement of drying time with steep hike observed between four and eight hours of drying.

In the case of *P. sajor-caju*, though the results were almost similar to *P. florida*, towards the termination of drying after 11 hours, $T_3$ was having minimum shrinkage (81.42%) and was superior to other two treatments ($P < 0.05$) viz., $T_1$ and $T_2$ which were on par to each other having 82.92 per cent shrinkage each. The treatment $T_4$ terminated after 8 hours with maximum shrinkage (84.52%) (Table 8).

Microwave oven drying

Per cent shrinkage in *P. florida* was maximum in $T_2$ (citric acid + blanching) at the end of the microwave oven drying (81.63%) after 90 mts; this was significantly different from $T_1$ and $T_3$ (78.11% and 76.41% respectively) but $T_1$ and $T_3$ were on par ($P < 0.05$). Drying without any pretreatment terminated after 75 minutes of drying with 80.34 per cent shrinkage (Table 8).

In *P. sajor-caju*, $T_4$ (without any pretreatment) showed the maximum shrinkage rate throughout the period of drying, which increased from 67.01 per cent after 15 minutes to 84.24 per cent after 75 minutes. The treatment $T_3$ (citric acid +

KMS + salt) showed the minimum shrinkage which was significantly superior to $T_1$ and $T_2$ ($P < 0.05$) with only 79.70 per cent shrinkage at the end of drying (90 mts.) (Table 8).

4.2.2.3 Reconstitution rate

Sun-drying

The pattern of reconstitution of sun-dried samples of *P. florida* after various pretreatments are shown in Fig.4a and Table 9. The rate of reconstitution was very fast in samples dried without any pretreatment ($T_4$) and reconstitution completed within an hour (348.39%) whereas all other samples took 90 minutes to attain constant weight showing the completion of reconstitution. The samples $T_1$ and $T_2$ were showing the same pattern, hence they were on par, but $T_3$ was superior to $T_1$ and $T_2$ which became significantly different after 90 minutes (216.36%) to $T_1$ and $T_2$ (210.08% and 209.96% respectively).

The trend was similar in *P. sajor-caju* (Fig.4b and Table 9).

Mechanical drying

When mechanically dried, samples without any pretreatment showed the fastest reconstitution which took only 60 minutes to complete the reconstitution (399.1%). The samples of $T_1$, $T_2$ and $T_3$ took 90 minutes to complete reconstitution. Percentage reconstitution at the end of 90 minutes differed significantly each other with $T_3$ (226.4%) superior to $T_1$ followed by $T_2$ (217.6% and 202.4% respectively) (Fig. 5a and Table 9).

In *P. sajor-caju* also, $T_4$ (without any pretreatment) was having the maximum percentage reconstitution (291.7%) which completed within 60 minutes.

Table 9. Rate of reconstitution of mushroom *P. florida* and *P. sajor-caju* dried under different techniques

| Treatment | *P. florida* | | | *P. sajor-caju* | | |
|---|---|---|---|---|---|---|
| | 30 | 60 | 90 | 30 | 60 | 90 |
| | (Minutes) | | | | | |
| $T_1SD$ | $200.90^{de}$ | $206.16^{def}$ | $210.08^{e}$ | $159.49^{i}$ | $162.82^{k}$ | $164.77^{g}$ |
| $T_2SD$ | $187.09^{de}$ | $191.33^{fg}$ | $209.96^{e}$ | $159.76^{i}$ | $163.23^{k}$ | $164.87^{g}$ |
| $T_3SD$ | $201.16^{de}$ | $209.33^{de}$ | $216.36^{d}$ | $165.91^{g}$ | $175.65^{f}$ | $179.83^{c}$ |
| $T_4SD$ | $334.96^{b}$ | $348.39^{b}$ | - | $277.61^{c}$ | $281.80^{c}$ | - |
| $T_1MD$ | $196.84^{de}$ | $201.25^{efg}$ | $217.58^{d}$ | $165.41^{h}$ | $166.25^{j}$ | $168.53^{f}$ |
| $T_2MD$ | $184.90^{e}$ | $186.83^{g}$ | $202.41^{f}$ | $165.31^{g}$ | $167.75^{i}$ | $170.47^{e}$ |
| $T_3MD$ | $204.39^{d}$ | $209.13^{de}$ | $226.40^{c}$ | $171.05^{e}$ | $181.15^{e}$ | $187.37^{b}$ |
| $T_4MD$ | $396.04^{de}$ | $399.12^{a}$ | - | $288.96^{b}$ | $291.66^{b}$ | - |
| $T_1MW$ | $201.83^{de}$ | $218.18^{d}$ | $236.06^{b}$ | $167.30^{f}$ | $171.94^{g}$ | $173.40^{d}$ |
| $T_2MW$ | $201.94^{de}$ | $211.34^{de}$ | $236.62^{b}$ | $165.51^{g}$ | $170.61^{h}$ | $173.60^{d}$ |
| $T_3MW$ | $231.90^{c}$ | $236.94^{c}$ | $262.94^{a}$ | $188.41^{d}$ | $194.58^{d}$ | $196.60^{a}$ |
| $T_4MW$ | $401.98^{a}$ | $409.00^{a}$ | - | $311.14^{a}$ | $316.50^{a}$ | - |

The values represent means of 3 replications
The values having different superscripts differ significantly at 5% level
- Denotes samples reconstituted completely within an hour

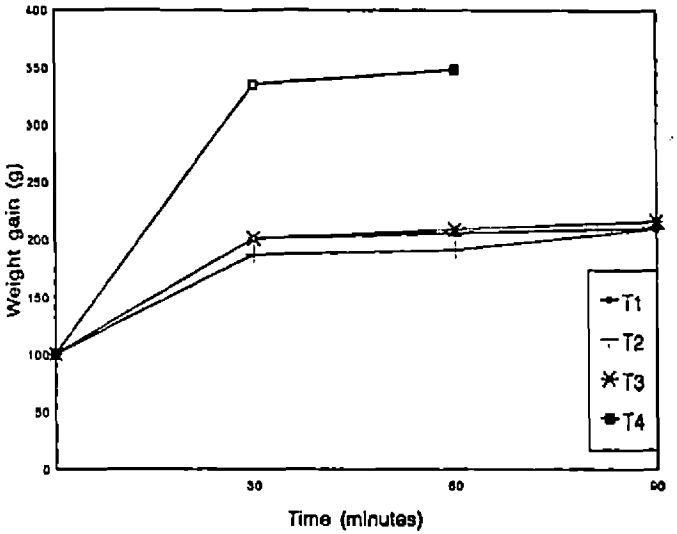



Fig.4a. Reconstitution curve of sun-dried mushroom *P. florida* under various pretreatments

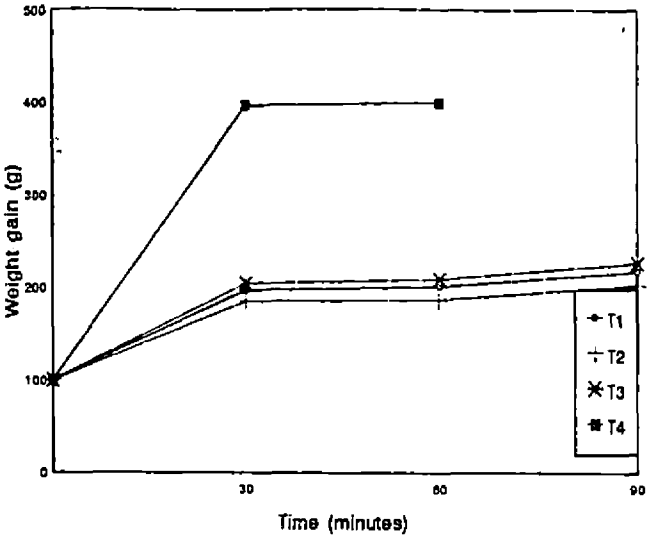



Fig.5a. Reconstitution curve of mechanically dried mushroom *P. florida* under various pretreatments

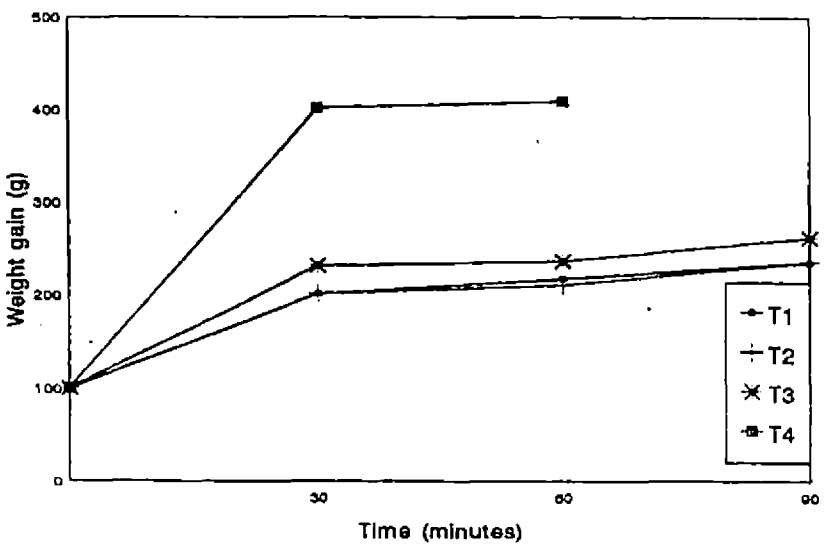



Fig.6a. Reconstitution curve of microwave oven dried mushroom *P. florida* under various pretreatments

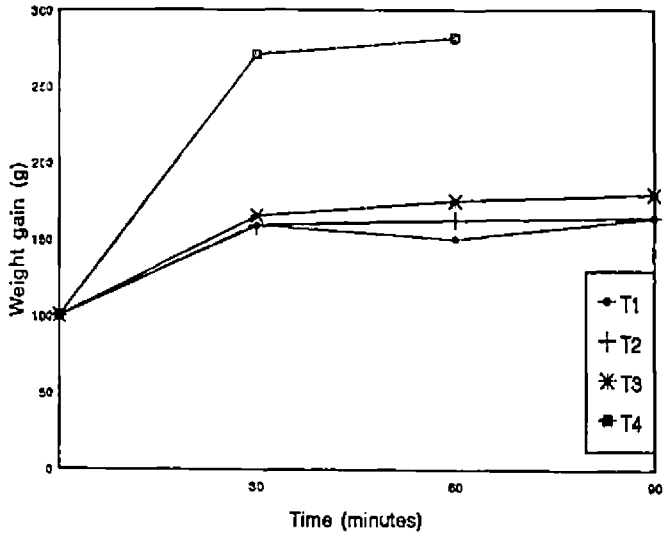



Fig.4b. Reconstitution curve of sun-dried mushroom *P. sajor-caju* under various pretreatments

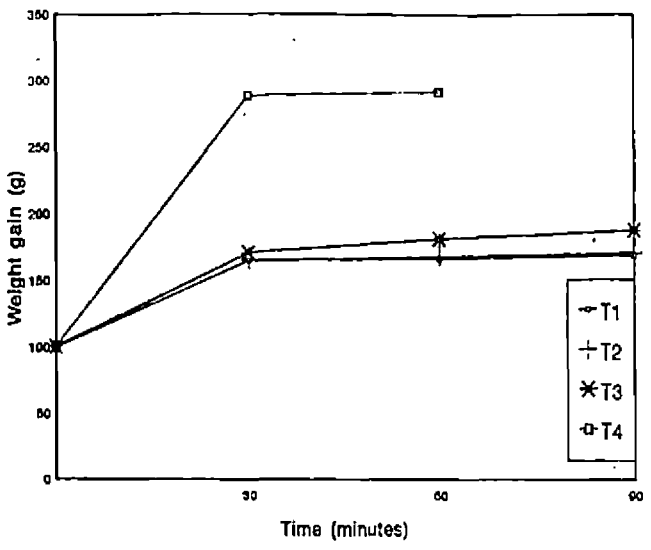



Fig.5b. Reconstitution curve of mechanically dried mushroom *P. sajor-caju* under various pretreatments

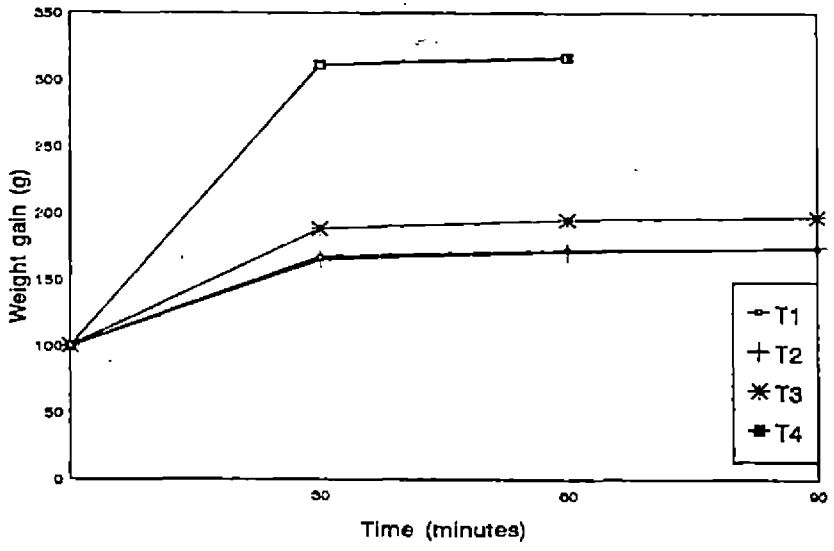



Fig.6b. Reconstitution curve of microwave oven dried mushroom *P. sajor-caju* under various pretreatments

Though $T_3$ was superior to $T_1$ and $T_2$ similar to *P. florida* (187.4%), the treatment $T_2$ was showing significantly higher reconstitution percentage (170.5%) than $T_1$ (168.5%) (Fig.5b and Table 9).

Microwave oven drying

Similar to other methods of drying, in microwave oven drying also $T_4$ (without any pretreatment) completed the reconstitution within 60 minutes whereas all other treatments took 90 minutes to attain constant weight showing the completion of reconstitution. The maximum reconstitution percentage was in $T_4$ (409.0%). After 90 minutes of reconstitution, $T_3$ (citric acid + KMS + salt) was superior (262.9%) to $T_1$ and $T_2$ which were on par (236.0% and 236.6% respectively) (Fig. 6a and Table 9).

Similar results were obtained for *P. sajor-caju* after completion of reconstitution to attain constant weight (Fig.6b and Table 9).

4.2.3 Moisture pick up

Moisture pick up of dried mushroom *P. florida* packaged in PP and PE separately during storage were analysed for a period of six months under ambient conditions and are presented in Table 10a. Comparing the moisture pick up between the type of packaging material used, throughout the period of storage, irrespective of methods of drying or type of pretreatments, no significant difference was observed ($P < 0.05$). But between methods of drying, moisture pick up was always high in sun-dried samples, followed by mechanically dried and the least in microwave oven dried, and they differed significantly throughout the period of storage. But between the various pretreatments, the trend was erratic throughout the period of storage.

Table 10a. Percentage moisture pick up of dried mushroom samples of *P. florida* during storage under ambient conditions with different drying techniques and packages

| Treatments | Months | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
| | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE |
| $T_1$SD | 5.57 | 5.53 | $6.03^{ab}$ | $6.03^{ab}$ | $6.73^{a}$ | $6.73^{a}$ | $7.40^{a}$ | $7.43^{a}$ | $7.83^{ab}$ | $7.87^{a}$ | $8.13^{a}$ | $8.17^{a}$ | $8.77^{a}$ | $8.73^{a}$ |
| $T_2$SD | 5.60 | 5.47 | $6.10^{a}$ | $5.97^{bc}$ | $6.47^{b}$ | $6.47^{b}$ | $7.07^{b}$ | $7.10^{b}$ | $7.77^{b}$ | $7.87^{a}$ | $8.10^{ab}$ | $8.07^{ab}$ | $8.47^{bc}$ | $8.50^{b}$ |
| $T_3$SD | 5.55 | 5.45 | $6.03^{ab}$ | $5.90^{cd}$ | $6.37^{bc}$ | $6.27^{c}$ | $7.10^{b}$ | $6.87^{c}$ | $7.53^{e}$ | $7.50^{c}$ | $7.93^{c}$ | $8.00^{bc}$ | $8.40^{cd}$ | $8.33^{d}$ |
| $T_4$SD | 5.43 | 5.43 | $5.87^{d}$ | 5.87d | - | - | - | - | - | - | - | - | - | - |
| $T_1$MD | 5.27 | 5.23 | $5.57^{f}$ | $5.57^{f}$ | $5.76^{def}$ | $5.73^{efg}$ | $6.03^{f}$ | $5.96^{fg}$ | $6.33^{f}$ | $6.30^{f}$ | $6.70^{e}$ | $6.67^{ef}$ | $7.20^{h}$ | $7.27^{h}$ |
| $T_2$MD | 5.33 | 5.30 | $5.67^{e}$ | $5.63^{ef}$ | $5.83^{de}$ | $5.80^{def}$ | $6.17^{e}$ | $5.97^{fg}$ | $6.47^{e}$ | $6.33^{f}$ | $6.76^{e}$ | $6.67^{ef}$ | $7.57^{f}$ | $7.47^{g}$ |
| $T_3$MD | 5.30 | 5.37 | $5.60^{ef}$ | $5.67^{e}$ | $5.87^{d}$ | $5.83^{de}$ | $6.27^{d}$ | $6.33^{d}$ | $6.77^{d}$ | $6.73^{d}$ | $7.07^{d}$ | $7.00^{d}$ | $7.73^{e}$ | $7.77^{h}$ |
| $T_4$MD | 5.37 | 5.30 | $5.67^{e}$ | $5.60^{ef}$ | - | - | - | - | - | - | - | - | - | - |
| $T_1$MW | 5.07 | 5.00 | $5.33^{hi}$ | $5.30^{ij}$ | $5.63^{gh}$ | $5.63^{gh}$ | $5.90^{gh}$ | $5.87^{gh}$ | $6.30^{f}$ | $6.33^{f}$ | $6.50^{g}$ | $6.57^{fg}$ | $6.87^{k}$ | $6.90^{k}$ |
| $T_2$MW | 5.07 | 5.03 | $5.30^{ij}$ | $5.23^{j}$ | $5.60^{hi}$ | $5.50^{i}$ | $5.77^{i}$ | $5.83^{hi}$ | $5.93^{i}$ | $6.03^{g}$ | $6.23^{h}$ | $6.27^{h}$ | $6.93^{jk}$ | $6.87^{k}$ |
| $T_3$MW | 5.17 | 5.10 | $5.40^{gh}$ | $5.33^{hi}$ | $5.70^{fgh}$ | $5.63^{gh}$ | $5.90^{gh}$ | $5.83^{hi}$ | $6.17^{g}$ | $6.13^{h}$ | $6.67^{ef}$ | $6.67^{ef}$ | $7.00^{ij}$ | $7.03^{i}$ |
| $T_4$MW | 5.13 | 5.13 | $5.43^{g}$ | $5.40^{gh}$ | - | - | - | - | - | - | - | - | - | - |

The values represent means of 3 replications
The values with different superscripts differ significantly at 5% level
- denotes the treatments discarded due to quality deterioration

Table 10b. Percentage moisture pick up of dried mushroom samples of *P. sajor-caju* during storage under ambient conditions with different drying techniques and packages

| Treatments | Months | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
| | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE |
| $T_1$SD | 5.60 | 5.58 | $6.00^{a}$ | $6.00^{a}$ | $6.43^{ab}$ | $6.50^{a}$ | $6.90^{a}$ | $6.90^{a}$ | $7.17^{a}$ | $7.20^{a}$ | $7.53^{a}$ | $7.50^{a}$ | $7.93^{a}$ | $7.93^{a}$ |
| $T_2$SD | 5.58 | 5.55 | $6.03^{a}$ | $6.07^{a}$ | $6.20^{c}$ | $6.27^{c}$ | $6.43^{c}$ | $6.50^{c}$ | $6.63^{b}$ | $6.67^{b}$ | $7.23^{b}$ | $7.27^{b}$ | $7.83^{b}$ | $7.80^{b}$ |
| $T_3$SD | 5.57 | 5.53 | $6.03^{a}$ | $6.07^{a}$ | $6.30^{bc}$ | $6.30^{bc}$ | $6.73^{b}$ | $6.70^{b}$ | $7.10^{a}$ | $7.13^{a}$ | $7.47^{a}$ | $7.50^{a}$ | $7.80^{b}$ | $7.83^{b}$ |
| $T_4$SD | 5.20 | 5.53 | $5.63^{b}$ | $5.93^{a}$ | - | - | - | - | - | - | - | - | - | - |
| $T_1$MD | 5.15 | 5.13 | $5.50^{bc}$ | $5.47^{c}$ | $5.77^{e}$ | $5.87^{e}$ | $6.23^{d}$ | $6.20^{de}$ | $6.47^{c}$ | $6.37^{cd}$ | $6.60^{c}$ | $6.67^{c}$ | $6.93^{cd}$ | $7.00^{c}$ |
| $T_2$MD | 5.16 | 5.10 | $5.53^{bc}$ | $5.50^{bc}$ | $6.00^{d}$ | $5.87^{e}$ | $6.10^{ef}$ | $6.07^{f}$ | $6.33^{de}$ | $6.33^{de}$ | $6.53^{cd}$ | $6.63^{c}$ | $6.87^{fg}$ | $6.90^{ef}$ |
| $T_3$MD | 5.23 | 5.20 | $5.60^{bc}$ | $5.53^{bc}$ | $5.77^{e}$ | $5.87^{e}$ | $6.00^{f}$ | $6.10^{ef}$ | $6.23^{ef}$ | $6.37^{cd}$ | $6.43^{de}$ | $6.60^{c}$ | $6.90^{d}$ | $6.87^{de}$ |
| $T_4$MD | 5.13 | 5.17 | $5.53^{bc}$ | $5.57^{bc}$ | - | - | - | - | - | - | - | - | - | - |
| $T_1$MW | 5.03 | 5.05 | $5.23^{d}$ | $5.30^{d}$ | $5.63^{f}$ | $5.56^{f}$ | $6.03^{f}$ | $6.10^{ef}$ | $6.13^{fg}$ | $6.27^{de}$ | $6.33^{ef}$ | $6.40^{e}$ | $6.53^{i}$ | $6.57^{hi}$ |
| $T_2$MW | 5.01 | 5.07 | $5.23^{d}$ | $5.30^{d}$ | $5.57^{f}$ | $5.60^{f}$ | $5.80^{g}$ | $5.83^{g}$ | $6.07^{g}$ | $6.07^{g}$ | $6.37^{ef}$ | $6.33^{ef}$ | $6.63^{hi}$ | $6.67^{gh}$ |
| $T_3$MW | 5.03 | 5.05 | $5.27^{d}$ | $5.30^{d}$ | $5.43^{g}$ | $5.43^{g}$ | $5.63^{h}$ | $5.63^{h}$ | $5.87^{h}$ | $5.93^{h}$ | $6.27^{f}$ | $6.33^{ef}$ | $6.63^{hi}$ | $6.60^{hi}$ |
| $T_4$MW | 5.05 | 5.07 | $5.27^{d}$ | $5.30^{d}$ | - | - | - | - | - | - | - | - | - | - |

The values represent means of 3 replications
The values with different superscripts differ significantly at 5% level
- denotes the treatments discarded due to quality deterioration

Same trend was observed in *P. sajor-caju* also (Table 10b).

4.2.4 Ascorbic acid, protein and residual $SO_2$

4.2.4.1 Ascorbic acid

There was a gradual decline in ascorbic acid content from first to sixth month of storage at ambient conditions for both *P. florida* and *P. sajor-caju*. Microwave oven dried samples showed the least reduction followed by mechanical drying and sun-drying, and differed significantly ($P < 0.05$), the trend continued upto six months. Among the different pretreatments, $T_3$ (citric acid + KMS + salt) retained the maximum ascorbic acid content, and was significantly different from $T_2$ and $T_1$ after six months of storage; $T_4$ (without any pretreatment) could be stored only for a month due to quality deterioration. Packaging material as far as ascorbic acid retention was concerned, no significant difference was observed between the methods of packaging, viz., PP or PE during any period of storage (Tables 11a and 11b).

4.2.4.2 Protein

Effect of treatments and methods of drying on protein content during storage of both mushrooms *P. florida* and *P. sajor-caju* packaged in PP and PE were studied and reported in Tables 12a and 12b. Results showed that there was no significant difference in the reduction of protein content due to various pretreatments in both the speces, however, a reduction in protein content was observed in all the pretreated samples immediately after drying, except in untreated samples ($T_4$); $T_4$ was discontinued after one month of storage due to quality deterioration. As no significant difference was observed between treatments immediately after drying, subsequent statistical analysis was carried out only to know whether any significant difference in reduction of the protein content exists

Table 11a. Ascorbic acid content of dried mushroom samples of *P. florida* during storage under ambient conditions with different drying techniques and packages
(mg/100 g)

| Treatments | Months | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
| | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE |
| $T_1$SD | 1.30 | 1.28 | $1.01^{f}$ | $1.08^{f}$ | $0.99^{l}$ | $1.04^{k}$ | $0.97^{k}$ | $0.92^{k}$ | $0.83^{k}$ | $0.87^{k}$ | $0.82^{j}$ | $0.81^{j}$ | $0.81^{g}$ | $0.80^{g}$ |
| $T_2$SD | 1.48 | 1.45 | $1.32^{ef}$ | $1.32^{ef}$ | $1.30^{j}$ | $1.30^{j}$ | $1.24^{j}$ | $1.28^{j}$ | $1.22^{j}$ | $1.21^{j}$ | $1.18^{i}$ | $1.18^{i}$ | $1.15^{f}$ | $1.14^{f}$ |
| $T_3$SD | 1.78 | 1.82 | $1.59^{def}$ | $1.59^{def}$ | $1.52^{i}$ | $1.51^{i}$ | $1.47^{i}$ | $1.44^{i}$ | $1.41^{i}$ | $1.39^{i}$ | $1.31^{h}$ | $1.30^{h}$ | $1.16^{f}$ | $1.14^{f}$ |
| $T_4$SD | 1.28 | 1.22 | $0.91^{f}$ | $0.89^{f}$ | - | - | - | - | - | - | - | - | - | - |
| $T_1$MD | 2.30 | 2.22 | $2.13^{cd}$ | $2.02^{cde}$ | $2.02^{g}$ | $1.97^{h}$ | $1.89^{h}$ | $1.87^{h}$ | $1.82^{g}$ | $1.72^{h}$ | $1.65^{f}$ | $1.53^{g}$ | $1.48^{e}$ | $1.41^{e}$ |
| $T_2$MD | 2.66 | 2.70 | $2.54^{bc}$ | $2.54^{bc}$ | $2.47^{e}$ | $2.48^{e}$ | $2.30^{f}$ | $2.36^{e}$ | $2.23^{e}$ | $2.29^{de}$ | $2.10^{d}$ | $2.11^{d}$ | $1.84^{d}$ | $1.87^{d}$ |
| $T_3$MD | 3.28 | 3.28 | $3.13^{ab}$ | $3.16^{ab}$ | $3.11^{b}$ | $3.11^{b}$ | $3.08^{a}$ | $3.02^{b}$ | $2.87^{b}$ | $2.96^{a}$ | $2.68^{b}$ | $2.73^{ab}$ | $2.40^{b}$ | $2.45^{b}$ |
| $T_4$MD | 1.21 | 1.20 | $0.95^{f}$ | $0.94^{f}$ | - | - | - | - | - | - | - | - | - | - |
| $T_1$MW | 2.34 | 2.32 | $2.21^{cd}$ | $2.21^{cd}$ | $2.13^{f}$ | $2.13^{f}$ | $2.08^{g}$ | $2.04^{g}$ | $1.96^{f}$ | $1.95^{f}$ | $1.88^{e}$ | $1.89^{e}$ | $1.82^{d}$ | $1.81^{d}$ |
| $T_2$MW | 2.78 | 2.75 | $2.59^{abc}$ | $2.58^{bc}$ | $2.57^{c}$ | $2.51^{d}$ | $2.42^{d}$ | $2.47^{c}$ | $2.35^{cd}$ | $2.42^{c}$ | $2.29^{c}$ | $2.31^{c}$ | $2.09^{c}$ | $2.09^{c}$ |
| $T_3$MW | 3.40 | 3.42 | $3.31^{ab}$ | $3.32^{ab}$ | $3.20^{a}$ | $3.20^{a}$ | $3.09^{a}$ | $3.10^{a}$ | $2.97^{a}$ | $2.91^{ab}$ | $2.79^{a}$ | $2.74^{ab}$ | $2.68^{a}$ | $2.63^{a}$ |
| $T_4$MW | 1.32 | 1.26 | $1.00^{f}$ | $0.99^{f}$ | - | - | - | - | - | - | - | - | - | - |

The values represent means of 3 replications
The values with different superscripts differ significantly at 5% level
- denotes the treatments discarded due to quality deterioration

Table 11b. Ascorbic acid content of dried mushroom samples of *P. sajor-caju* during storage under ambient conditions with different drying techniques and packages
(mg/100 g)

| Treatments | Months | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
| | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE |
| $T_1SD$ | 1.66 | 1.63 | $1.51^{jkl}$ | $1.51^{jkl}$ | $1.40^{j}$ | $1.40^{j}$ | $1.28^{i}$ | $1.29^{i}$ | $1.19^{j}$ | $1.17^{j}$ | $1.13^{k}$ | $1.03^{l}$ | $0.93^{j}$ | $0.91^{j}$ |
| $T_2SD$ | 1.90 | 1.85 | $1.70^{ijk}$ | $1.72^{ghij}$ | $1.60^{i}$ | $1.61^{i}$ | $1.49^{h}$ | $1.52^{h}$ | $1.39^{hi}$ | $1.40^{hi}$ | $1.19^{j}$ | $1.27^{hi}$ | $1.08^{i}$ | $1.13^{i}$ |
| $T_3SD$ | 2.35 | 2.39 | $2.10^{ef}$ | $2.11^{ef}$ | $1.92^{g}$ | $1.93^{g}$ | $1.82^{f}$ | $1.85^{f}$ | $1.70^{f}$ | $1.71^{f}$ | $1.63^{f}$ | $1.60^{f}$ | $1.52^{g}$ | $1.52^{g}$ |
| $T_4SD$ | 1.50 | 1.53 | $1.311$ | $1.32^{l}$ | - | - | - | - | - | - | - | - | - | - |
| $T_1MD$ | 1.86 | 1.89 | $1.72^{hij}$ | $1.72^{ghij}$ | $1.62^{i}$ | $1.61^{i}$ | $1.52^{h}$ | $1.52^{h}$ | $1.35^{i}$ | $1.44^{gh}$ | $1.23^{ij}$ | $1.29^{gh}$ | $1.11^{i}$ | $1.10^{i}$ |
| $T_2MD$ | 2.23 | 2.41 | $1.95^{fg}$ | $2.28^{de}$ | $2.12^{f}$ | $2.18^{e}$ | $2.02^{e}$ | $2.07^{e}$ | $1.93^{e}$ | $1.99^{d}$ | $1.86^{e}$ | $1.89^{de}$ | $1.81^{ef}$ | $1.77^{f}$ |
| $T_3MD$ | 2.95 | 2.98 | $2.79^{bc}$ | $2.75^{c}$ | $2.66^{b}$ | $2.57^{c}$ | $2.42^{b}$ | $2.43^{b}$ | $2.31^{b}$ | $2.34^{b}$ | $2.24^{b}$ | $2.25^{b}$ | $2.20^{b}$ | $2.09^{c}$ |
| $T_4MD$ | 1.73 | 1.71 | $1.44^{l}$ | $1.48^{kl}$ | - | - | - | - | - | - | - | - | - | - |
| $T_1MW$ | 2.23 | 2.20 | $1.94^{fgh}$ | $1.92^{fghi}$ | $1.79^{h}$ | $1.77^{h}$ | $1.61^{g}$ | $1.62^{g}$ | $1.47^{g}$ | $1.46^{g}$ | $1.32^{gh}$ | $1.34^{g}$ | $1.20^{h}$ | $1.21^{h}$ |
| $T_2MW$ | 2.70 | 2.65 | $2.47^{d}$ | $2.43^{d}$ | $2.35^{d}$ | $2.30^{d}$ | $2.23^{c}$ | $2.17^{d}$ | $2.14^{c}$ | $2.01^{d}$ | $1.97^{c}$ | $1.92^{cd}$ | $1.86^{d}$ | $1.85^{de}$ |
| $T_3MW$ | 3.15 | 3.18 | $3.04^{a}$ | $2.99^{ab}$ | $2.86^{a}$ | $2.91^{a}$ | $2.76^{a}$ | $2.72^{a}$ | $2.60^{a}$ | $2.60^{a}$ | $2.50^{a}$ | $2.50^{a}$ | $2.32^{a}$ | $2.29^{a}$ |
| $T_4MW$ | 1.65 | 1.62 | $1.50^{jkl}$ | $1.51^{jkl}$ | - | - | - | - | - | - | - | - | - | - |

The values represent means of 3 replications
The values with different superscripts differ significantly at 5% level
- denotes the treatments discarded due to quality deterioration

between the types of packages and duration of storage within the same treatment. Results showed that there was no significant difference between the types of packaging material used, irrespective of treatments or duration of storage. Comparing the reduction of protein with the storage period, no significant reduction was observed till three months of storage in all the samples, but a significant reduction was observed after three months of storage ($P < 0.05$), with respect to the original sample.

4.2.4.3 Residual $SO_2$

The residual $SO_2$ of samples pretreated with KMS + citric acid + salt and dried under different methods were analysed after reconstitution in boiling water for five minutes.

Table 13 shows that the maximum residual $SO_2$ was in the microwave oven dried samples throughout the period of storage and was significantly different from other samples in *P. florida* ($P < 0.05$). The samples dried mechanically and dried under sun also differed significantly with each other, with higher values observed in mechanically dried samples, in all the six months period. But there was no significant difference between packaging materials in all the methods of drying.

Results and trends were similar in *P. sajor-caju* also, with microwave oven drying showing the maximum residual $SO_2$ content throughout the period of storage (Table 13).

Sensory evaluation

Eventhough the treatment $T_3$ (citric acid + KMS + salt) in terms of quality attributes of dried samples are outstanding compared to others, on

Table 12a. Protein content of dried mushroom samples of *P. florida* during storage under ambient conditions with different drying techniques and packages
(%)

| Treatments | Months | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
| | PP | PE | PP a↓ | PE a↓ | PP ab↓ | PE ab↓ | PP bc↓ | PE bc↓ | PP cd↓ | PE cd↓ | PP d↓ | PE d↓ | PP e↓ | PE e↓ |
| $T_1$SD | 24.53 | 24.54 | 24.52 | 24.56 | 24.52 | 24.56 | 24.41 | 24.44 | 24.30 | 24.33 | 24.07 | 24.24 | 23.98 | 23.95 |
| $T_2$SD | 24.74 | 24.80 | 24.74 | 24.80 | 24.76 | 24.80 | 24.42 | 24.76 | 24.31 | 24.71 | 24.13 | 25.03 | 23.99 | 25.00 |
| $T_3$SD | 24.79 | 24.75 | 24.78 | 24.75 | 24.76 | 24.73 | 24.72 | 24.66 | 24.75 | 24.60 | 24.72 | 24.52 | 24.71 | 24.48 |
| $T_4$SD | 25.47 | 25.33 | 25.43 | 25.33 | - | - | - | - | - | - | - | - | - | - |
| $T_1$MD | 24.57 | 24.60 | 24.55 | 24.55 | 24.43 | 24.39 | 24.32 | 24.11 | 24.24 | 24.22 | 24.07 | 24.10 | 23.93 | 24.07 |
| $T_2$MD | 24.65 | 24.78 | 24.62 | 24.74 | 24.55 | 24.66 | 24.52 | 24.63 | 24.51 | 24.61 | 24.51 | 24.58 | 24.44 | 24.51 |
| $T_3$MD | 24.58 | 25.02 | 24.57 | 25.00 | 24.50 | 24.89 | 24.42 | 24.73 | 24.40 | 24.68 | 24.34 | 24.39 | 24.30 | 24.38 |
| $T_4$MD | 25.58 | 25.22 | 25.55 | 25.18 | - | - | - | - | - | - | - | - | - | - |
| $T_1$MW | 24.67 | 24.95 | 24.62 | 24.95 | 24.46 | 24.50 | 24.40 | 24.30 | 24.36 | 24.18 | 24.30 | 23.96 | 24.27 | 23.91 |
| $T_2$MW | 24.63 | 24.46 | 24.60 | 24.45 | 24.56 | 24.54 | 24.54 | 24.32 | 24.35 | 24.28 | 24.30 | 24.24 | 24.27 | 24.15 |
| $T_3$MW | 24.57 | 24.62 | 24.55 | 24.62 | 24.50 | 24.46 | 24.40 | 24.52 | 24.27 | 24.55 | 24.21 | 24.52 | 24.17 | 24.60 |
| $T_4$MW | 24.19 | 25.33 | 25.17 | 25.30 | - | - | - | - | - | - | - | - | - | - |

The values represent means of 3 replications
The values with different superscripts differ significantly at 5% level
- denotes the treatments discarded due to quality deterioration

Table 12b. Protein content of dried mushroom samples of *P. sajor-caju* during storage under ambient conditions with different drying techniques and packages

(%)

| Treatments | Months | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
| | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE | PP | PE |
| | | | a↓ | a↓ | ab↓ | ab↓ | bc↓ | bc↓ | cd↓ | cd↓ | d↓ | d↓ | e↓ | e↓ |
| $T_1$SD | 34.70 | 34.68 | 34.70 | 34.68 | 34.68 | 34.66 | 34.63 | 34.62 | 34.61 | 34.60 | 34.57 | 34.57 | 34.56 | 34.54 |
| $T_2$SD | 34.68 | 34.63 | 34.63 | 34.60 | 34.63 | 34.58 | 34.61 | 34.54 | 34.60 | 34.51 | 34.56 | 34.48 | 34.50 | 34.45 |
| $T_3$SD | 34.65 | 34.67 | 34.65 | 34.61 | 34.60 | 34.65 | 34.58 | 34.63 | 34.51 | 34.56 | 34.51 | 34.56 | 34.48 | 34.53 |
| $T_4$SD | 35.29 | 35.42 | 35.25 | 35.40 | - | - | - | - | - | - | - | - | - | - |
| $T_1$MD | 34.76 | 34.75 | 34.73 | 34.72 | 34.74 | 34.68 | 34.72 | 34.64 | 34.65 | 34.60 | 34.65 | 34.60 | 34.61 | 34.57 |
| $T_2$MD | 34.77 | 34.83 | 34.76 | 34.81 | 34.73 | 34.80 | 34.70 | 34.78 | 34.59 | 34.71 | 34.59 | 34.71 | 34.57 | 34.68 |
| $T_3$MD | 34.81 | 34.83 | 34.81 | 34.83 | 34.74 | 34.80 | 34.70 | 34.76 | 34.59 | 34.67 | 34.59 | 34.67 | 34.56 | 34.58 |
| $T_4$MD | 35.42 | 35.43 | 35.39 | 35.40 | - | - | - | - | - | - | - | - | - | - |
| $T_1$MW | 35.72 | 34.76 | 35.69 | 34.76 | 34.68 | 34.66 | 34.65 | 34.63 | 34.60 | 34.56 | 34.60 | 34.56 | 34.60 | 34.50 |
| $T_2$MW | 34.81 | 34.73 | 34.81 | 34.70 | 34.76 | 34.68 | 34.74 | 34.65 | 34.66 | 34.59 | 34.66 | 34.59 | 34.64 | 34.55 |
| $T_3$MW | 34.78 | 34.81 | 34.78 | 34.80 | 34.73 | 34.75 | 34.68 | 34.70 | 34.59 | 34.66 | 34.59 | 34.66 | 34.54 | 34.61 |
| $T_4$MW | 35.44 | 35.43 | 35.40 | 35.41 | - | - | - | - | - | - | - | - | - | - |

The values represent means of 3 replications

The values with different superscripts differ significantly at 5% level

- denotes the treatments discarded due to quality deterioration

Table 13. Residual $SO_2$ of KMS treated dried mushroom *P. florida* and *P. sajor-caju* during storage under ambient conditions (ppm)

| Treatments | *P. florida* | | | | | | *P. sajar-caju* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| | (months) | | | | | | | | | | | |
| $T_3SD_{PP}$ | $90.20^{d}$ | $75.53^{c}$ | $66.03^{b}$ | $52.47^{b}$ | $33.60^{c}$ | $18.90^{c}$ | $84.30^{c}$ | $79.20^{c}$ | $69.47^{c}$ | $60.63^{bc}$ | $34.37^{c}$ | $25.27^{c}$ |
| $T_3SD_{PE}$ | $89.83^{c}$ | $76.03^{c}$ | $67.90^{b}$ | $55.53^{b}$ | $31.47^{c}$ | $15.50^{c}$ | $86.60^{c}$ | $79.33^{c}$ | $68.97^{c}$ | $57.57^{c}$ | $34.23^{c}$ | $24.97^{c}$ |
| $T_3MD_{PP}$ | $105.13^{b}$ | $92.17^{b}$ | $80.90^{a}$ | $57.12^{b}$ | $51.26^{b}$ | $33.87^{b}$ | $98.70^{b}$ | $85.93^{b}$ | $75.17^{b}$ | $61.50^{b}$ | $41.33^{b}$ | $29.57^{b}$ |
| $T_3MD_{PE}$ | $102.83^{b}$ | $89.00^{b}$ | $76.17^{ab}$ | $58.87^{b}$ | $53.80^{b}$ | $36.30^{b}$ | $96.73^{b}$ | $81.80^{c}$ | $73.03^{b}$ | $60.37^{bc}$ | $41.07^{b}$ | $31.53^{ab}$ |
| $T_3MW_{PP}$ | $126.67^{a}$ | $97.30^{a}$ | $85.00^{a}$ | $70.40^{a}$ | $62.17^{a}$ | $53.23^{a}$ | $109.07^{a}$ | $93.63^{a}$ | $81.63^{a}$ | $65.83^{a}$ | $44.07^{ab}$ | $34.83^{a}$ |
| $T_3MW_{PE}$ | $127.00^{a}$ | $99.40^{a}$ | $75.67^{a}$ | $67.57^{a}$ | $55.97^{ab}$ | $51.87^{a}$ | $114.27^{a}$ | $96.53^{a}$ | $82.13^{a}$ | $66.13^{a}$ | $47.73^{a}$ | $35.40^{a}$ |

The values represent means of 3 replications
The values with different superscripts differ significantly at 5% level

reconstitution the samples are less comparable to fresh samples in terms of texture, flavour and appearance. However, the keeping quality was appreciable and as powdered mushroom product, the quality was excellent, hence the monthly sensory quality evaluation of reconstituted samples were not carried out.

# Discussion

# 5. DISCUSSION

Mushroom, an edible fungus, is the most priced commodity among vegetables, for its nutritive value and for characteristic aroma. But unlike fruits and vegetables, mushrooms lack thick protective surface coating of suberin or cuticle. Their richness in water content and phenols leads to rapid loss of water and enzymatic browning resulting in fast deterioration at ambient temperature; added to it, mushrooms respire at a very fast rate, which enhances further to the rapidity of deterioration. Mushrooms are appreciated with its colour and flavour, but due to the fast respiration and deterioration, it looses its texture, develop off-flavour and undergoes discolouration, limiting the marketing period only to a few hours under ambient conditions, resulting in financial loss to the mushroom growers. By evolving a simple and cheap technique to extend the shelf-life of mushroom atleast by a few hours under ambient conditions could make the materials to reach any refrigerated storage before the onset of discolouration or deterioration. Besides this, the preservation of mushrooms into more stable products at the time of gluts in the market could add value to the highly perishable commodity. The results of the studies conducted to evolve a simple and cheap technique to extend the shelf-life of fresh mushrooms and to improve the quality of dehydration technique are discussed in this chapter.

## 5.1 Standardisation of packaging and storage technique to extend the shelf-life of fresh mushrooms both under ambient and refrigerated conditions

Mushrooms lack a protective epidermal structure to prevent excessive moisture loss and has very high transpiration rates. The discolouration in mushrooms is caused by drying, bruising and enzymatic browning. Besides moisture, mushrooms are sensitive to desiccation and drought, consequently a

suitable packaging is essential during storage. Providing a packaging to mushrooms with a suitable material is a rate limiting step in weight loss (Gormley and MacCanna, 1967). By reducing the rate of transpiration, freshness can be maintained, therefore a film with correct water vapour transmission rate is of prime importance. Moisture retentive over wraps or film caps usually are beneficial in reducing the moisture loss.

In the present study, the treatments, PP with no ventilation and PP with air blown in were recorded as the most superior treatments in all the attributes, which could store mushrooms successfully for 36 hours, under ambient conditions and 10 days under refrigerated storage (4±1°C).

The activity of tyrosinase responsible for mushroom browning is dependent on $O_2$ concentration (Duckworth and Coleman, 1970); at lower $O_2$ concentration (below 21% $O_2$) the enzyme activity is reduced. When mushrooms stored in PP without any ventilation, they respire fast and modifies the surrounding system equally fast, thus the package acts as a sort of modified atmosphere due to the build up of $CO_2$ and reduction of $O_2$ within the bags which also reduced the rate of metabolism of the commodity. Therefore in the present study, the retention of colour by mushrooms packaged in PP without ventilation and with air blown in could be attributed to the reduced $O_2$ during storage, which suppressed the enzymatic browning and reduced microbial population. The findings of Doores *et al.* (1987), Beelmen *et al.* (1989) and Hotchkiss and Banco (1992) supported this result, they had stated that the improved colour might be attributed to the lower deterioration resulting in from low $O_2$ in MAP. Balakrishnan (1994) also got similar results.

During the process of respiration and transpiration, the produce looses water, which is not replinished after harvest. Loss of moisture is the most obvious

way in which freshness is lost and it affects the appearance, texture and saleability under open conditions.

Physiological loss in weight (PLW) is the loss of saleable weight, and hence has to be minimised. Minimising the water losses from the produce involve lowering the capacity of the surrounding air to take up additional water, that is, the vapour pressure difference between the produce and the air surrounding it should be minimised. This is the principle behind providing a pre-package to the fresh mushroom.

Loss of water from the produce as a result of respiration and transpiration reduces the fresh appeal. In the modified atmosphere packaging, utilization of $O_2$ for respiration produces respiratory heat and water, resulting in high humidity around the commodity.

Polypropylene with no ventilation and PP with air blown in recorded the least PLW upto the end of the storage. The PP acts as a controlled condition and it reduces the weight loss and extends the shelf-life of the mushrooms. The low PLW is due to the high humidity created within the packages by the respiring fruits and low water vapour transmission rate of the packaging material.

In mushrooms packaged in PP with 0.4 per cent ventilation, the PLW was higher compared to the those packaged in PP with no ventilation and PP with air blown in; here the loss of moisture by transpiration from mushrooms will be higher through the ventilation, which resulted in rapid weight loss. The results are in conformity with the findings of Saxena and Rai (1988). The excessive water loss through the ventilated PP films caused rapid browning on the mushroom surfaces. This fact is supported by Roy *et al.* (1995) who reported that loss of whiteness in mushrooms was proportional to loss of water during storage whether covered or

uncovered. The highest PLW was noticed in control samples; here the rapid loss of moisture from the mushrooms can be attributed to the rapid browning in control samples.

Out of the packaged samples, the PLW was maximum in mushrooms packaged in kraft paper bags followed by those in cake boxes. It is due to the higher rate of water vapour transmission of the packaging material used. This resulted in higher transpiration rate, and thus low relative humidity in the system. The higher water absorption property of the paper resulted in faster drying up and browning.

The results showed that the mushroom packaged in PP bags with in-package fumigant deteriorated faster in texture and they decayed faster. The results are in conformity with the findings of Dhar (1992). However, the treatments in which mushrooms pretreated with citric acid solution, air dried and stored in PP with 0.4 per cent ventilation was keeping more compared to those stored in PP with in-package fumigant. The result is in conformity with the findings of McCord and Kilara (1983) who reported that citric acid at pH 3.5 was effective in inhibiting browning of mushrooms; the use of citric acid as acidulant was capable of inhibiting both enzymatic (by lowered pH) and non-enzymatic activity (by citric molecule). However, the steeping in citric acid solution might have imbibed the water into the tissues of the mushrooms, thus inviting faster microbial attack and faster decay compared to mushroom packaged in PP with no ventilation.

Storage under low temperature is suggested as an excellent method for restricting deterioration of harvested mushroom for a limited period of time. Maturation and textural changes are slowed down at low temperature, thereby maintaining an excellent quality. The most important parameters for extending the shelf-life of mushrooms are low temperature and correct internal relative humidity.

The results of the present study showed that under low temperature also (4 ± 1°C) the same treatments, that is, PP without ventilation and PP with 'air blown in' were having the maximum shelf-life. Storage under low temperature reduces the activity of the enzymes and retards the growth which is mostly responsible for the better keeping quality. Low temperature also prevents microbial infection and discourages further development of rot caused by bacteria and molds. The treatments, PP with no ventilation, and air blown in, was kept under low temperature storage (4 ± 1°C) for 10 days without any change in colour, flavour and texture or decay. When stored in 0.4 per cent ventilated PP bags, they could be kept for seven days only with little change in colour, flavour and texture. Hence the results here indicate that packaging fresh mushrooms in unventilated PP bags is superior to that in air ventilated PP bags. These results are in conformity with the findings of Dhar (1992) who observed intense browning, excessive veil opening along with increased cap diameter and heavy water condensation in perforated packs, which resulted in quick spoilage of mushrooms.

The rate of PLW was lower in mushrooms stored under low temperature storage, compared to those stored under ambient conditions. Minimising water losses from the produce involve lowering the capacity of the surrounding air to take up water, that is, the vapour pressure difference between the produce and the air surrounding it should be reduced. The RH under refrigerated system is higher, compared to ambient conditions, hence the vapour pressure difference is reduced, resulting in lower rate of moisture loss from the commodity.

The PLW was the lowest for mushrooms packaged in PP with no ventilation and PP with air blown in, when compared to all other treatments. The same reasons under ambient conditions may be attributed to this also.

The decay percentage was also the lowest in mushrooms packaged in PP with no ventilation and PP with air blown, in both under ambient and refrigerated conditions. Reduced $O_2$ in the modified atmospheric packaging brought about reduction in spoilage (Doores *et al.*, 1987, Beelman *et al.*, 1989). The findings of Beit-Halachmy and Mannheim (1992) and Saray *et al.* (1995) further authenticated this result.

The combined effects of PLW and spoilage determine the ultimate marketability of the produce (Onwuzulu *et al.*, 1995). Hence the treatments in which mushrooms were packaged in PP with no ventilation and PP with air blown in, were having the highest marketability compared to all other treatments for *P. florida* and *P. sajor-caju* under both ambient and refrigerated conditions.

Ascorbic acid content of fresh *Pleurotus* spp. ranged between 2.2 and 5.0 mg/100 g on fresh weight basis, depending upon the species [Crisan and Sands (1978); Bano and Rajarathnam (1982); Li and Chang (1985); Rai *et al.* (1988); Rai and Saxena (1989)]. A decline in ascorbic acid content was observed in both *P. florida* and *P. sajor-caju*, with the advancement of storage period both under ambient and refrigerated storage in the present study.

Ascorbic acid in fruits and vegetables is sensitive to degradation as the plant tissues contain certain enzymes like ascorbic acid oxidase, phenolase etc. which are responsible for its oxidative degradation (White and Salvey, 1974), especially when cellular disorganisation occur due to mechanical damage, rotting or senescence, these oxidative activities become operative and leads to vitamin loss (Harris and Karmas, 1977). Therefore the gradual decline of ascorbic acid during storage might be due to senescence. The control samples lost the maximum ascorbic acid content during storage, this is because of the high $O_2$ content in the air, which

makes mushrooms more susceptible to disintegration of ascorbic acid as suggested by Singh *et al.* (1970).

The loss of ascorbic acid was minimum in the mushrooms packaged in PP with no ventilation followed by those packaged in PP with air blown in, both under ambient and refrigerated storage; the $O_2$ concentration within the modified atmospheric packaging is reduced due to respiration, which might have brought down the rate of oxidative changes including the oxidation of ascorbic acid. In addition to this, ascorbic acid is water soluble. The lower rate of moisture loss, that is, lower PLW might have also contributed to the maximum retention of ascorbic acid.

The rate of loss of ascorbic acid was comparatively low in samples stored at low temperature storage compared to mushrooms stored under ambient temperature. Probably under low temperature storage, the rate of metabolic activities is also low, thus the enzyme activity is lowered. Ascorbic acid is water soluble, hence its loss is related with PLW, as low temperature storage reduces PLW compared to ambient conditions, the loss of ascorbic acid will also be proportionately lower.

When the protein content of fresh mushrooms during storage both under ambient and refrigerated conditions are concerned, no significant reduction was observed in both speces of mushrooms, as they were not exposed to any protein denaturing conditions during storage.

The fresh mushroom samples packaged with in-package fumigant (KMS + citric acid) were analysed for the residual $SO_2$ content. The samples were cooked in boiling water for five minutes, as it is consumed only in the cooked form. On

analysing, no residual $SO_2$ could be detected; sulphur dioxide is sensitive to heat, and hence might have escaped from the samples at the time of boiling.

Mushroom samples of both *P. florida* and *P. sajor-caju* packaged in unventilated PP bags after 36 hours were organoleptically evaluated in comparison with fresh mushroom samples. All the parameters of the packaged samples of each species (viz., overall appearance, colour, flavour and texture) were rated statistically on par with those of corresponding fresh samples, indicating total consumer acceptability of the packaged samples.

Based on all the results *vide supra*, it may be concluded that mushroom samples packaged in unventilated PP bags can keep well for 36 hours under ambient conditions for both speces with minimal deterioration in quality attributes; and within this period, one can transport this produce to any marketing centre having cold storage facility without the help of a refer-van.

## 5.2 Quality improvement in dehydration and storage

Mushrooms being a highly perishable commodity and due to the market glut during the time of harvest, some means of its preservation becomes imperative. Dehydration is a widely used method for long term storage of oyster mushroom (Saxena and Rai, 1989) and is comparatively a cheaper method employed on commercial scale. It involves simple air drying to modern freeze drying techniques. Even though freeze drying has several advantages over air drying, it is an expensive technique. Therefore air drying is most commonly employed.

Drying refers to the removal of water by heat to such a level that biochemical and microbial activity is checked due to reduced water activity in the product.

In the present study, out of the four pre-treatments tried and three methods of drying employed viz., sun-drying, mechanical drying and microwave oven drying, all the blanched samples [blanching in boiling water ($T_1$), blanching in citric acid solution ($T_2$), blanching in (citric acid + salt) solution followed by dipping in KMS + citric acid solution for 30 minutes ($T_3$)] were not showing any deterioration even after six months of storage whereas the samples dried without any pre-treatment, showed deterioration even after one month of storage. By drying, the water activity get reduced to such a level that biochemical activity and microbial activity are kept at minimal, which was further maintained by providing packaging to the product. The dehydrated mushrooms are comparatively hygroscopic, therefore unless stored properly will pick up moisture rapidly and will invite microbial spoilage, thus deteriorating the product. So providing a suitable packaging to the dried product becomes inevitable.

The unblanched samples were showing faster deterioration compared to the blanched samples after drying. Blanching is a hot-water treatment in which vegetables or fruits are usually heated in water or live steam before processing (Kalra, 1990). This is to inactivate the enzymes, to prevent browning in the dried product.

Mushrooms are more susceptible to enzymatic browning when dried in a moist condition at 30-35°C, but browning can be inhibited if the temperature is above 60°C. The blanching of mushrooms by immersion in boiling water for two minutes, helped in obtaining good quality dried mushrooms (Singh *et al.*, 1995). Superior quality dried mushrooms were obtained by Pruthi *et al.* (1978) when water blanched for three to four minutes than steam blanched samples. In the present study, the control lot (unblanched) though initially was better in colour, texture and rehydration properties, during storage, it was more susceptible to darkening and off-flavour development than the properly blanched lots.

Mushrooms have very delicate texture and aroma and as such they require special precautions during the dehydration process. Blanching itself seemed to adversely affect the quality of the product, especially the colour, texture and rehydration properties. However, for complete inactivation of enzyme, blanching was found very essential (Pruthi *et al.*, 1978). These reasons may be attributed to the initial retention of better colour and texture, in the unblanched lots compared to the blanched lots.

This is also in conformity with the findings of Kumar *et al.* (1980) who observed that the blanched and sugar treated dehydrated *P. flabellatus* had no visible browning upto six months, whereas the unblanched dehydrated mushrooms had a shelf-life of only one month, which turned distinctly dark in colour, leathery in texture and slightly bitter in taste.

The mushroom samples dried after blanching in ctiric acid + salt solution and dipping in KMS + citric acid solution for 30 minutes showed the best colour and overall appearance among the blanched samples. Sulphuring or sulphiting is known to prevent the enzyme catalyzed oxidative changes, inhibit microbial deterioration and facilitate drying by plasmolyzing the cells (Tanga, 1974). The texture was adversely affected compared to unblanched dried samples, which might be due to blanching treatment. However, blanching was found essential to completely inactivate the enzymes and to prevent browning of the dried product. Bano *et al.* (1992) found that the samples without blanching, but with $SO_2$ tratement in solution did not stay for long time, evidently reflecting on the enzymatic browning.

Out of the three methods of drying, the mushrooms dried under microwave oven was found to have the best colour, flavour and texture. The results are in corroboration with the findings of Ruello (1984) and Rao *et al.* (1995) who

reported that microwaved food had appearance and taste quite different from conventionally cooked food, thus resulting in better sensory quality. Retention of characteristic aroma compound (1-octen-3-ol) and its oxidation products (1-octen-3-one) were positively affected by microwave oven drying (Rao *et al.*, 1995).

Mechanically dried mushroom samples were having better overall acceptability compared to sun-dried samples. This is supported by Mudahar and Bains (1982), Katiyar (1985), Bano *et al.* (1992), Geetha *et al.* (1995) and Suharban and Natarajan (1995).

The time taken for drying the blanched mushrooms was 14 hours in sun-drying, 11 hours in mechanical drying and only 90 minutes in microwave oven drying. The unblanched samples took relatively lesser time in all the three methods of drying. This difference in time for drying may be attributed to difference in bound moisture content as suggested by Suguna *et al.* (1995).

Sahni *et al.* (1998) reported that microwave energy is believed to inactivate microbes by the conventional thermal mechanism including potentially irreversible heat denaturation of enzymes, proteins, nucleic acids or other cellular constituents vital to cell metabolism and reproduction resulting in cellular death. However, Chipley (1980) proposed that an athermal mechanism of lethal action exists, an effect attributable only to the intrinsic nature of microwave, and unrelated to lethality caused by heat. These findings are supported by Rao *et al.* (1995). Bano *et al.* (1992) suggested that at a temperature of 55 to 60°C, the insects and microbes on the mushroom would be killed within a few hours, during mechanical drying. Therefore, all these factors including fast drying in a dust free atmosphere might have attributed to the better appearance of microwave oven dried and mechanically dried samples, over sun-dried samples.

Dehydration ratio is an indicator of yield. Yield and quality of the dried product are influenced by factors such as initial moisture content, drying temperature and time, susceptibility of the material to heat damage, pre-drying treatment and moisture content of the finished produce (Kaushal and Sharma, 1995).

Highest yield was recorded in microwave oven drying followed by mechanical drying and sun-drying. The highest yield in microwave oven drying may be attributed to the shorter period of exposure of the material to heat damage; followed by mechanical drying and sun-drying due to longer time of exposure to heat damage. This finding is supported by Decareau (1984) who reported that microwave processing resulted in shorter processing time, higher yields and better quality than by conventional drying. The report of Ruello (1984) that fast cooking time of microwaves resulted in the retention of volatile substances which were usually expelled during conventional cooking, further authenticated the result.

Out of the four pretreatments, $T_3$ (citric acid + KMS + salt) recorded the highest yield, followed by $T_2$ (blanching in citric acid solution), $T_4$ (untreated dried samples) and $T_1$ (blanching in boiling water) in the respective order. Probably the particles of citric acid, KMS and salt might have entered the intercellular spaces of mushrooms, thus contributing to the higher weight; in addition, steeping of mushrooms in citric acid + KMS solution must have increased the bound moisture content, thus resulting in higher weight of the dried product, which is evident from the residual moisture content of the samples immediately after drying, that is, $T_3$ was having highest residual moisture content compared to other treatments. The mushrooms lost weight due to blanching, which resulted in lower yield of $T_1$ compared to $T_4$ (the untreated dried samples).

The rate of drying was rapid for the samples dried without any pretreatment in all the methods of drying, compared to all other treatments, which is due to the lower bound moisture content in these samples as mentioned earlier (Suguna *et al.*, 1995).

Similar to dehydration ratio, microwave oven dried samples showed minimum shrinkage, that is, higher shrinkage ratio, followed by mechanical and sun-drying; this again can be attributed to the duration of heat involvement, more the time of exposure to heat, more will be the textural break down; microwave oven drying involved the least time, hence the higher shrinkage ratio.

Among the different pretreatments, the treatment $T_3$ (citric acid + KMS + salt) recorded the lowest shrinkage. This is in agreement with the findings of Nehru *et al.* (1995) who reported that the samples dried after 0.5 per cent KMS treatment was superior to water blanched, untreated and sodium benzoate treated samples with respect to colour, appearance, flavour and texture.

Comparing the various methods of drying, microwave oven drying was superior to mechanical and sun-drying with respect to rehydration ratio. Better texture retention by the microwave oven drying compared to other methods might have attributed to this.

The fastest rehydration and highest reconstitution ratio was exhibited by the samples dried without giving any pretreatment, when compared to the blanched samples. This result was in conformity with the findings of Pruthi *et al.* (1978) and Suguna *et al.* (1995), who reported higher and faster rehydration in the unblanched mushrooms compared to the blanched samples. The elasticity of cell walls and swelling power of starch, which are important for good rehydration are reduced during heat treatment as suggested by Arsdel and Copley (1963); the lower

rehydration ratio of blanched samples can be explained by this. The rehydration ratio of blanched, sulphited lots were higher than that of non-sulphited, blanched lots, this might be because of the better texture retention in the sulphited lots. During the rehydration, the steeping liquid in the case of unblanched lots, turned brown and turbid whereas for the blanched sulphited lots, the solution remained clear; probably in the former, starch might not have undergone gelatinization.

The residual moisture content was maximum in the sun-dried samples followed by mechanical and microwave oven dried samples. This indicates that microwave oven drying was the most efficient with maximum removal of moisture in a shorter duration. When comparing the treatments, the treatment $T_3$ (blanching in citric acid + salt solution followed by steeping in KMS + citric acid solution) was having the highest residual moisture content, this might be because of the increased bound moisture content due to steeping, resulting in higher initial moisture content. A gradual increase in the moisture content was observed during storage in all the dried samples irrespective of packaging material used; however the increase did not cross nine per cent, above which mushrooms were moist and unacceptable (Pruthi *et al.*, 1978).

A substantial reduction in the ascorbic acid content was observed in all the dried samples, however the reduction was the least in microwave oven dried, this is supported by the findings of Mabesa and Baldwin (1978); and the maximum loss was observed in sun-dried samples, this may be due to the longer exposure to sun-drying. Loss in ascorbic acid can be attributed to factors such as cellular disorganisation, exposure to heat etc. (Harris and Karmas, 1977). In the present study also, wherever dried samples with better texture, better retention of ascorbic acid was found. A reduction of ascorbic acid was also found in all the samples during storage, this is in agreement with the findings of Mudahar and Bains (1982).

A significant reduction of protein in the blanched samples compared to unblanched samples immediately after blanching was observed. Pruthi *et al.* (1984) and Nehru *et al.* (1995) obtained similar results. A reduction of protein may be attributed to the denaturation of protein due to the heat treatment during blanching. A gradual decline of protein from first to sixth months of storage was observed and the reduction was found to be significant. This is in conformity with the findings of Rai and Saxena (1989), who observed a decline in soluble proteins during storage. Kaushal and Sharma (1995) also got similar results, this is because of the increased proteinase activity during storage.

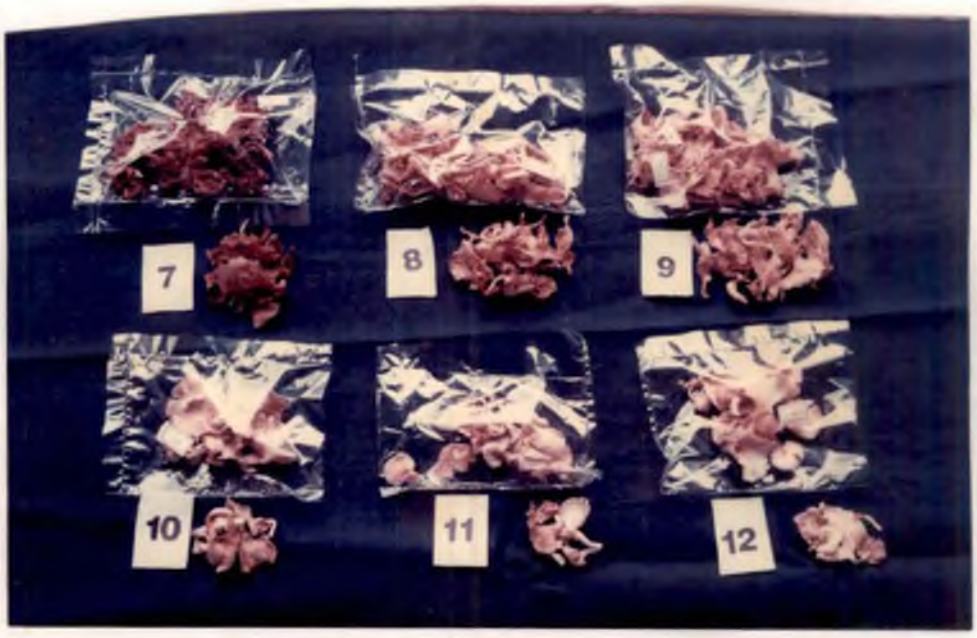
When the samples dried after treating with citric acid + KMS + salt were analysed for the residual $SO_2$ content, all were having levels within the prescribed FPO limit (2000 ppm).

Maximum residual $SO_2$ was detected in the microwave oven dried samples, with the pre-treatment, $T_3$ (citric acid + KMS + salt), compared to mechanical and sun-drying; the time of exposure to heat was minimum in microwave oven drying, therefore maximum $SO_2$ was retained in the samples. Since sulphur dioxide will escape as gas when exposed to heat for longer periods, sun-dried samples showed minimum residual $SO_2$ followed by mechanically dried samples. Mudahar and Bains (1982) suggested that the higher residual $SO_2$ in the dehydrated samples, both free and bound seemed to be responsible for restraining the growing reactions in those samples of mushroom.

Concluding the above results, mushrooms pretreated with citric acid + KMS + salt and subsequently dried under microwave oven gave the best result (Plate 5). Though microwave oven drying looks an expensive proposition, the quality wise it outstands all other methods of drying and hence can fetch premium price. The samples though steeped in KMS solution, the residual $SO_2$ was much

Plate 5. Dehydrated mushroom *P. florida* packaged in PP bags under various methods viz.,

7. Citric acid + KMS+salt followed by sun-drying
8. - do - mechanical
9. - do - microwave oven
10. No pretreatment, but sun-dried
11. - do - mechanical
12. - do- microwave oven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below the permissible level, hence can be recommended. However, on a commercial drying, microwave oven can be substituted with a mechanical dryer with a little compromise to the quality. Dried samples will have to be stored in a well protected moisture barrier, polyethylene or polypropylene bags to prevent further absorption of moisture till its use.

# Summary

# 6. SUMMARY

Studies on the possibility of extending the shelf-life of oyster mushroom (*Pleurotus florida* Eger and *Pleurotus sajor-caju* (Fr.) Singer) were carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara during 1997-98. The main objectives were to develop a simple and cheap storage technique to extend the shelf-life of fresh mushroom and to improve the quality of dehydration for better colour retention, lesser shrinkage and faster reconstitution and for better storage of two species, viz., *P. florida* and *P. sajor-caju*.

The PLW was the least when fresh mushrooms were stored in polypropylene (PP) without ventilation and PP with air blown in. The spoilage was also the least in these samples and could be stored for 36 hours without any deterioration, while the control samples spoiled within a few hours.

Under refrigerated conditions also, the mushrooms packaged in PP with no ventilation and PP with air blown in were showing the least PLW and could be kept for 10 days without any deterioration whereas those packaged in PP with 0.4 per cent ventilation remained only for seven days. The samples stored in PP with no ventilation were organoleptically rated on par with that of fresh samples in colour, flavour, texture and overall appearance; the marketability was also on par with the fresh samples.

Under dehydration studies, the samples pretreated with citric acid + salt + KMS was found to be the best in quality. Though the untreated dried samples was having better colour and rehydration properties initially, they failed on subsequent storage; they remained only for a month without any change, whereas the former remained for six months without any change. Comparing the various methods of drying, microwave oven drying was superior to mechanical and sun-drying with

respect to rehydration ratio. The samples dried after the pretreatment, citric acid + KMS + salt, recorded the lowest shrinkage, longer storage and better yield. Between polypropylene and polyethylene (PE), as a packaging material for dried mushroom, no significant difference was observed.

Microwave oven drying though appears to be an expensive proposition, in terms of quality, it has an edge over other methods of drying. However, on a commercial scale, mechanical dryer can be substituted for microwave oven with a compromise to the quality. Dried materials will have to be packaged within PE or PP films to prevent further resorption of moisture.

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# SHELF-LIFE OF OYSTER MUSHROOM

## [*Pleurotus florida* Eger and *Pleurotus sajor-caju* (Fr.) Singer]

By

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## ABSTRACT OF A THESIS

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## ABSTRACT

An experiment was conducted at the Department of Processing Technology, College of Horticulture, Vellanikkara, during 1997-98 to evolve a simple and cheap storage technique for mushroom both under ambient and refrigerated conditions and to improve the quality of dehydration and storage for better colour retention, lesser shrinkage and faster reconstitution.

Packaging of mushrooms in PP without ventilation and PP with air blown in was evolved as a simple and cheap technique to extend the shelf-life of fresh mushroom species *Pleurotus florida* and *Pleurotus sajor-caju* for 36 hours under ambient conditions and 10 days under refrigerated conditions with least deteriorative changes, the former having the same sensory attributes as that of fresh mushroom. Fresh mushroom will perish within a few hours of harvest under ambient conditions.

The mushroom samples of *Pleurotus florida* and *Pleurotus sajor-caju* dehydrated after pre-treating with citric acid + salt solution + KMS showed better colour, lesser shrinkage and higher reconstitution and could be stored for six months without any deterioration, when packaged in polypropylene or polyethylene bags.