DRYING STUDIES OF OYSTER MUSHROOM

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DECLARATION

We hereby declare that this project report entitled "***DRYING STUDIES OF OYSTER MUSHROOM "*** is a bonafide record of project work done by us during the course of study and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of another University or Society.

Place : Tavanur

Date :

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CERTIFICATE

Certified that this project report, entitled, *"**DRYING STUDIES OF OYSTER MUSHROOM** "* is a record of project work done jointly by Athira P and Binitha V. Pai under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of another University or Society.

Place: Tavanur
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ATHIRA P.

BINITHA V.PAI

Dedicated to our Loving Parents

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SYMBOLS AND ABBREVIATIONS

%	percentage
/	per
° C	degree celsius
µm	micro meter
CA	Citric Acid
cm	centimeter
Cu	copper
db	dry basis
EDTA	Ethylene Diamine Tetra Acetic
EMC	Equilibrium Moisture Content
et al.	and other people
etc.	etcetera
Fe	Iron
ft	feet
g/l	gram per litre
HCl	Hydrochloric Acid
HDPF	High Density Polythene Film
hrs.	hours
J	journal
KAU	Kerala Agricultural University
Kg	Kilogram
Kg/ft^2	Kilo gram per feet square
Kg/m^3	Kilogram per meter cube
KMS	potassium metabisulphite
KPa	Kilo pascal
LLDPE	linear low-density polyethylene
m/s	meter per second

m^2/s	meter square per second
mg	milligram
mg/Kg	milli gram per kilogram
min.	minutes
ml	milliliter
mW/ cm^2	milli watts per centimetre square
mm	millimeter
Mn	manganese
MP	metallised polyster
MPa	mega Pascal
N	normal
NaCl	Sodium Chloride
$NaHSO_3$	Sodium thiosulphate
NaOH	sodium hydroxide
no	number
Pa	Pascal
PE	polyethylene
PFP	Paper aluminium foil poly ethylene laminate
PHT&AP	Post harvest technology and agricultutral processing
PP	polypropylene
ppm	parts per million
RH	relative humidity
s	second
W	Watt
wb	wet basis
Zn	Zinc

Introduction

INTRODUCTION

The fruits and vegetables are of immense significance to man. Being rich source of carbohydrates, minerals, vitamins and dietary fibres, they have several direct and indirect advantages. India holds the first position in fruit production and the second in vegetable production in the world. Fruits and vegetables are living organisms and are highly perishable commodities. They are affected by a number of factors leading to the post harvest spoilage and hence post harvest losses are the major source of human food loss. The post harvest technology of horticultural crops envisage the development of appropriate techniques to reduce post harvest losses to prevent spoilage and helps to utilize maximum crops in a nutritious and safe manner. To reduce the losses, the biological and environmental factors involved in deterioration of perishables must be studied; and the post harvest technological procedures may be used.

Mushrooms, ‘white vegetables’ or ‘boneless vegetarian meat’ contain ample amounts of proteins, vitamins and fibres. Mushroom contains 20 to 35 per cent protein (dry weight) which is higher than those of vegetables and fruits and is of superior quality. It is considered ideal for patients of hypertension and diabetes. Mushroom offers prospects for converting lignocellulosic residues from agricultural fields and forests into protein rich biomass. Such processing of agro waste reduces environmental pollution. The by product of mushroom cultivation is a soil conditioner and also a good source of manure. It will open up new job opportunities especially in rural areas. Every part of the world is blessed with rich natural mushroom flora of its own, the type and nature depends on many of the ecological factors. Most of them are highly prized edible ones, but knowledge of identifying them is a must for their utilisation. The increased productivity demands proper post harvest infrastructure to increase shelf life and marketability. Since mushrooms are

perishable and delicate in nature, it cannot be kept fresh for more than 24hrs. After maturing of fruit body, the deterioration starts with the formation of brown colouration. This results in the quality deterioration and loss of marketability. To overcome this problem, especially during peak season, suitable post harvest management practices are to be followed to maximize the shelf life and marketability of mushrooms.

Mushroom has a huge domestic and foreign market. It is estimated that there is a world market for 20 lakh tonnes per annum in which the contribution of India is negligible (www.fao.org). In the domestic market the availability of mushroom is limited to cities and big towns only. Mushrooms are available in raw form and in dried form. There is huge international demand for dried mushroom and the farmers get a farm gate price of around Rs.250 per kg for dried oyster mushroom. There are exporters in the market who are willing to supply the spawn (seed material) and buy the dried mushrooms. The production of mushroom has increased at a fast rate from 4000 tonnes in 1985-86 to 30,000 tonnes in 1996-97 (Suresh Chandra and Samsher, 2006). Regular availability of mushroom is assured by preservation techniques. The most accepted technique for mushroom preservation is drying.

Drying is a preservation technique that reduces the moisture content of agricultural products in order to prevent spoilage and to maintain their quality. In practice, the agricultural products are dried either on paved grounds in the sun or with a drying system using an energy source. The natural sun drying has been used all over the world for thousands of years. This method has several disadvantages like damage to products by rodents, birds, animals, degradation through rain, snow, wind, contamination by dust, dirt, environment pollution, splitting of grain, insect infestation. Open air drying changes the surface characteristics of material and alters its reflectivity and colour. Chemical changes to carotenoid and chlorophyll pigments are caused by heat and oxidation in drying. Longer dying time and higher drying temperatures result in pigment losses (Verma and Joshi, 2000).

In the drying process it is essential to consider two important criteria like product characteristics and drying conditions. Product quality is of great importance in food drying. In fact, the first objective is to remove moisture from the product and to stabilize it. But in food drying many other changes may occur like physico-chemical modifications that modify the overall quality of the final product. Thus, drying of products must also preserve various quality criteria, like nutritional factors (vitamin, minerals), colour, shape and texture.

With this point of view, a project was undertaken at Kelappaji College of Agricultural Engineering and Technology, Tavanur to study the effects of different methods of drying and pretreatments on quality retention of oyster mushroom with the following objectives.

1) To study the effect of different methods of drying on the oyster mushroom,
   a. Sun drying
   b. Convective drying.
   c. Fluidized bed drying.
   d. Freeze drying.
2) To study the effect of pretreatments on the quality of products
   a. Control mushroom.
   b. Blanched mushroom.
   c. Chemically treated blanched mushroom.
3) To analyse the quality of dried mushrooms in terms of
   a. Moisture content
   b. Protein content.
   c. Ash content.
   d. Rehydration ratio.
   e. sensory evaluation.
   f. Cooking quality.
4) Storage studies of these dried mushrooms.

Review of Literature

REVIEW OF LITERATURE

This chapter gives general information on Oyster mushroom, its chemical composition, various methods of drying and its effects on the quality of end products and storage studies of mushroom. Research done on these aspects are also reviewed and discussed in detail.

2.1 Oyster Mushrooms

The oyster is one of the most commonly sought wild mushrooms. The Oyster mushrooms (Pleurotus ostreatus) belong to the family Tricholomataceae. It looks, smells, and tastes like oysters. With virtually no stalk, this mushroom's oyster-shaped caps usually grow in layers on dead deciduous wood (or on some supermarket shelves), like clusters of oysters. It can also be cultivated on straw and other media. The moist, hairless, fragrant, white to smoky-gray caps are 2 to 8 inches wide. The spores are white. The Oyster Mushroom is wide-spread in temperate forests throughout the world. It is a saprophyte that acts as a primary decomposer on wood (http:// en.wikipedia.org/wiki/Oyster_mushroom).

Wasser and Weis (1999) conducted studies on the therapeutic effects of substances occurring in higher Basidiomycetes mushrooms. The study highlighted some of the recently isolated and identified substances of higher Basidiomycetes mushrooms origin that expressed promising antitumor, immune modulating, cardiovascular and hypercholesterolemia, antiviral, antibacterial, and antiparasitic effects. Anti tumour polysaccharides such as hetero-beta-glucans and their protein complexes (e.g., xyloglucans and acidic beta-glucan-containing uronic acid), as well as dietary fibers, lectins, and terpenoids were isolated from medicinal mushrooms. Both cellular components and secondary metabolites of a large number of mushrooms were used to treat a variety of diseases.

2.2 Chemical Composition of Oyster Mushrooms

Ekanem and Ubengama (2002) conducted study to evaluate the chemical composition, anti nutritional factors and shelf life of oyster mushrooms. The evaluation of moisture content, crude protein, ether extract, crude fibre and ash was done according to the AOAC procedures.

Composition

Calories	686.52 kcal/100 gram
Protein	15-25%
Crude fibre	7.4%
Moisture	90%
Ash content	9.8%
Calcium	0.018%
Magnesium	0.996%
Iron	0.121%
Zinc	0.221%
Phosphorous	0.222%

Table 2.1.Chemical composition of Oyster mushroom

Singh *et al*. (2003) conducted a study on nutritional composition, processing and preservation of the edible mushrooms found in Manipur for sustainable economic development. Nutritional composition viz., moisture, crude protein, fat, total ash and crude fibre were analysed for 14 edible mushrooms found in the Manipur, India. The moisture content ranges from 40.07 to 92.92 per cent, crude protein 8.89 to 27.29 per cent, fat 1.50 to 8.50 per cent, total ash 4.75 to 21.00 per cent and crude fibre 3.25 to 13.00 per cent. The processing of the mushrooms was done by direct sun drying as well as oven drying. Sun drying was found to be superior in retaining the best colour and condition for Auricularia spp., Lentinula spp., Pleurotus spp. and Schizophyllum commune. The dried mushrooms can be preserved in room condition for six months without any unwanted fungal and bacterial growth. Artificial cultivation of edible mushroom generates additional income for economically backward communities.

2.3. Drying Studies

Drying of agricultural products is the most widely used method of preservation. It refers to the removal of water from products containing 70 to 95 percent water that provides enough moisture to permit action by their own enzymes and those of micro organisms. The removal of water content below a certain level at which enzyme activity and growth of micro organisms is affected adversely ensures preservation for a long time. The desired products save energy, money and space in shipping, packaging, storing and transportation. It protects the products from attack of insects, moulds and other micro organisms during storage.

Micro organisms that cause food spoilage and decay cannot grow and multiply in the absence of water. When water content is reduced below 10 per cent, the micro organisms are not active. Drying involves two basic phenomena, vaporization of moisture from the surface of material and movement of moisture from internal part of material to its surface. Movement of moisture takes place due to diffusion, cell concentration and vapour pressure gradient.

2.3.1. Methods of drying

Maeda and Salunkhe (1981) studied the retention of Ascorbic Acid and Total Carotene in Solar Dried Vegetables. Four vegetables (African spinach, cow pea, sweet potato and cassava leaves) were dried in the open sunshine and in enclosed convectional solar driers with and without shade provision. Total carotene and ascorbic acid content in the fresh leaves and in leaves dried under the three drying conditions were assayed. The study showed that maximum retention of the two vitamins is obtained by drying vegetables in enclosed solar drier with shade. Direct sun exposure of vegetables as often practiced in the tropics resulted in marginal retention of the two vitamins.

Onayemi and Badifu (1987) conducted a study on the effect of blanching and drying methods on the nutritional and sensory quality of leafy vegetables. The type and conditions of the blanching treatment prior to drying affect the retention of ascorbic acid, carotene and ash in the dried vegetables. The sun-dried vegetables had inferior colour, texture and acceptability compared to the vegetables dried in the cabinet dryer. There were significant differences in the rehydration and drying ratio of the dried vegetable.

Pan *et al.* (1997) conducted a study on effect of a tempering period on drying of carrot in a fluidised bed drier. Drying of sliced carrot in a fluidised bed was studied experimentally for various air temperature, bed height and size of cubes. Effect of a tempering period that may be implemented into a drying cycle was examined with respect to drying kinetics and energy consumption. Although two stage drying with a tempering period increases the overall drying time, it shortens the drying time in a fluidized bed drier thus reducing energy consumption.

Pal and Chakravarthy (1997) conducted a study on a thin layer convective drying of mushrooms. Dehydration characteristics of the Oyster Pleurotus variety of mushroom were studied. Both untreated and treated (steam blanching followed by sulphating and citric acid pre-treatment before drying) mushrooms were dried in the thin layer drying experimental equipment at each of the drying air temperatures of 45, 50 and 60°C with air velocities of 0.9 and 1.6 m/s. Studies on the equilibrium moisture content (EMC) of both untreated and treated dehydrated mushrooms were performed at different relative humidities ranging from 11.2 to 86.3 per cent at 30°C. Taking drying time and quality of the dehydrated product into account, a combination of a drying air temperature of 50°C and an air velocity of 0.9 m/s appears to be suitable for drying of both untreated and treated mushrooms for a good dehydrated product.

Khalloufi *et al.* (2000) conducted study on the water activity of freeze dried mushrooms. Sorption isotherms obtained at 4, 13 and 27ºC were obtained for three types of wild and commercial mushrooms. The product was freeze dried for 72 hrs. and equilibrated over saturated salt solutions in a range of RH from 11 to 87 per cent. The equilibrium

moisture content was obtained when there was no appreciable change in sample weight. The sorption isotherms were determined for different freeze dried mushroom species .The effect of temperature on EMC was significant for mushrooms.

Czapski and Szudyga (2000) conducted a study on frozen mushrooms quality as affected by strain, flush, treatment before freezing and time of storage. Four strains of mushrooms (*Agaricus bisporus*)—U3, hybrids of U3 (3/1, M-300) and in-between strain No. 200—were treated before freezing: washed in water, washed in water containing sodium metabisulfite (3g/l), and washed in water containing sodium metabisulfite (5g/l) then immersed in boiling water for 20 s. Appearance and whiteness of frozen mushrooms were most affected by the washing in water containing sodium metabisulfite. The residue of sulfur dioxide changed from 52 mg/Kg after 1 day to 27 mg/Kg after 90 days of storage. The whitest mushrooms (fresh and frozen) were for No. 200 strain. Short-time immersion in boiling water markedly increased toughness of stored frozen mushrooms.

Kramkowski *et al.* (2001) conducted a study on the influence of temperature of freeze drying process on the mechanical properties of dried mushrooms. The result of this study was high value of maximum stress in the fresh mushrooms (0.5-0.7 MPa) undergoes high reduction in effect of freeze drying process (to the value of 0.05-0.04 MPa). The freeze-dried material preserves approximately constant stress value in a wide strain range.

Martinez-Soto *et al.* (2001) conducted a study on effect of pre-treatment and drying on the quality of oyster mushroom. Fruiting bodies of oyster mushroom were dried by hot-air drying, vacuum-drying and freeze-drying in order to compare food qualities after drying. Prior to drying, mushrooms were subjected to blanching or dipping in sodium metabisulphite solution (1 or 5 g/l) or dipping in citric acid solution (1 or 5 g/l). Drying of raw mushrooms was taken as a control. Blanching reduced the attractiveness of dry mushrooms, sodium metabisulphite improved it. It has been found that pre-treatment and drying method affects the course and rate of drying. Samples subjected to hot-air drying and vacuum-drying were darker than those freeze dried, which were clearly more attractive. The hot air and vacuum dried mushrooms on rehydration were inferior in quality

to the freeze dried samples. Flavour of the freeze dried mushroom was not significantly different from that of the hot air dried mushrooms. Food quality of dried mushrooms depends significantly on the type of drier used.

Kaur and Bawa (2002) conducted studies on fluidised bed drying of peas. Pre-treated and fluidised bed dried peas samples, showed that the drying air temperature, volume of air, weight of samples and pre-treatment effected the drying characteristics and quality. Unblanched, water blanched and alkali blanched peas samples dried in a fluidised bed drier at a speed of 6 m/s, using sample weight of 350 gram at varied drying temperatures.i.e. 100˚C, 120˚C and 140˚C showed the best results in terms of dehydration characteristics. Dried peas samples were rehydrated, chemically analysed and organoleptically evaluated to assess the product quality in terms of vitamin C retention. Higher the drying temperature, more were vitamin C losses. Sensory evaluation of rehydrated pea samples showed that the scores varied with the pre-treatment and temperature of drying.

Sablana *et al.* (2003) conducted a study on the effect of convective drying on apparent density, porosity and moisture diffusivity of potato and apple. During air drying apparent density of apple and potato varied from 676.2 to 839.6 kg/m^3 and 1214 to 1050 kg/m^3 respectively. In both cases porosity increased with decrease in moisture content. Drying temperature in the range of 60 to 80ºC did not have any effect on the degree of pore formation. With in the same temperature range effective moisture diffusivity for potato varied from 3.03×10^{ro} to 3.76×10^{ro} m^2/s and for apple it varied from 4.78×10^{ro} to 7.21×10^{ro} m^2/s respectively.

Arora *et al.* (2003) conducted a study on drying kinetics of Agaricus bisporus and Pleurotus florida mushrooms. Mushrooms were blanched in boiling water for 1 min. and immersed in solution containing 0.1 per cent citric acid and 0.25 per cent potassium metabisulfite for 15 min at room temperature. Treated mushrooms were dried in a tray dryer at selected temperatures (45°C, 50°C, 55°C, 60°C and 65°C). Results indicated that

drying took place in the falling–rate period, and the drying kinetics was adequately described by Page's model.

Kar and Gupta (2003) conducted an experiment on air drying of osmosed button mushrooms. Mushroom quarters osmosed in brine with solution to sample ratio of 6:1 and a temperature of 40˚C were dried in single layer at 55, 65 and 70˚C. The drying was carried from an initial moisture content of about 550 per cent (d.b) to nearly constant product weight of 7.5 per cent, 6.3 per cent and 5 per cent (d.b) respectively for 55, 65 and 75˚C. Drying process was essentially in falling rate period and could be completed in 300 to 600 minutes depending upon the air temperature. Shrinkage as measured by the product volume could be linearly related to moisture content. Rehydration and sensory attributes indicated that drying osmosed mushrooms at 65˚C could yield a highly acceptable product at speed of 6m/s and 140˚C. Alkali treatment did not have any added advantage over water blanching.

Kumar *et al*. (2004) conducted a study on effect of freeze drying on the quality of onion slices. Freeze dehydration was carried out in a pilot scale freeze dryer. The sample was frozen to -25±2°C for 4 hrs in stainless steel trays (loading density 0.63kg/ft²) and dehydrated at 100-300 µmHg absolute pressure and 40 to 60°C temperature. When the product was dried to less than 3 per cent moisture, it was removed from the drier and packed in PFP pouches in a room maintained at 20 to 30 per cent humidity. The product is of better appearance, colour and flavour. They readily rehydrate in cold water with in 2 minutes and absorb 82 per cent water with a rehydration ratio of 1:8.

Kalbarczyk (2004) conducted an experiment on the effect of liophilization on the aroma components in the fruit body of edible mushrooms. The qualitative and quantitative analysis of content of the volatile aroma compounds in the fruit bodies of two species of edible mushrooms was done. Oyster and nameko was performed by gas chromatography coupled with mass spectrometry. The most important components determining the aroma of these mushrooms were octen-1, 3 –ol and octanal. It also showed that a substance was affected by the method of liophilization. The sublimatic drying enabled the retention of 50

per cent aroma compounds in oyster fruit bodies and 39.2 per cent in nameko. Freezing of fruit body after harvesting enabled the retention of 63.5 per cent of aroma compounds in oyster fruit body and 75 per cent in nameko fruit body.

Gothandapani *et al*. (2004) conducted a study on evaluation of different methods of drying on the quality of oyster mushroom. Mushroom was dried in three methods viz., sun drying, thin layer drying and fluidized bed drying. It was found that fluidized bed drying with a temperature of 50°C for a period of 80 to 120 minutes was having a lower browning index. From the results it was found that different drying methods did not have any effect over the biochemical constituents of mushrooms. But treatment with potassium metabisulphide and blanching reduces the nutritive quantity due to the removal of water soluble nutrients. Browning index showed much variation. Treatment with chemicals and blanching improved the colour of mushroom when compared with sun dried samples. The microbial growth of oyster mushroom was considerably reduced by drying. The rate of microbial deterioration is high in other two.

Juan *et al.* (2004) conducted an experimental study on technological parameters of freeze-drying of mushroom. The purpose of this study was to determine the most efficient parameters for freeze drying of mushroom in order to improve process efficiency and product quality. Drying time, volume shrinkage, water absorption, pressure in drying chamber, temperature of the board, velocity of decreasing temperature during freezing and thickness of material were studied using 2 orthogonal experiments with 4 factors and 5 levels and a single factor experiment. Mathematical models were established to describe the parameters. The optimal combinations of the parameters for freeze drying technology were as follows: pressure in drying chamber- 111 Pa; temperature of the board- 42.5°C; velocity of decreasing temperature during freezing - 0.29°C/min; and thickness 6-10 mm.

Rodriguez *et al.* (2005) conducted a study on kinetic and quality study of mushroom drying under microwave and vacuum. In this work different ways of microwave vacuum drying were compared to freeze-drying. Results show that a decrement of the applied pressure produces a certain increase in the drying rate together with lower moisture

in the dehydrated product at the end. Temperature control inside the sample helps to ensure a better quality in the dehydrated product, than when controlled at the surface. Diffusivity coefficients show a correspondence with product temperature during drying. The microwave dried samples obtained with moderate power and temperature control of product show an important degree of quality similar to that obtained by freeze-drying.

Giri and Prasad (2006) conducted study on quality and sorption characteristics of microwave-vacuum, air and freeze dried button mushroom. Button mushrooms (Agarics bisporus) were dehydrated by three different drying techniques viz. hot-air, microwave-vacuum and freeze-drying to a moisture content of about 6 per cent (w.b.). Dehydrated samples were compared on the basis of different quality parameters such as colour, texture (hardness), rehydration ratio and sensory evaluation. Statistical analysis shows that freeze drying produced the best quality dehydrated products having maximum rehydration ratio, highest instrumental colour (L-value) and lowest hardness; the microwave-vacuum dried mushrooms were rated as equal to freeze-dried samples by a sensory panel in terms of appearance, colour and overall acceptability.

Giri and Prasad (2006) reported shrinkage and density changes during microwave-vacuum drying of button mushroom. Shrinkage characteristics and apparent density of whole button mushrooms were determined at various moisture content levels (ranging from 5 to 92 per cent wet basis) during microwave-vacuum drying at two different power (150 and 250 W) and pressure (10 and 20 kPa) levels. The above properties during convective hot air drying at 60°C were also measured for comparison. In both microwave-vacuum and air-drying methods, the shrinkage (volumetric and diametric) of mushroom showed a linear behavior with moisture content. Experimental data showed that the effect of the system pressure on shrinkage and density was more significant than the power level during microwave-vacuum drying. Moisture content and method of drying also affected shrinkage statistically.

Sampaio *et al*. (2006) conducted a study on effect of the drying process on the quality of shiitake mushroom. Edible mushroom are highly perishable foods. In this work,

the effects of some drying parameters on the quality of Shiitake mushroom were investigated: geometry of the raw material (whole and sliced), drying temperature (50°C and 70ºC) and final moisture content (5 per cent and 15 per cent wb). Experimental kinetics of drying was built and color and texture analyses were done in fresh and in rehydrated dried product. Drying kinetics showed that drying happened in falling-rate period and sliced mushroom dried at 70ºC required lesser drying time than other treatments. Mushroom dried at 70ºC showed less darkening. Drying time affected mushroom quality, evaluated by great hardness, gummosis and darkening.

Mishra (2006) conducted a study on drying characteristics of carrot under microwave-vacuum condition. Drying with moisture reduction provides extended shelf life to fresh fruits and vegetables. In this research microwave under vacuum was used to study the drying characteristics of carrot. Four different process variables such as microwave power (P), vacuum level (V), rotational speed (R) of the sample holder and time of drying (t) were considered. These variables were adjusted to get different drying conditions. Under these conditions experiments were done to find out the weight loss, moisture content, drying curve and quality parameters for carrot. The results show that the target moisture content could be achieved in much lesser time of drying when vacuum is supplemented to microwave drying.

Chandra and Samsher (2006) conducted experiments to study the dehydration and sensory quality evaluation of edible mushrooms. Several drying techniques like sun drying, solar drying, hot air drying, tray drying, fluidized bed drying, vacuum drying and freeze drying were adopted. Various pre-treatments of mushrooms before drying (washing in water, KMS or other formulations, blanching, sulphiting, steeping) have been attempted to check the browning reaction, flavour retention and quality of dehydrated mushroom slices.

2.4. Effect of Different Pre-treatments

Mate *et al.* (1999) conducted a study on the effect of blanching on the mechanical and rehydration properties of dried potato slices. Short-time blanched (2 min., 90°C), long-

time blanched (30 min., 90°C) and non-blanched potato slices were dried in a convective air drier and their mechanical and rehydration properties were compared. Blanching increased the flexibility and strength of dried potato slices, although the effects of short and long blanching were not significantly different. Unblanched potato slices did not have larger rehydration ratios than blanched ones. After rehydration for 30 min, samples from all treatments had higher strength and flexibility than cooked potatoes.

Negi and Roy (2000) conducted experiments to study the effect of blanching and drying methods on carotene, ascorbic acid and chlorophyll retention of leafy vegetable. Leaves of savoy beet (Beta vulgaris var bengalensis), amaranth (Amaranthus tricolor) and fenugreek (Trigonella foenum graecum) were subjected to different blanching and drying treatments to establish the retention of carotene, ascorbic acid and chlorophyll. The vegetables were blanched at 95±3 °C in water, water followed by potassium metabisulphite (KMS) dip, salt solution, salt solution followed by KMS mixture of sodium bicarbonate, magnesium oxide and KMS and dried in sun, shade, solar drier, cabinet drier and low temperature drier. Water blanching followed by KMS dip was found most suitable for blanching and low temperature drying had least drastic effect on carotene, ascorbic acid and chlorophyll content of the processed product.

Cokuner and Ozdemir (2000) conducted a study on acid and EDTA blanching effects on the essential element content of mushrooms (Agaricus bisporus). Many chemicals such as citric acid, ascorbic acid, hydrogen peroxide and ethylene diamine tetra acetic acid (EDTA) have been used as browning inhibitors as well as to control spoilage during storage and canning operations. In this study, four essential mineral elements were determined in fresh and blanched mushrooms (Agaricus bisporus). The effects of citric acid and EDTA blanching on the copper, zinc, iron and manganese content of mushrooms were investigated. Statistical analysis indicated that the differences in Fe, Cu, Mn and Zn levels between fresh and blanched mushrooms were not significant for citric acid blanching. However, mushrooms blanched with EDTA solutions contained significantly lower concentrations of Fe and Cu than those found in fresh mushrooms on a dry weight basis.

Papakumari *et al.* (2003) conducted studies on the influence of pretreatments on the drying parameters of chilli. The chilli was treated with calcium carbonate, potassium sulphate and potassium nitrate and time taken to come to safe moisture content of 8 to 10 per cent was studied. Significant visual difference was observed due to drying methods while tray drying was most effective method with less wrinkles on pod after drying. Pod colour on drying was bright red in tray drying, red in solar drying and light red in open yard sun-drying methods. Time for drying to a safe moisture content of about 9 per cent was significantly influenced by methods of drying. Tray drying was superior with less percentage of damaged pods.

Kar *et al*. (2004) conducted a study on microwave drying characteristics of button mushroom (Agaricus bisporus). Microwave drying behaviour of button mushroom was experimentally studied in relation to pretreatments: (1) blanching in boiling water for 3 min. and steeping in solution of 0.5 per cent NaHSO3+ 0.25 per cent citric acid (CA) at room temperature for 15 min; (2) blanching in boiling water for 3 min. and steeping in solution of 1 per cent KMS+ 0.25 per cent CA at room temperature for 15 min; (3) blanching in boiling water for 3 min. and steeping in solution to 0.1 per cent KMS+ 0.2 per cent CA+ 6 per cent sugar+ 3 per cent NaCl at room temperature for 15 min; (4) steeping in solution of 0.5 per cent KMS at room temperature for 15 min, no blanching; and (5) steeping in solution of 0.1 per cent KMS+ 0.2 per cent CA+ 6 per cent sugar+ 3 per cent NaCl at room temperature for 15 min, no blanching, and microwave power levels (155, 215, 275, 340 and 400 W). The optimum conditions of drying were established on the basis of rehydration ratio and sensory evaluation. Drying with pretreatment of blanching in boiling water for 3 min followed by steeping in solution of 0.1 per cent KMS+ 0.2 per cent CA+ 6 per cent sugar+ 3 per cent NaCl at room temperature for 15 min. at the microwave intensity of 400 W yielded an acceptable dehydrated product in about 45 min.

Arumuganathan *et al.* (2004) conducted a study on drying characteristics and effect of pretreatments on the quality of sun-dried oyster mushroom (Pleurotus florida). Samples of oyster mushroom were sun-dried after washing with 0.05 per cent potassium metabisulfite (KMS), 0.1 per cent citric acid, 0.05 per cent KMS+ 0.1 per cent citric acid,

125 ppm EDTA, 125 ppm EDTA+ 0.1 per cent citric acid, 100 ppm ascorbic acid, 100 ppm ascorbic acid+125 ppm EDTA, 100 ppm ascorbic acid+ 0.1 per cent citric acid, 0.05 per cent KMS+125 ppm EDTA, or 2, 4 or 6 per cent hydrogen peroxide. The mushrooms were dried for 15 hrs. to reduce the moisture content to 9 per cent. The quality of the dehydrated oyster mushroom was significantly affected by the pretreatments. Mushrooms washed with 0.05 per cent KMS+ 0.1 per cent citric acid produced good-quality dried product with the greatest reflectance values both before drying (71 per cent) and after drying (70 per cent).

Raj *et al.* (2006) conducted a study on effect of pre-treatment on the quality characteristics of dehydrated onion rings during storage. Two onion varieties ‘Poona Red ‘ and ’Bellary Red ‘were pre-treated with 0.25 per cent potassium metabisulphite and 0.05 per cent citric acid either alone or in combination and dehydrated to assess their effect on physico- chemical properties during storage at ambient temperature. Onion rings pre-treated with 0.2 per cent KMS were better for dehydration and had significantly less increase in moisture, reducing sugar while significantly less decrease in non reducing sugar, ascorbic acid and acidity during storage.

2.5. Storage Studies

Peter and Bosede (1999) conducted study on the quality changes in dried tomatoes stored in sealed polythene and open storage systems. The changes in quality attributes of dried tomatoes during storage using High Density Polythene Film (HDPF) and normal (traditional) open storage systems were quantified. 300g of the dried tomato fruits were packaged in each of the six high-density polythene film (HDPF) bags while similar quantities were in open bowls as practiced by the rural processors. Periodic assessment of some quality parameters, microbial loads, moisture content, color, vitamins A and C and phosphorus were conducted for a period of three months to ascertain how these two storage systems influence the changes in these quality attributes.

Burton1 *et al.* (2005) conducted a study on combination of plastic permeable film system for controlling post-harvest mushroom quality. Combination of micro porous and a relatively impermeable film was used to overwrap mushrooms. The modified atmosphere created by respiration could be controlled by adjusting the area of microporous film which in turn reduced the loss of mushroom quality assessed by developmental stage, colour, and weight loss and disease incidence.

Jayathunge and Illeperuma (2005) conducted a study on extension of post harvest life of oyster mushroom by modified atmosphere packaging technique. Mushrooms were packaged in polypropylene, low-density polyethylene, linear low-density polyethylene (LLDPE) packages after washing with 0.5 per cent calcium chloride and 0.5 per cent citric acid (CA), and based on off-colour and off-odour development, suitable packaging material and washing solution were selected. Effectiveness of magnesium oxide in modifying the in-package gaseous atmosphere and thereby extending the post harvest life was tested by monitoring the physicochemical properties. Oxygen concentration was 5.5 per cent and 9.9 per cent and carbon dioxide concentration was 8.1 per cent and 4.5 per cent, in the control and packages containing 3 g of magnesium oxide respectively. Packaging mushroom in 0.015 mm LLDPE packages with 3 g of magnesium oxide after washing with 0.5 per cent calcium chloride and 0.5 per cent CA was successful in extending the post harvest life at 8°C and 70 per cent RH from 6 days in commercial samples to 12 days.

Roopa *et al.* (2006) evaluated the effect of various packaging materials on the shelf stability of banana chips. Stability of banana chips packed in polyethylene (PE), polypropylene(PP), paper aluminium foil polyethylene laminate(PFP), PP/Nylon/PP and metallised polyster (MP) and stored at 5°C, ambient (19 to 33°C) and 37°C was determined. Slices (2.4mm thick) of banana were fried in coconut oil for 5 minutes at 150°C, cooled and packed. Sensory evaluation showed that banana chips stored after packing in PE and PP were acceptable up to 3 months while those in PFP, PP-Nyl-PP and MP were acceptable up to 4 months stored under ambient temperature at 37°C.

Materials and Methods

MATERIALS AND METHODS

This chapter mainly deals with the various drying methods used for drying mushroom and also the methodology for determining the quality of dried mushroom samples.

3.1 Test sample

The study was undertaken using oyster mushroom which was cultivated in the product analysis lab of the Department of PHT&AP, Kelappaji College of Agricultural Engineering and Technology, Tavanur by the following procedures.

3.1.1 Mushroom Cultivation

Paddy straw is the most suitable substrate for mushroom cultivation. Straw is cut into small bits of about 8-10 cm. in length or it can be made into small round twists and tied up. It is soaked in clean water overnight and excess water drained off. Then sterilize the substrate. Boil water in wide mouthed container and put wet substrate. Dip it in water for about 15-20 minutes. After sterilization, spread it over mesh and allow straw to cool down to room temperature. The spawn was procured from Kerala Agricultural University. Polyethylene bags (150-200 gauge) of size 25 cm. in diameter, 40-50 cm. in length are ideal for cultivation. A few holes were punched here and there for facilitating cross ventilation. A substrate is taken to form a layer of about 10-15 cm. at the bottom of the bag. A thin layer of spawn is spread over this along the circumference. Above this, a second layer of straw is spread and the same also is spawned. The polyethylene bag is filled up alternating with spawn and straw, finally the cover is made compact and the top tied. The filled bags can be kept lengthwise on a flat surface either on a platform or can be arranged on a shelf keeping at a distance of about 15 to 20 cm. in a cool, dark place. Spawn run will be optimum at temperature of 20 to 30°C, under relative humidity of 70-85 per cent. In 15 to 20 days white thread like mycelium can be seen inside the packet. In this stage polybags are ripped open. It can be hung or stacked lengthwise on the shelves of mushroom houses.

If moisture is not sufficient, water is to be sprinkled twice or thrice a day using sprayer. The mushroom initials appear in 5 to 10 days and the same can be harvested in another week's time. Flushes will continue to appear for a period of 3 to 5 weeks and they can be harvested at intervals of 5 to 8 days (KAU, Technical Bulletin-17).

3.2 Treatments

Three different treatments were used for this study

1. Control sample: Mushroom harvested within 3 hrs from the start of experiments.
2. Blanched sample: The mushrooms immersed in boiling water at 100°C for 4 minutes and drained by using filter paper.
3. Chemically treated blanched sample: Water blanched mushrooms steeped in 1% sodium benzoate along with 0.2% citric acid (overnight).

3.3 Methods of Drying

To study the drying characteristics of mushrooms a series of experiments were conducted in a freeze dryer, fluidized bed dryer, convective dryer and traditional sun drying. The above said treated samples were kept in various driers till the moisture content of the dried sample was in the range of below 10 percent. The time taken for each sample to reach this range of moisture content was noted. (Chandra and Samsher, 2006)

3.3.1. Freeze Drying of Mushrooms

The study was conducted using DELVAC freeze drier which had the following specifications, condenser capacity- 5 kg, condenser volume- 7.3 litres, condenser temperature- -55°C ±5°C, heat extraction rate- 180/kcal, digital vacuum and digital temperature display, 220/230 volt, 50 hertz single phase through servo stabilizer. The sample was frozen in a freezing chamber at- 40°C for 1 hour. The drying was conducted by heating plate at temperature of 30°C under pressure of 0.13 millibar in the drying chamber.

Plate 3.1 Freeze Dryer

3.3.2. Fluidized Bed Drying

A study was conducted using fluidized bed dryer. As per the reference (Verma and Joshi, 2000), the drying temperature of mushrooms is recommended in the range of 60 to 65°C. So the oyster mushrooms were dried in dryer at 60°C. The inlet temperature was controlled by using a thermostat and the time was set using a timer. There was a sudden removal of moisture from the sample; hence the weight of the sample was noted at an interval of 20 minutes.

Plate 3.2 Fluidized Bed Dryer

3.3.3. Convective Drying

The sample sets mentioned before were dried in a convective dryer. The dryer contained an air circulating fan to maintain a uniform temperature distribution .The samples were dried in a convective dryer at 60˚C. The weight of the sample was taken at an interval of one hour.

Plate 3.3 Convective Dryer

3.3.4 Sun Drying

The samples were dried in the open under sun. The ambient temperature was measured with a thermometer and intensity was measured using a suryamapi. The temperature was recorded as 35 to 40 °C and intensity was 56 mW/ cm^2. The weights were noted at an interval of one hour.

3.4 Analysis of Dried Mushrooms

3.4.1 Moisture Content

Moisture content was determined by using vacuum oven method (Ranganna, 1991). The dried sample was kept in the oven at 70˚C and 0.6 kg/cm^2 pressure for 4 hours.

Moisture content (%) = $\frac{Wm \times 100}{Wd}$

Where,

Wm= weight of moisture in gram

Wd= weight of sample in gram

Moisture content was expressed in wet basis.

3.4.2 Protein Content

The protein content was estimated using protein estimator with Copper sulphate, Potassium sulphate, concentrated sulphuric acid, Boric acid (4 per cent), sodium hydroxide (40 per cent), Methyl red and hydrochloric acid (0.1 N) as reagents.

3.4.2.1. Digestion

Copper sulphate and potassium sulphate were mixed in the ratio 1:5. Three gram of the mixture was mixed with 0.5 gram of dried sample in a tubular flask. Then 10 ml. sulphuric acid was added to it and heated at 400˚C for 2.5 hours. Appearance of light green colour indicates the complete digestion of protein in the sample. The sulphuric acid was neutralized by a scrubber system.

3.4.2.2. Distillation System

A fully automatic, completely programmable auto sequencing system was used for distillation. It involves three steps, boric acid addition, alkali addition and finally distillation. The nitrogen free extract was collected in a conical flask.

3.4.2.3. Titration System

The nitrogen free extract was titrated using 0.1 N HCl with methyl red as the indicator. The appearance of pale pink colour gave the end point.

Protein = $\frac{14 \times \text{normality of acid} \times \text{Titre value} \times 100 \times 6.25}{\text{Wt.of sample} \times 1000}$

Protein content is expressed in percentage.

Plate 3.4 Pelican's Protein Estimator

3.4.3 Rehydration Ratio

5 g of the sample was weighed and immersed in boiling water for 10 minutes at 100˚C. The sample was placed over a Whatman No: 4 filter paper to drain the excess water. Gentle suction was applied to ensure complete draining of water. Weight of rehydrated sample was taken (Ranganna, 1991).

Rehydration ratio = $\frac{\text{Weight of rehydrated sample}}{\text{Weight of dried sample}}$

3.4.4 Ash Content

The sample was weighed and placed in a crucible. The crucible was kept in a muffle furnace at a temperature of 525˚C for 5 hours. The white ash was obtained and weighed (Ranganna,1991).

$$\text{Ash content} = \frac{\text{Weight of white ash}}{\text{Weight of dried sample}}$$

Ash content expressed as kg of ash per kg of dry sample.

Plate 3.5 Muffle Furnace

3.4.5 Sensory Evaluation of Dried Sample

The 9- point hedonic rating scale was used for the purpose.

9 –Like extremely

8 – Like very much

7 – Like moderately

6 – Like slightly

5 – Neither like nor dislike

4 – Dislike slightly

3 – Dislike moderately

2 – Dislike very much

1 – Dislike extreme

The samples were arranged on a table with specific codes. The scale was easily understood by each of the panelists and their response was converted to numerical values for computation purposes. The panel included 12 experts. The final result was obtained by calculating the average of marks given by the panelist.

3.4.6 Cooking Quality

The recipe was prepared by adding same quantity of ingredients to the different samples. The recipe was subjected to analysis by the panelist and marks were awarded as per the preference. The final result was obtained by calculating the average of marks given by the panelist.

3.5 Storage Studies

Polyethylene and polypropylene are the most commonly used packaging materials. Hence, both of 400 gauge thicknesses were selected for packaging. The samples were packed using a hand sealing machine and stored at room temperature (27°C).

Results and Discussion

Results and Discussion

The cultivated mushrooms were subjected to different pre-treatments and then dried by various drying methods. The influences of these on the quality of mushrooms were studied.

This chapter highlights the results of various methods of drying of mushrooms and the quality evaluation of the dried samples.

4.1 Test Samples

The Oyster mushroom cultivated in the Product Analysis Lab, Kelappaji College of Agricultural Engineering and Technology, was used for the study. The initial moisture content, protein content and ash content were estimated by the standard methods explained in chapter III and the results were tabulated.

1.	Initial moisture content	90%
2.	Protein content	25.2% (db)
3.	Ash content	9.8%

Table 4.1: Composition of fresh mushrooms

4.2 Effect of Different Methods of Drying and Pretreatments on Quality

An investigation on the effect of various drying methods on the quality of the dried mushroom was done. Mushroom is a rich source of proteins, crude fibre and minerals. In this study moisture content, protein content, ash content, rehydration ratio, cooking quality

and sensory quality were considered as basic parameters of quality analysis. The details are discussed below.

4.2.1 Moisture content

4.2.1.1. Freeze drying

In the case of freeze drying intermittent observation of moisture content of mushroom is not feasible. But for prolonged shelf life of mushroom the recommended moisture content must be below 10 percent. In order to reach this ideal moisture content the period of drying was determined by the trial and error basis. Freeze drying for four hours was sufficient to reach the ideal moisture content. Hence the period of drying was fixed as 4 hrs. for further studies.

Sample	Drying time (hours)	Moisture content (per cent)
Control	4.0	9.0
Blanched	4.0	6.0
Chemical treatment	4.0	5.0

Table 4.2 Effect of Freeze drying on moisture content

From the above table, it is found that control sample had moisture content of 9 per cent whereas the pretreatments reduced the moisture content to a range of 5 to 6 per cent. This reduction in moisture content of the pretreated sample is due to the relaxation of the tissues that enabled the easy removal of water (www.agen.ufu.edu).

4.2.1.2 Fluidized Bed Drying

Control sample and the treated samples were subjected to drying in a fluidized bed drier maintained at a constant temperature of 60°C. This process required lesser drying

time compared to other drying methods. In fluidized bed driers, drying time is greatly shortened and all the particles are equally dried while they float in fluidized bed. In homogenized bed all the particles are exposed to same conditions of drying.

Sample	Drying time (hours)	Moisture content (per cent)
Control	2 hours 20 minutes	8.0
Blanched	1 hour 40 minutes	7.0
Chemical treatment	1 hour 40 minutes	7.0

Table 4.3 Effect of Fluidised bed drying on moisture content

The above table shows that control sample had moisture content of 8 per cent with a drying time of 2 hours 20 minutes whereas pretreatments reduced the moisture content to 7 per cent with a drying time of 1 hour 40 minutes. This is because in pretreated mushroom, tissues are relaxed which enabled easy removal of moisture.

Fig.4.1 Drying Characteristics of Fluidized Bed dried Mushroom

From the above figure, it is observed that for the first 30 minutes, there is a sudden decline in moisture content. This is due to the evaporation of moisture from the surface. After that there is a decrease in drying rate. This is due to the time taken for diffusion of moisture from the interior to the surface. The drying rate reached a constant value after 90 minutes of drying in pretreated samples whereas it was after 140 minutes in the case of control sample. The pretreatment enhances the rate of diffusion of moisture to the surface.

4.2.1.3. Convective Drying

A convective dryer maintained at 60°C was used for drying. The dried samples gave higher browning values due to longer drying time. Uniform drying was not ensured even if it was equipped with a fan.

Sample	Drying time (hours)	Moisture content (per cent)
Fresh	8.0	12.0
Blanched	7.0	11.0
Chemical treatment	6.0	10.0

Table 4.4 Effect of Convective drying on moisture content

From the above table it is inferred that the convective drying of control sample for 8 hrs. reduced the moisture content to only 12 per cent whereas in pretreated samples the moisture content was brought to 11 per cent within 6 to 7 hrs. Inspite of the shrinkage and browning during drying, quality of convective dried mushroom was better than sun dried mushroom.

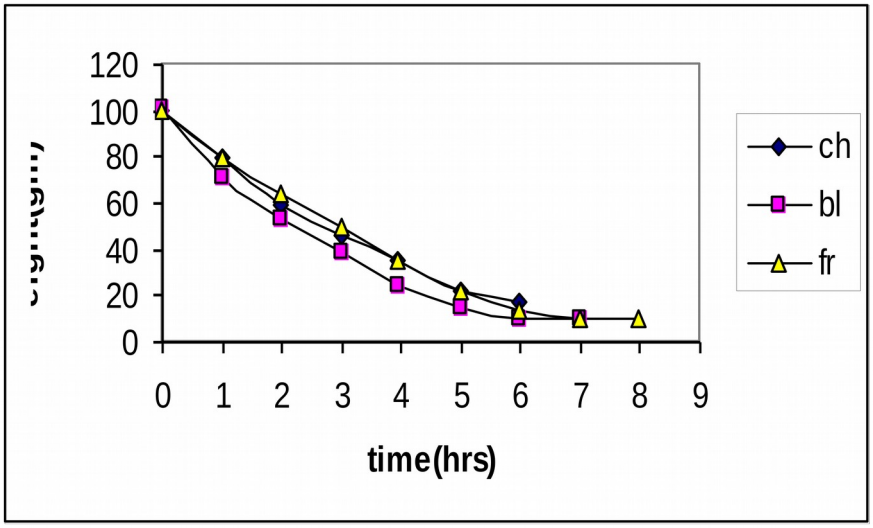


Fig 4.2 Drying Characteristics of Convective dried Mushroom

From the above figure, it is clear that there is a gradual decrease in the moisture content of the sample. This is because of the slow diffusion of water molecules from the interior to the surface implying that drying process is in falling rate period. Constant drying rate was obtained after 8 hrs in the case of control sample and after 6 to 7 hrs for pretreated samples.

4.2.1.4 Sun Drying

The samples were dried in open air under an ambient temperature of 35 to 40°C and the intensity of sunlight was 56 mW/cm². It is a slow process and it is not possible to dry the mushrooms below 10 percent moisture level. The entire process is unhygienic and requires large floor area.

Sample	Drying time (hours)	Moisture content (per cent)
Fresh	6.0	12.0
Blanched	6.0	11.0
Chemical treatment	5.0	11.0

Table 4.5 Effect of Sun Drying on moisture content

From the above table, it was noted that in sun drying of fresh samples weight of the sample became constant after 6 hrs of drying. Hence sun drying could not lower the moisture content below 12 per cent. Pretreatments relaxed the tissues and thus reduced the moisture content to 11 per cent in 5 hrs. The dried product was of poor quality and hard due to structural changes.

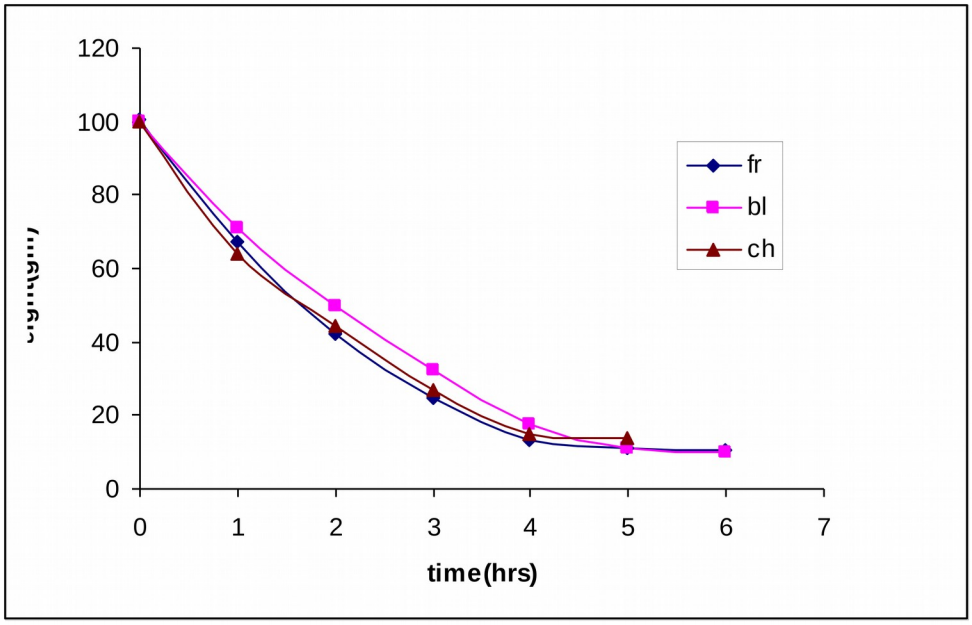


Fig.4.3 Drying Characteristics of Sun dried Mushroom

From the above figure it is inferred that there is a gradual removal of moisture content up to 4 hrs. In control and blanched sample, constant sample weight was obtained after 6 hrs. Chemically treated samples gave constant weight after 5 hrs.

4.2.2 Protein

The cultivated mushrooms subjected to four different drying methods and two pretreatments were used in protein estimation and the results were tabulated.

Methods of drying	Control sample	Blanched sample	Chemically treated sample
Freeze dried	24.7	22.7	22
Fluidized bed dried	23.24	21.5	21
Convective dried	22.6	20.5	20
Sun dried	22.6	19.5	19

Table 4.6 Effect of different methods of Drying on protein content

The protein content of the fresh mushroom was estimated as 25.2 per cent. The above table shows that freeze dried control sample gave a protein content of 24.7 per cent which was higher than other dried samples. Chemically treated freeze dried mushroom gave the best quality when compared to other samples with a protein content of 22 per cent. Control sample had higher protein content in the range of 24.7 to 22.6 per cent compared to pretreated samples. Protein content of the blanched sample was estimated to be 22.7 to 19.5 per cent where as chemically treated samples had protein content of the value of 22 to 19 per cent. In pretreated samples the decrease in protein content when compared to control sample was due to the heat treatment given at 100°C for 3 minutes. This application of moderate moist heat to proteins caused coagulation and shrinkage. The denaturation of protein was also noticed. This may be due to the Millard reaction (Swaminathan, 1995).

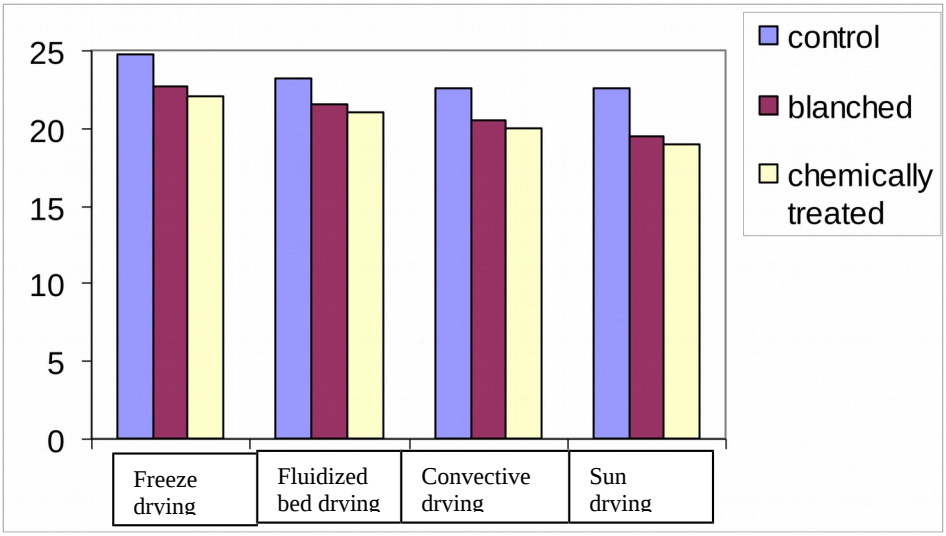


Fig.4.4 Effect of different methods of Drying on protein content

4.2.3 Ash Content

The minerals present in the mushroom constitute the ash content. Ash content of the samples were estimated by the procedure explained in chapter III and the results were tabulated

Methods of drying	Control sample	Blanched sample	Chemically treated sample
Freeze dried	9.76	9	9
Fluidized bed dried	9.5	7.7	7.5
Convective dried	5.4	4.2	3.8
Sun dried	4.5	2.8	2.8

Table 4.7 Effect of different methods of Drying on ash content

From the above table, freeze dried mushrooms gave a higher ash content in the range of 9.76 to 9 per cent when compared to other drying methods. In freeze drying the samples were subjected to low heat treatment. So there was no loss of minerals. The drying at higher temperature leads to loss of minerals in other drying methods (www.agen.ufu.edu).

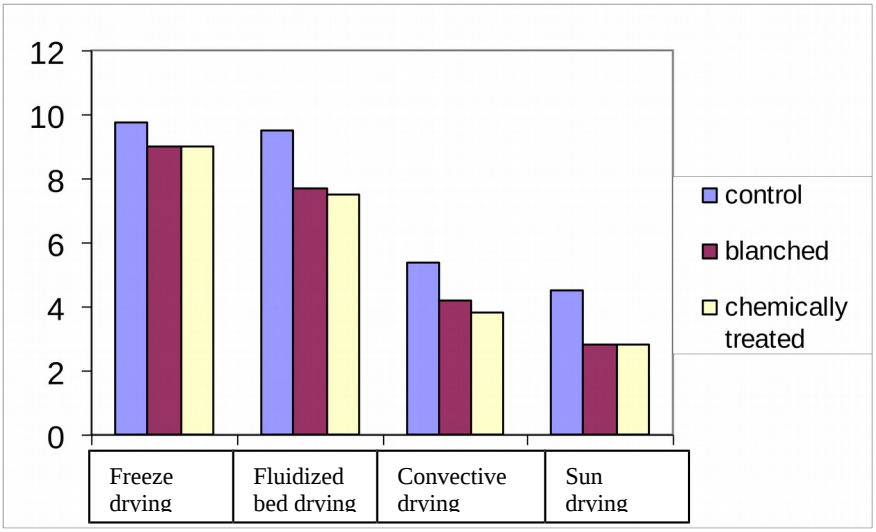


Fig 4.5 Effect of different methods of Drying on ash content

4.2.4 Rehydration Ratio

The cultivated mushrooms subjected to four different drying methods and two pretreatments were used in rehydration study and the results were tabulated.

Methods of drying	Control sample	Blanched sample	Chemically treated sample
Freeze dried	8	7	6.5
Fluidized bed dried	6.4	3	3
Convective dried	4.5	3	2.7
Sun dried	4.3	3	2.4

Table 4.8 Effect of different methods of Drying on rehydration ratio

From the above table it is observed that rehydration ratio of freeze dried sample was higher than other methods. Freeze dried control sample exhibited a higher rehydration ratio of 1:8 when compared to other samples. In this, drying was conducted at a lower temperature; mobility in extremely viscous phase is low that no structural change occurs during drying. The resultant structure consists of pore space. In other methods of drying the lower rehydration ratio is due the heat treatment at 60°C. This cause some shrinkage and distortion of cells and capillaries. Protein, sugars and salts are altered and they cannot fully reabsorb the water. In blanching and chemical treatment, the samples under go heat treatment at 100°C for 3 minutes. In spite of this heat treatment chemically treated freeze dried mushrooms gave a higher rehydration ratio of 1:6.5 than other treated samples (Norman and Joseph, 1996).

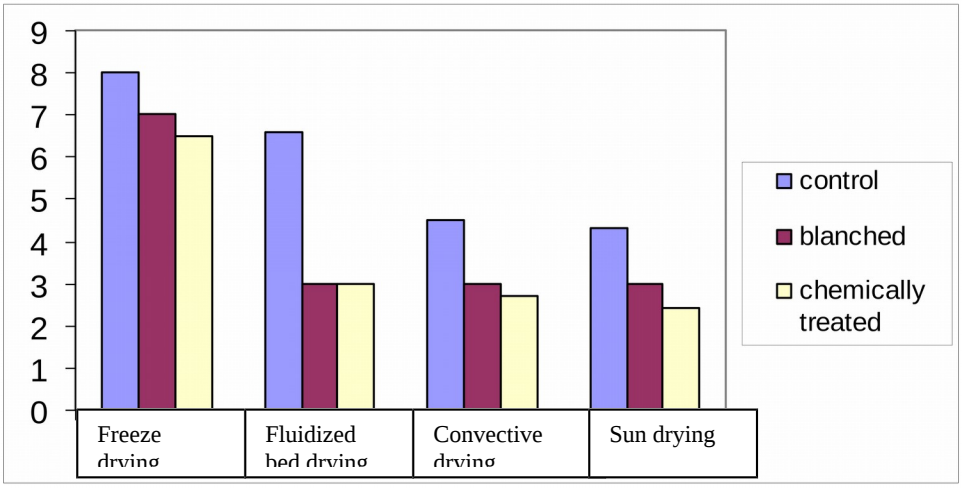


Fig 4.6 Effect of different methods of drying on rehydration ratio

4.2.5 Cooking Quality

The marketability of food material depends on its cooking quality. Here the parameters under consideration were taste, flavor, general acceptability and colour. The cooking quality analysis was done by a panel of 12 judges who are experts in this field. The marks assigned by the panelist are given as table.

Table 4.9: Cooking quality test result

Samples Code	Taste	Flavour	General Acceptability	colour
514	5	7	6	6
262	8	8	8	8
783	6	5	6	7
489	8	8	8	9
660	6	5	5	7
777	6	6	4	8
739	3	7	4	7
467	7	8	8	9
378	7	6	5	7
543	4	6	5	8
867	6	7	5	7
286	6	7	6	8

The identification of the sample codes are given in the Appendix- V.

From the above table, the freeze dried products showed high quality. The freeze dried products had the same taste as that of the control sample (fresh mushroom). Sun dried and convective dried products were rubbery in texture. All the samples had the same flavour and colour that depends on the addition of the ingredients. Freeze dried products had better general acceptability.

4.2.6 Sensory Analysis

Sensory quality greatly influences the market performance of product. Sensory analysis (preference test) was carried out in the Sensory Analysis Lab. 12 panelists were assigned to assess the difference in the mushroom products using a 9 point Hedonic scale test. The panelist evaluated parameters such as colour and general acceptability. These panelists assessed the difference in different drying methods and pretreatments used in the study.

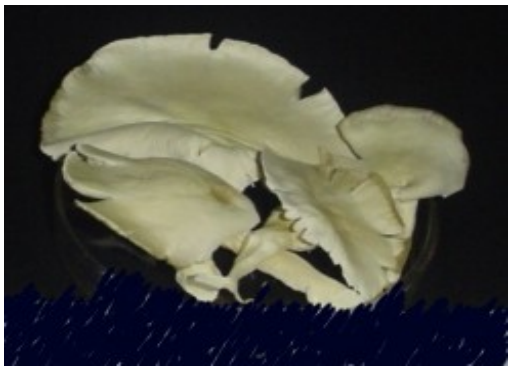
Samples	Colour	General Acceptability
514	6	6

262	8	8
783	2	3
489	8	8
660	4	5
777	5	4
739	5	4
467	8	8
378	4	4
543	4	4
867	4	4
286	5	4

Table 4.10: Sensory evaluation result

From the above table, chemically treated and blanched freeze dried products showed the better colour retention. Fresh freeze dried products developed very light brownish tint. The samples other than freeze dried developed brown colour and they shrinked during drying. The freeze dried products had better general acceptability.

Freeze dried



blanched+ Freeze dried

blanched+ Chemical treatment + Freeze dried

fluidized bed dried

Blanched+Fluidized bed dried

Blanched+ Chemical treatment + Fluidized bed dried

Convective dried

Blanched + Convective dried

Blanched +chemical treatment + Convective dried

Sun dried

Blanched+ Sun dried

Blanched + chemically treated + Sun dried

Plate 4.1 Dried mushrooms

4.3 Storage Studies

Food product available in the market is an outcome of group of activities, of which selection of appropriate packaging material is very important. Polyethylene and polypropylene are the most commonly used packaging materials, so in this study these packaging materials were selected. The storage study results are tabulated below

Sample	Polyethylene (days)	Polypropylene (days)
control freeze dried	3	3
blanched+freeze dried	30	30
chemical treatment+freeze dried	34	34
control sundried	No significant change	No significant change
blanched +sundried	No significant change	No significant change
chemical treatment+ sundried	No significant change	No significant change
control fluidized	**5**	**5**
blanched+fluidised	No significant change	No significant change
chemical treatment +fluidized	No significant change	No significant change
control convective	2	2
blanched +convective	4	4
chemical treatment+ convective	No significant change	No significant change

Table 4.11: Result of Storage study

From the above table it is noted that the freeze dried control sample gave a shelf life of only 3 days where as chemically treated freeze dried products exhibited the longest shelf life of 34 days. Sun dried and fluidized bed dried products shrinked while drying, so they did not show any change during storage but exhibited poor quality. The packaging material did not show any significant difference in the shelf life.

From the above results it is clear that freeze dried product retained the colour and texture when compared to other products. But chemically treated freeze dried products exhibited better cooking and sensory quality and longer shelf life.

Summary and Conclusion

SUMMARY AND CONCLUSION

Mushrooms when compared to other vegetables are perishable and it can be stored for only 24 hours under ambient conditions. They are considered as the boneless meat of vegetarians. The best method of preservation is drying. Conventional drying methods resulted in browning which is undesirable. Here comes the importance of pretreatments in drying. The pretreatments improved the appearance and shelf life of products.

In this study we used four drying methods viz., freeze drying, fluidized bed drying, convective drying and sun drying. The quality of the product was expressed in terms of protein content, ash content, rehydration ratio, sensory evaluation result and cooking quality result.

In the light of above literature, results obtained in present study are summarized below:

- The effects of different methods of drying on the quality of mushrooms were studied and it was noted that freeze dried product retained firmness and colour compared to other drying methods.

- The effect of different pretreatments on the quality of mushrooms was studied and it was noted that pretreatments improved the quality of the products. The chemical treatment improved the appearance of freeze dried products but reduced the nutritional value.

- Freeze dried product exhibited the best quality with a higher protein content, ash content , rehydration ratio, lower moisture content, better cooking and sensory quality.

- Chemically treated freeze dried mushroom had the longest storage life with better colour and firmness under ambient condition.

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DRYING STUDIES OF OYSTER MUSHROOM

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ABSTRACT OF THE PROJECT REPORT
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Abstract

ABSTRACT

Mushrooms are highly perishable and can be stored for 24 hours under the ambient conditions. Mushrooms were subjected to four different drying methods namely; freeze drying, fluidized bed drying, convective drying and sun drying. The study involves two pre treatments, blanching and blanching with chemical treatment. The quality parameters were analyzed and freeze dried products exhibit good rehydration ratio, cooking quality and better colour and firmness retention. The drying time was comparatively lesser than other methods. Chemically treated freeze dried mushrooms were reported to be the best among the freeze dried products. Longer shelf life of 34 days was noted with polypropylene and polyethylene.

Appendices

APPENDIX I

1. **Preparation of Sodium Hydroxide solution (40%)**

   400 g of sodium hydroxide crystals were dissolved in 1000 ml of distilled water.

2. **Preparation of Boric Acid Solution (4%)**

   40 g of boric acid powder dissolved in 1000 ml of distilled water.

3. **Preparation of copper sulphate and potassium sulphate mixture**

   Copper and potassium sulphate powder were mixed in 1:5 ratios.

4. **Preparation of 0.1 N Hydrochloric Acid**

   0.1 N HCl was obtained by dissolving 3.648 ml of HCl in 1000 ml of distilled water.

APPENDIX II

Variation of moisture content of fresh mushrooms during fluidized bed drying

Time(minutes)	Weight(g)	Kg of water/Kg of dry matter
0	100.3	9
20	34.72	7.56
40	16.3	2.124
60	11.45	0.558
80	9.83	0.186
100	9.08	0.086
120	8.84	0.276
140	8.67	0.0196

Variation of moisture content of blanched mushrooms during fluidized bed drying

Time(minutes)	Weight(g)	Kg of water/Kg of dry matter
0	100.82	9
20	35.96	8.138
40	15.62	2.54
60	11.19	0.555
80	8.7	0.31
100	7.97	0.0915

Variation of moisture content of chemically treated blanched mushrooms during fluidized bed drying

Time(minutes)	Weight(g)	Kg of water/Kg of dry matter
0	100.11	9

20	**30.4**	**8.7**
40	**10.8**	**2.45**
60	**9.07**	**0.21**
80	**8.19**	**0.11**
100	**8**	**0.023**

APPENDIX III

Variation of moisture content of fresh mushrooms during convective drying

Time	Weight(g)	Kg of water/Kg of dry matter
0	**100.1**	**9**
1	**79.28**	**2.26**
2	**63.34**	**1.73**
3	**49.15**	**1.54**
4	**35**	**1.53**
5	**23.73**	**1.22**
6	**14**	**1.04**
7	**9.3**	**0.51**
8	**9.2**	**0.0108**

Variation of moisture content of blanched mushrooms during convective drying

Time	Weight(g)	Kg of water/Kg of dry matter
0	**101.8**	**9**
1	**70.83**	**3.62**
2	**53.2**	**2.11**
3	**39**	**1.7**
4	**23.73**	**1.35**
5	**15.69**	**0.964**
6	**10**	**0.68**
7	**8.5**	**0.179**
8	**8.34**	**0.019**

Variation of moisture content of chemically treated blanched mushrooms during convective drying

Time	Weight(g)	Kg of water/Kg of dry matter
0	**100.04**	**9**
1	**79**	**0.604**
2	**58.49**	**0.589**
3	**45.37**	**0.377**
4	**34.94**	**0.029**
5	**34.8**	**0.004**

APPENDIX IV

Variation in moisture content of fresh mushroom during sun drying

Time	Weight(g)	Kg of water/ Kg of dry matter
0	**100.22**	**9**
1	**67.26**	**3.23**
2	**42.22**	**2.5**
3	**24.79**	**1.743**
4	**13.2**	**1.59**
5	**10.95**	**0.225**
6	**10.1**	**0.085**

Variation of moisture content of blanched mushroom during sun drying

Time	Weight(g)	Kg of water/Kg of dry matter
0	**100**	**9**
1	**70.83**	**2.91**
2	**49.6**	**2.12**
3	**31.94**	**1.76**
4	**17.4**	**1.48**
5	**10.67**	**0.673**
6	**10**	**0.067**

Variation of moisture content of chemically treated blanched mushrooms during sun drying

Time	Weight(g)	Kg of water/Kg of dry matter
0	100	9
1	64	3.6
2	44	2
3	26.7	1.73
4	14.65	1.205
5	13.66	0.099

APPENDIX V

The identification of sample codes is as follows

514 fresh fluidized

262 blanched+freeze dried

783 fresh convective

489 fresh freeze dried

660 sundried

777 blanched +sundried

739 chemical treatment+sundried

467 chemical treatment+freeze dried

378 chemical treatment+fluidised

543 blanched convective

867 chemical convective

286 chemical fluidised